FlexWood
Flexible Wood Supply Chain

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Industrial evaluation of round wood characteristics with respect to product specifications

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SEVENTH FRAMEWOR PROGRAMME

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FlexWood Project Partners

Website: www.flexwood-eu.org

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Abbreviations

DoW	Description of Work
ERP	Enterprise Resource Planning
FVA	Forest Research Institute of Baden-Württemberg
FWC	Forest Wood Chain
GSM	Global System for Mobile Communications
HKS	Handelsklassensortierung für Rohholz
IWW	Institute for Forest Growth Freiburg
m³	cubic meter
mio	million
o.b.	over bark
RVR	Rahmenvereinbarung für den Rohholzhandel in Deutschland
TLS	terrestrial laser scanning
u.b.	under bark

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1. Executive Summary

Wood is among mankind's oldest basic materials. Due to competition from steel, concrete and plastic composites, the market share in areas traditionally held by wood during the past century have declined. However, in times of global change and out of society's awareness concerning finiteness of exploitable resources and the need for sustainable economic activity, wood has achieved a renewed importance as basic material and as potential carbon storage.

Trees are able to biochemical synthesise wood as basic material that is mechanically stable, light and durable, while utilizing nearly inexhaustible resources such as CO_2, water, sunlight and minimal minerals and micronutrients. Wood can either be used by mechanical treatment, chemical digestion or energetic use by combustion (Becker, 2010). Within this deliverable, the research focus is use as solid wood product.

Grown in forest stand, each log destined for sawmilling purposes must include wood properties required for the final products. In order to achieve good economical results, the sawmiller is anxious to buy logs with inherent positive wood properties or, conversely, avoid wood with properties that could have a negative impact on processing logs (dimension, length, taper, etc.) or the wood product itself (knots, rot, discolouration, etc.).

The more specified the demand on round wood characteristics, the fewer the raw material will be available with simultaneously increased price. The sawmiller must find a trade off to obtain wood raw material in demanded qualities at affordable prices with less effort invested in sorting.

The aim of this deliverable is to reveal how these requirements on roundwood characteristics, with respect to product specifications, are transposed along different national Forest Wood Chains (FWC) in Europe. The main stakeholders with an essential interest in roundwood characteristics were identified as being the forest enterprise, as raw material producer, and the sawmill, as first consumer. Their ability to collect information, use medias for data storage and exchange, as well as their typical data exchange structures were identified. The former is to be consistently paid for delivered log qualities, the latter has to pay for achieved log qualities and is supplied with demanded logs in the same round.

Demanded roundwood characteristics for assortment building in Germany are usually defined in pre-contracts or follow European, national or state grading rules and standards. Finnish sawmills prefer log grading rules that are defined sawmill-wise per tree species. The assortment price as a function of supply and demand is continuously adapted to changing market conditions and based on the comparison to defined log qualities.

An inquery in different European regions was concerned with the data that is gained, the degree of details (log, batch, assortment), media for data storage and logistics (paper, electronically) and the method of data collection (measurement, random sampling or simulation).

The results showed that within these requested national FWC's severe differences exist, which apply to nearly every stage along the FWC, beside internal sawmill processes.

Finnish companies buy their raw material as standing stock and logs are cut to demand (log dimension and qualities) by private harvesting entrepreneurs under factory's control. The FWC data exchange relies on one standard (StanForD) and uses GSM technology for transfer. All acting stakeholders are aligned towards industry needs. Industrial needs on roundwood characteristics can be varied and individually adapted to sawmill needs.

In contrast, German FWC's are specified by a high number of independent stakeholders. Wood raw material is bought after felling at forest roadside or sawmill gate. Required roundwood characteristics are respected through defined national or state grading rules that consist of a set of quality parameters. Bucking is done on basis of standard length (short

roundwood) or long roundwood and the experiences of acting forest enterprise or independent hired personal. Industry needs can be respected directly, but must be defined in a pre-contract. The data exchange is often disabled by surplus interfaces and changing medias for data storage and transport. Data transport in that from is vulnerable to data loss and transcription errors. More advanced electronic platforms have been developed but are not yet used to a large extent. The standard for data exchange is still a paper tally sheet.

In both countries, the data exchange between forest enterprise and sawmill is mainly limited to condensed information, such as volumes, log numbers, tree species and average log quality grades.

2. Introduction

2.1 Objectives of the Deliverable

The aim of this deliverable is to reveal data streams within the FWC that deal with specifications on roundwood with respect to product specifications. Those specifications are made by consuming industries to exclude logs from production processes that won't be profitable to use due to poor quality features (e.g. knot, rot, spiral grain, etc.) or not matching geometric composition (e.g. diameter, curvature, ovality, etc.). They are then applied at stand level to choose a matching tree, fell it, buck and sort it in demanded assortments.

Industrial key demands on wood quality properties and their level of importance had been handled in "D 3.1 Industrial requirements, gaps and improvement needs" in an earlier stage of the project. Based on this knowledge, the way in which these needs are implemented and respected along national Forest Wood Chains in Finland and Germany have been investigated.

It is of a particular interest within this deliverable to analyse the derivation of data (process/location) on roundwood specifications, the degree of detail (log/pile/batch), horizontal (enterprise) and vertical (FWC) data use and which media is used for data storage and transport. In this case, the central research question was limited to specifications on logs that are destined to be used in the sawmilling industry for solid wood products. Logs for energetic use, pulp and paper or industrial roundwood for panels were excluded.

Due to the limitations in involved task partners in Task 6100 and in consideration of the little time available, it was not possible to achieve a complete FWC overview throughout all nations that are involved in FlexWood. The survey was therefore limited to those nations of the active task partners of Task 6100, which are Germany and Finland.

Germany and Finland as national entities were chosen to be representatives for central and northern Europe respectively. Both national FWC's were first explored and analysed stepwise singly, before being compared with each other. The aim is to reveal weak points and improvement potential out of both analysing methods. Weak points can be seen in redundant data elevation or breaks in media within the FWC, which may cause loss of information, longer production times and mismatching allocated raw material.

2.2 Work Package Task Status

Task 6100 Data collection including scanning of logs and sawn timber

Large scale data collection

Large scale data collection for softwoods could be fulfilled by means of 3D measurement data at different German sawmills. The data was collected by laser triangulation method that allows achieving a complete surface representation of a log. The logs were scanned 360° with 360 laser points per cross section. Dependent on changing feeding velocities, lateral resolutions of 0.5 to 1 cm in the z-plane are accessible. This measurement method achieves very detailed information on volume, taper and curvature of the log, but is also limited to external dimensional behaviour. Within this research it was not possible to obtain the information on the part of the tree from which the log was originally gained. All together, there are data sets available for 120000 logs of spruce and fir that will be used to compare different measurement techniques and algorithms on their preciseness on volume measurements. It will also serve as entrance data for simulated breakdown. The breakdown pattern per log can be varied to compare different sawing patterns and technologies to assess their impact towards volume recovery of sawn goods. The results will then be statistically analysed. The virtual breakdown will be done with an industrial program that is delivered to Forest Research Baden-Württemberg (FVA) at the beginning of 2011.

The large scale data collection for hardwoods turned out to be a task that could not be fulfilled. In German hardwood sawmills is no 3D measurement unit available that could deliver requested data. Instead, FVA will use its Microtec© DiShape® that is equivalent to used industrial standards, to establish a database by means of beech log sample material that will be harvested at the test sites in Karlsruhe in December 2010.

Small scale data collection

The small scale data collection is still pending due as terrestrial laser scanning technology (TLS) must be carried out after leaf fall and ground vegetation reduction in winter, in order to provide satisfactory scanning results. 20 beech trees have been approved for removal by the local district manager of the communal forest in Karlsruhe. They are individually marked with letters from A-T accordingly and will be harvested in December 2010, after the manual measurement of tree parameters (dbh, height, crown base and crown projection area), bark surface structures and laser scanning. Pre harvest measurements will be done by the Institute for Forest Growth (IWW) as defined in the Description of Work (DoW) for task interaction of Task 4200 and 6100.

The trees have been chosen in all social classes in dbh ranges of 30 to 55 cm. It is expected to achieve an amount of 50 logs to be scanned at FVA's CT. Due to log length limitations of the CT scanning facility to a maximum length of 5.50 m, the beech logs will be bucked at corresponding standard lengths to guarantee a frictionless handover to subsequent conversion stages without surplus material loss out of this bucking action.

Logs of dimensions over 40 cm have to be quartered prior to scanning process, to achieve material dimensions that the CT is able to radiograph reliably. Previous scan trails have revealed that the CT is limited to 40 cm of fresh beech logs. After scanning, these quarters will be digitally reassembled to one log. The quartered logs will serve as specimen material for destructive wood property investigations to derive correlative functions of CT values and underlying wood properties. All other logs will be cut by contract sawing, to be brought back to FVA for a second CT scanning and manual grading of sawn timber, which allows the link of wood raw material to products. The results will be compared with the outcome of virtual breakdown. The raw data sets of beech logs will also be used for multiple virtual breakdowns, where different simulated sawing techniques will be applied, to be evaluated on their influence on volume yield.

Afterwards, the data sets of TLS and CT measurement will be matched by coordinate transformation, which allows the assessment of internal stem quality features out of external shape and bark characteristics.

Test sawing in Finland

Test sawing was carried out at a large Finnish sawmill. Three batches of pine logs were sawn. One hundred logs were sorted into each batch by top diameter and quality grade. Top diameter classes of batches were 175 mm, 212 mm and 330 mm. Logs were marked with RFID-tags in the log yard. Orientation (sweep direction) was marked by line to top end of logs. Logs were driven once again through the log sorting line, where they were 3D-scanned and x-ray (four directions) scanned. In the sawing line the RFID-tags were detected. Sawn timber pieces were manually marked so that the pieces could be traced back to their position in the sawing pattern.

Sideboard edger's scanner measured crosscut profile of unedged sideboard at two centimeters intervals. Width and length of the sideboard were also registered. At the sorting station all four sides of sawn timber piece were scanned (FinScan BoardMaster) and map of characteristics of sawn timber piece was recorded. The map consists of characteristics that contribute to the quality of sawn timber piece, for instance size, quality and position of knots.

Data format

To model internal log knottiness, a user friendly data format was developed. It describes the knot in its geometrical behaviour with Cartesian coordinates. The pith is the intersection point of the X, Y and Z level, where Z is the height of the knot starting point related to the stump (stem) or from the butt end of the log.

Knots and knot parts are also classified in live, dead and rotten parts, which are of major interest for quality grading of sawn goods.

The dimensional knot behaviour is described stepwise (every 20 mm of the pith) in terms of horizontal diameter of the knot, vertical diameter of the knot and height of the center of point of the knot cross-section. The knot angle at the X/Y plane is described in compass angles to the pith of the knot, outgoing from predefined 15° measurement lines (Figure 1).

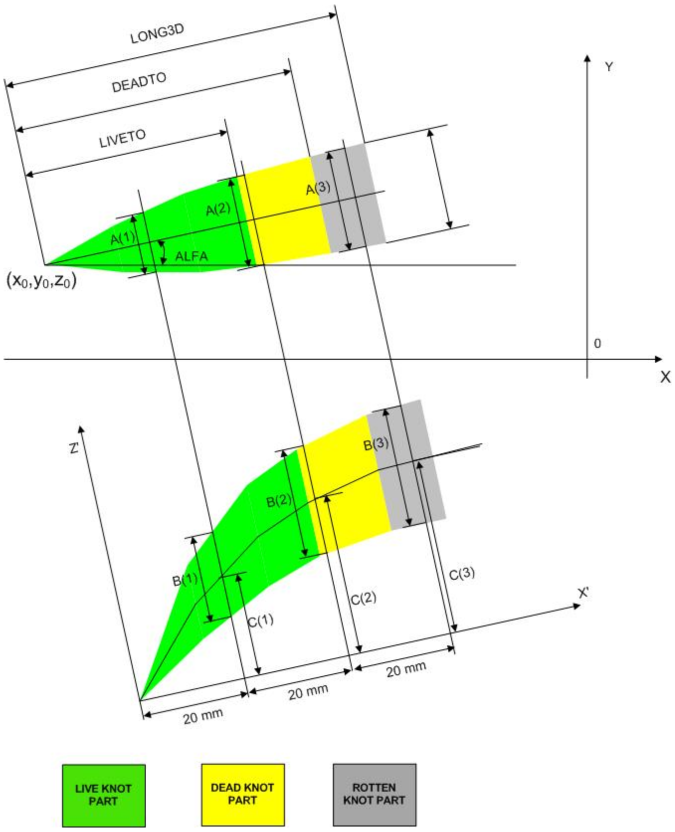


Figure 1: Data format knot description

WP 6000 Deliverables

Del. no.	Deliverable name	Delivery date	Status
6.1	Industrial evaluation of product specification for solid wood products	Month 12	Current report
6.2	Concept of improved conversion chains for the European sawmilling industry	Month 18	
6.3	Adapted conversion models	Month 26	
6.4	Technological specification of interfaces between manufacturing systems and logistic concepts	Month 26	
6.5	Concept on implementation of flexible production and future manufacturing systems	Month 26	

3. The Approach

3.1 The rationale

The deliverable 6.1 is a result of task 6100. It is the first of five deliverables to be submitted for work package 6000 by the end of the Project. Parts of D 3.1 (chapters 4.3 - 4.6) submitted in month 7 can be seen as basic information source for detailed description of industries demanded log properties for specified processes and products at the sawmilling industry.

To achieve a consistent information structure and content among both task partners, a set of research questions was elaborated and exchanged. The research questions were applied on stakeholders of the FWC that have an essential interest on data, dealing with roundwood specifications, which are the forest enterprise as primary producer of raw material and the sawmill as the first consumer and value creator.

The agreement and specification of roundwood characteristics between forest enterprise and consuming sawmills is the main interface upon which their economical relationship is based. From the different stakeholder perspectives, specification on roundwood characteristics can be ranked differently in its importance. The forest enterprise will be paid for its raw material and achieved log qualities out of silvicultural concepts and tending operations and thus receives feedback on the value of driven forestry concepts. The sawmiller as value creator is dependent on buying material that matches his demands for high volume and value yield. The better raw material matches demand, the more the sawmiller is willing to pay. This is then a direct incentive for the forest owner to produce demanded log qualities.

The information flow of both national Forest Wood Chains were queried and investigated by national experts of the FVA and VTT. Instruments of investigation were literature review, expert's opinions as well as telephone and direct interviews of respective stakeholders at the forestry and sawmilling sector.

The results were listed by nation and compared with each other. Outcomes with mainly analogue results are only described as one entity with comments to national peculiarities.

4. Information flow between forest enterprise and sawmill – general description –

4.1 Germany

There is no uniform information structure that can be seen as to be representative for data exchange between forestry and sawmilling industry. The way data is gained, stored and channelled is strongly depended on the agreed method of measurement for invoicing. If available, it is preferred to have the measurements done at sawmill facilities, assuming they are certified. In 2010 there were only 88 (Anonymous, 2010) sawmills registered with certified measurement systems installed. The most common parameter collected is volume, by means of log length and mid diameter. Some facilities are also able and certified to collect taper and curvature. The majority of log grading is undertaken at stand level or roadside, but can be counterchecked by values of taper and curvature by means of 3D scanning. Downgrading is possible. The forester at stand level must rely on given results of the measurement unit on basement of certification. The measurement protocol is usually double-checked with the previously counted number of logs at roadside level.

When a certified measurement system cannot be used, measurements for invoicing are carried out in forest stand or at roadside. The data is stored in a mobile data acquisition device or listed on paper. This information is then collected and sent in a condensed version to potential or existing buyers.

Individual demand of sawmills on roundwood specifications, that are deviant from standard grading rules, can only be respected by a pre-contract. Underlying needs of sawmills regarding quality and bucking can thus be respected. Logs that are cut without contract are bucked and sorted by means of experience to be offered to potential buyers afterwards.

The current regular data exchange between forest enterprise and sawmill is still done on paper. Condensed information sheets are exchanged. More modern information channels are given but only used to some extent.

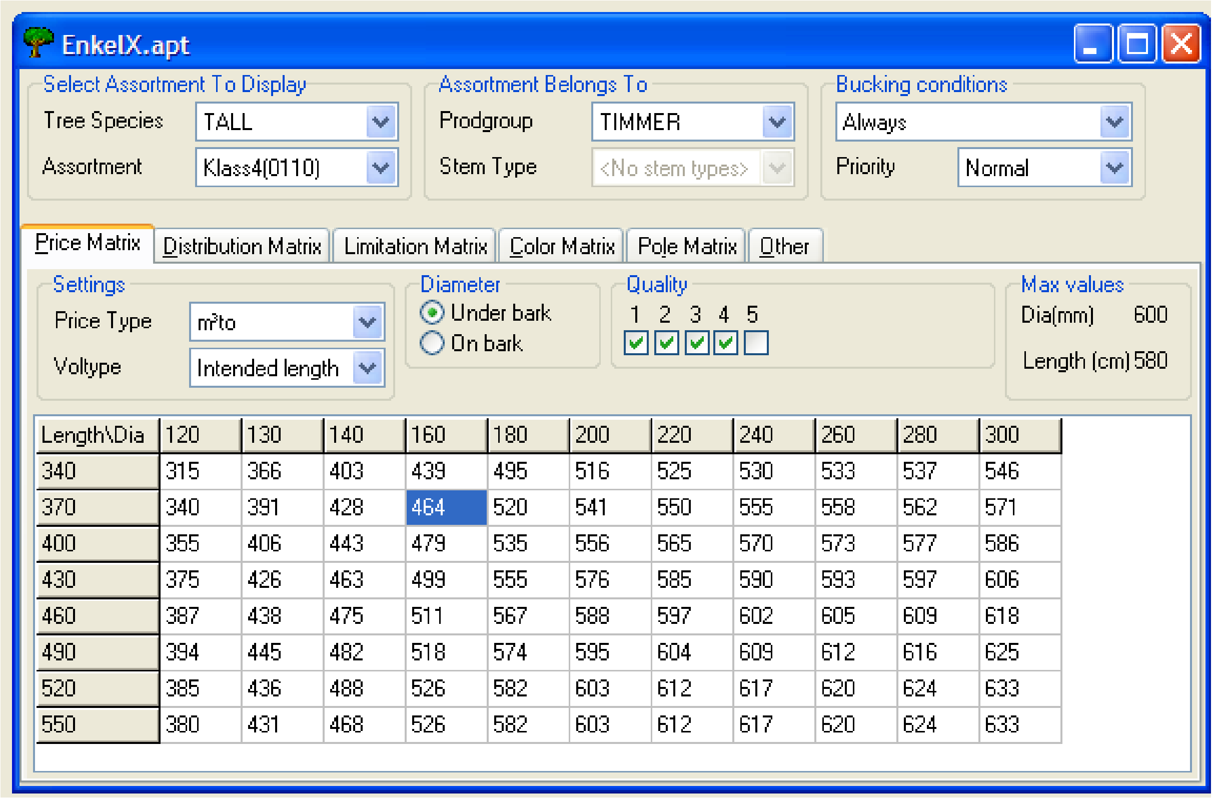
4.2 Finland

In contrary to German information structures, the Finnish information channels are characterised as being strictly oriented by the needs of the sawmilling industry. The data exchange between forest stand and sawmill takes place via a platform called StanForD (Standard for Forest Data and Communication), developed by Skogforsk/Sweden. These general communication standard channels and formats provide speed, safety and easy data exchange and facilitate the implementation in information and communication systems of sawmills.

Sawmill demands on roundwood specifications are respected through price and demand matrixes that are electronically sent to harvesters before felling actions. Data transport between sawmill and harvester is done by Global System for Mobile Communications (GSM) networks.

Demand and price matrixes normally contain information on timber assortment, top diameter, length and the expected price per assortment (Figure 2). Those matrixes are relatively constant, but can be adapted to current market needs and changing situations.

Status reports of work progress and assortments harvested are given back, vice versa, by the harvester.



Length\Dia	120	130	140	160	180	200	220	240	260	280	300
340	315	366	403	439	495	516	525	530	533	537	546
370	340	391	428	464	520	541	550	555	558	562	571
400	355	406	443	479	535	556	565	570	573	577	586
430	375	426	463	499	555	576	585	590	593	597	606
460	387	438	475	511	567	588	597	602	605	609	618
490	394	445	482	518	574	595	604	609	612	616	625
520	385	436	488	526	582	603	612	617	620	624	633
550	380	431	468	526	582	603	612	617	620	624	633

Figure 2: Standard sawmill demand and price matrix (Lundqvist, 2009)

5. Information level forest stand and roadside

This chapter deals with information gained at stand level or forest roadside. Potential processes for information gaining were identified as to be during felling actions or in the time period that logs are piled at roadside. During felling actions, data gathering and storing is highly dependent on the method of felling that is chosen and its level of mechanisation.

In Finland trees are usually bought on stock and cut by company-owned entrepreneurs. In contrast, German forest enterprises prefer to sell logs at roadside or sawmill gate. Harvesting and hauling is mainly done by personal of the forest enterprise or hired independent forestry entrepreneurs.

Table 1: National forest ownerships

	Finland	Germany
Forest area	20 mio ha	11,1 mio ha
Private	52 %	43,6 %
State	35 %	33,3%[1)]
Companies	8 %	-
Municipalities & congregations	5 %	19,5 %
Trusteeships	-	3,6 %

1) Federal and state ownership together

Logs being felled in a fully mechanised way by harvesters are measured automatically and simultaneously when being fed through the processor head for debranching and bucking. The information on volume, length of assortment and number of logs is stored at the onboard computer. Additional information on log grades can be attached to the protocol by way of manual input of the harvester operator. The operator decides grade in which to sort on the basis of external log appearance. The stored information can then be read out to mobile data storage devices or directly be send via mobile communication networks to concerning stakeholders, downstream the Forest Wood Chain. These information flows, gathered in fully mechanised harvest operations, are characterised by a quick, safe and easy data exchange between the forest entrepreneur in forest stand and consuming industries. By using the same medium with matching data formats, interfaces are reduced and data exchange is facilitated. Risks of data loss and transcription errors are minimised.

In contrast, less mechanised felling processes are characterised by changing media for data storage and transport, as well as an increased amount of interfaces.

Measuring in forest stand is then done manually by the forest worker after felling, debranching and bucking. Parameters are measured using a measuring tape and calliper. Results are registered log wise on paper with the note of quality grade. High value assortments (Grade A or veneer logs) are excluded from grading in forest stand. This is done by the forester at roadside. Written data must be transferred afterwards to a mobile data acquisition device for further data handling and exchange. The possibility of data loss and transcription errors is given in this break of media.

Data gathering at roadside is associated with a significantly lower expense then in forest stand. Log parameters here are measured in piles through random sampling and are then extrapolated to the entirety. The set of output parameters and the degree of precision is highly dependent on the chosen method of random sampling and its determined sampling size. Traditional tools for measuring are calliper and measuring tape.

5.1 Germany:

The most important factor concerning whether or not information will be gained at forest stand is the presence or absence of a licensed 3D measurement unit at the sawmill. Is the latter given, measurement in forest stand is limited to control measurements to reduce personal costs. In case of an agreed measurement at the sawmill as basement for accounting, the effort for the foresters is reduced significantly. It is then sufficient to only count the number of logs as check measurement and security, in case the data protocol of the sawmill were to be lost. Measurements of harvesters are also suitable as check measurements, but are not accepted as a base for accounting and payment. Its mainly the wide range of harvester manufacturers that are cumbersome to achieve a certified measurement standard that is accepted by all stakeholders. Additionally, the measurement is done over bark (national accounting standard under bark) and unwanted debarking through the feeding rolls is always possible, which may cause falsified results.

Alternatively, the volume measurement as basis for accounting can be made in forest stand or roadside by employees of the forest enterprise itself. Depending on which assortment had been bucked, different measurement methods can be applied, with varying results in parameters and degree of detail.

Long roundwood in dimensions of 30 cm and above is usually manually measured stem wise. The result is a full inventory account. Every log length is measured with a measuring tape and the mid diameter is gained with a calliper. The diameter value of underbark deduction is gained from fixed values or representative measurements.

The single stem volume is calculated by the following function:

volume (m³ u.b.)= length (m)* mid diameter u.b. (cm²)* π/40000

The log is then individually marked with a number plate and registered with comments to tree species and quality grade in a mobile data acquisition device. Measuring and data storage is usually done in forest stand, contemporary with felling and bucking, by skilled forest workers.

Dealing with assortments of standard lengths, it is in general satisfactory to use a sampling procedure at the piling ground to determine desired parameters. The most common and reliable method is called the “cross sectional area method” (Figure 2). As the name implies, butt end diameter and top end diameter from cross sectional areas were taken from predefined lines at the piling site to calculate underlying mid diameters. In addition to the counted number of logs, the length and representative measured mid diameters, the total log volume (m³ u.b.), the dimension class distribution, the average single stem mid diameter and the average single log volume are generated.

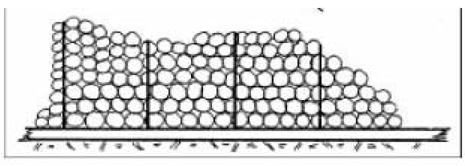


Figure 3: Random sampling method “cross sectional area”

Other alternatives sampling procedures are to reduce to cubic measures, without dimension class distribution or only use mid diameters in a predefined number of samples.

All data from forest stand or forest roadside is stored in a mobile data acquisition device for further use. From this, data tally sheets and customer information are generated.

In general, information between forest stand and sawmill is exchanged on paper. The tally sheet information, gained by the forester, can be provided in different information cascades, as they are listed below.

1. Type of measurement (individual measurement, measurement by sample)
2. Assortment (roundwood long, roundwood short) total volume m³ u.b., number of logs, main tree species, average m³ of a log and the average length
3. Cubic meters listed by tree species, quality grade and dimension class
4. m³ and fraction percentage of felled tree species, m³ and percentage rate of every quality grade, m³ and percentage rate of every dimension class
5. Number of logs listed by piling site
6. Individual description of every log by tree species, dimension class, log length and m³ u.b.

To inform customers, it is customary to aggregate several tally sheets. The information on roundwood are then condensed to

1. m³ listed by tree species, quality grade and dimension class and summed up volume
2. m³ and percentage rate of felled tree species, m³ and percentage rate of every quality grade, m³ and fraction percentage of every dimension class

More advanced in data exchange and implemented in 2003, it is also possible to transfer data electronically via the ELDAT platform. It was developed by the awareness of the forestry sector to exchange data in a unique medium and data formats for easy implementation to information and communication networks of respective stakeholders. Considering the wide range of technical hardware used along the FWC between dispatcher and acceptor, data can be provided in different formats. For older technical standards, the electronic tally sheet is provided as .csv file. More modern systems can obtain data as .xml file. Data is exchanged as email, or downloaded from the server.

5.2 Finland

The information flow from forest stand to sawmill is very much aligned on the needs of sawmills. The trees are bought on stock and cut by private harvesting entrepreneurs under sawmills control. Measurements on product specifications are done by the processor head of the harvester (log length, volume, etc.) and manual input of the operator (quality grade). Gained information can be transferred, in any order if necessary, using the StanForD system. The data is sent electronically through GSM networks. This information channel is mainly used by sawmills to request production reports by timber assortments from ongoing felling actions. It is also used as a controlling instrument, to check whether their log order has been fulfilled by the particular date. Production reports are generated automatically out of several harvester output files. Most common reports dealing with timber assortments only comprise of condensed information on volumes and pieces, top diameter and length. If necessary, these reports could be extended to individual stem measurements.

6. Information level sawmill

This chapter deals with all the processes taking place at the sawmill that have a connection to information gaining on roundwood characteristics and its further use for improved production. Within both investigated countries, the sawmilling industry inherent big market shares at the roundwood market. In Germany it is clearly dominant with a relative market share of nearly 60%.

Table 2: National benchmarks on roundwood consumption

	Finland	Germany
Forest	20,0 mio ha	11,1 mio ha
Average annual harvest	50 mio m³	50 mio m³
Use of roundwood in sawmills	44 %	59.9%[2)]

Differentiations between softwood and hardwood sawmills will just be done for Germany if processes or treatments of logs are divergent from each other. In Finland, 99.5 % of the average roundwood consumption are dispensed on conifers, which make a differentiation between hardwood and softwood obsolete.

Table 3: Average national roundwood consumption at sawmills per year

	Finland	Germany
Roundwood consumption a^{-1}	22 mio m³	30 mio m³[2)]
Conifers	21.89 mio m³	27.94 mio m³[2)]
Broadleaves	0,11 mio m³	1.99 mio m³[2)]

[2)] *Holzrohstoffbilanz Deutschland – Bestandsaufnahme 2002; Zentrum Holzwirtschaft, Arbeitsbereich Öko nomie der Holz- und Forstwirtschaft, Hamburg 2004)*

Within a sawmill, different processes and locations are of major interest because of their importance in gaining information on roundwood specifications, namely the log yard (bucking and sorting), breakdown and optimisation, feedback to the forest enterprise and the horizontal data use at the sawmill. These processes/locations will be presented in the following chapters 6.1 to 6.4.

6.1 Log yard/bucking/sorting

6.1.1 Germany:

Logs entering the sawmill are usually quality graded in forest stand or at roadside. The sawmill has the ability to countercheck grading results if there is suspicion of wrong grading or to verify measured data from the forest enterprise.

By means of 3D scanning facilities, parameters such as volume, log length, curvature and taper can be obtained and counterchecked against absolute limits of national grading rules or predefined parameter limits of delivery contracts. If the measuring unit is certified, deviations from quality grades can be obtained and claimed in opposite to the forest enterprise. Other relevant quality parameters, such as rot or knottiness, can be assessed by the operator of the bucking station. Amendments to the measurement protocol are possible. Technical solutions for downgrading on basis of optical deviations from quality grades are only accepted if documented in a photo-optical way, which is rarely found in practice. Logs that fall below demanded top diameters can be rejected. In terms of bucking decision and quality control, sawmills without a 3D measurement unit must rely on tools such as the calliper, measurement tape and the visual inspection of skilled workers. Sorting and bucking is usually based on current market demands or contracts. They can be changed under varying market conditions and customer demands.

3D log measurements are only done under bark after debarking and the data is stored electronically.

Bucking is mainly done on the assessment of the operator, which is supported by measurement results on length and diameters. Direct geometrical information is not taken into consideration. Bucked logs are sorted into boxes as batches, to be treated with the same blade settings. Smaller sawmills prefer sorting in piles rather than boxes.

The sorting of logs is mainly done by means of tree species or tree species groups with similar wood properties (e.g. spruce/fir), top diameter and length. Quality information such as grades are provided due to grading in forest stand and the assessment of the bucking operator.

Log quality information delivered from the forest enterprise are mainly sent on paper tally sheets. This information can be used for sawmill processes, but must be transcribed manually. Transcription errors may be the result.

6.1.2 Finland

With one exception, all Finnish sawmills order short roundwood. The logs are cut to demand by integrated harvesting entrepreneurs and then brought to the sawmill. As a standard procedure, logs are 3D measured over bark when they enter the production site for sorting. Parameters that are usually obtained include: top diameter, length, taper, sweep, ovality, volume with bark and bumpiness. The operator is also able to visually define quality grades by means of knots/knottiness and rot.

Acceptance measuring (volume of logs with bark) for payment can by carried out on the grounds of 3D-scanning in the sawmill. Currently this can also be carried out by harvester measurements in the forest.

The main parameter for log sorting into batches is the top diameter. In traditional sawing processes, it is the determining parameter for log volume recovery after breakdown. Measuring is done with a 3D measurement unit over bark as described above and being reduced by correction coefficients to be used as sorting diameter under bark. Amongst others, coefficients can be determined by WoodCIM-program developed by VTT. The sorting diameter may be corrected if defined parameters exceed a certain limit value.

E.g.:

If sweep exceeds a certain limit value, sorting diameter must be corrected downwards.

If taper exceeds a certain limit value, sorting diameter must be corrected upwards.

Depending on tree species, spruce and pine logs are sorted differently into log classes (batches).

Spruce logs are typically sorted by their top diameter only, and if needed by top diameter and length. The applied sorting rules for pine are more differentiated, where the log quality aspect is respected to some extent. The sorting is mainly done by top diameter and quality grade and, if required, by top diameter, length and quality grade. Logs are normally sorted by quality grade into butt logs, middle logs and top logs. Occasionally valuable butt logs are sorted out as well. Knotty butt logs of low quality can be downgraded to middle logs. Top logs have the highest knot proportion, whereas the most knots are sound.

X-ray scanning as innovative scanning technology implemented in 10 big Finnish sawmills for pine log sorting. They are installed in the same line with the 3D scanner and used for knot and heartwood detection. The technology is based on one or two directional discrete x-ray scanners. Logs with identified high heartwood percentages can be used, for example, to produce windows or other products where a high natural durability is required. For high quality products, x-ray scanning is used to identify distances between knot whorls, that are then cross cut out to produce knot free sawn pieces for finger jointed knotless bars.

6.2 Breakdown planning and optimisation

As breakdown technology and optimisation of both investigated countries differ little between Germany and Finland, they can be treated as one unit within this subchapter with additional comments to national peculiarities.

In practice, all the information needed in the planning of sawing patterns comes from the measurements carried out in the sawmill, which includes scanning of logs, as well as visual grading and sorting into batches (log classes).

Log class limits (top diameter) are optimised considering the most important sawing patterns. Generally, 1-5 different sawing patterns are used in one top diameter class. Scanners installed in front of sawing machines allow improved log feeding. Sideboard thickness and/or width can be changed on base of this scanner information. Parameters taken into account are top diameter, curvature and ovality.

The only difference in the production in Germany is the use of quality information of assortments graded according to the existent grading rules in forest stand or roadside and delivered by the forest enterprise.

Breakdown planning and optimisation in hardwood sawmills is generally based on visual inspection by the sawing operator. Technical breakdown assistance by 3D measurement is not use significantly by the industrial at the moment. The influence that the sawing operator has on the value outbreak is strongly dependent on the used sawing technique. Using traditional frame saws as head saw, the log is aligned once according to an assessment of external log characteristics and insight to revealed cross section, then cut in one process to boards. More advanced band saw technology allows to “fillet” the log. The operator has the opportunity change and adjust sawing patterns if internal wood properties behave differently than expected from the outside assessment. Optical scanners have been tested for breakdown assistance, but results are still unsatisfactory. The practical implementation remains at an experimental stage.

6.3 Feedback to forest enterprise

6.3.1 Germany

Information exchanged back to the forest enterprise, reverse to the material flow, is mainly restricted to volumes for accounting or amendments to delivered log parameters. Logs with unsatisfying parameters such as diameter, length or quality parameters exceeding ordered quality can be claimed and a price reduction can be obtained. As evidence, the sawmill must provide 3D measurement protocols covering volume, diameters, curvature and taper if the measurement unit is certified. Photo-optical documentation of log defects can also be used, but is seldom found in practical application. More common are log quality amendments of the bucking operator to the measurement protocol, derived from visual inspection at the bucking station.

6.3.2 Finland

Reports of realised log distributions are compared to demanded assortments that are defined in matrixes and used in onboard computer of harvesters for bucking instructions. Length cutting accuracy is also validated.

6.4 Horizontal data use at sawmill

Wood supply and wood purchasing is the greatest running cost factor for a sawmill. As revealed in representative studies in Germany, this can be from 47% to 64% of overall costs depending on the sawmill size (Röder, 2003). Information on received log volumes, qualities and final outbreak with achieved prices is fed into companies internal "Enterprise Resource Planning" (ERP).

ERP is used to apply company's resources (assets, capital equipment and employees) in the most efficient way. Typically, all business processes are represented in that complex application software.

Average functions are:

1. Materials Administration (acquisition, stock keeping, scheduling and assessment)
2. Production
3. Finance and Accounting
4. Controlling
5. Human Resources Management
6. Research and Development
7. Disposition and Marketing
8. Master Data Management

Every listed function of ERP is affected by specifications on roundwood, whereas most information is used in very condensed form. Most detailed information on roundwood characteristics are to be expected at material administration, finance and accounting as well as controlling.

Finnish companies use StanForD technology to automatically transfer harvester data directly into ERP systems, which allows enhanced tactical planning and controlling functions. Sawmills log yard inventory data as well as forest inventory data can also be used in production planning and optimisation.

German sawmills must rely on measurements collected at the production site, due to log sorting or breakdown optimisation. If needed, data from the forest enterprise can be used as well, but must then be brought in compatible data format, which, in business issues, means transcription of paper stored data or formatting of send data packages. Both imply risks of data loss and transcription errors.

7. Future trends

Innovative scanning technologies will become more important along the FWC. At forest stand level it is expected that novel laser based remote sensing scanning technologies will contribute valuable input to manual forest inventory systems in the near future, possibly replacing them if they are further developed. TLS scanning technology is the most promising technique to provide detailed stem quality information prior to felling actions. In connection with aerial laser scanning, this will be a powerful tool for stand inventory assessment, including quality standing tree information. The allocation and mobilisation of wood will be improved, helping meet the problem of raising competition between solid wood products, industrial roundwood and energetic use, which is expected to intensify within the next several years.

Data exchange will be simplified and standardised between acting stakeholders in order to minimise redundant data collection and implementation barriers for internal information and communication use. Finnish sawmills have already implemented such system by using StanForD and the benefits are visible. Data packages along the FWC are easily accessible and can be used optionally as a result of standardised data formats and easy implementation. The Germany forestry sector has been aware of that need since 2003 and provides the ELDAT platform for electronic data exchange. This is currently not used to the expected scale, but time and benefits of involved user groups may bring this application to a wider application.

The use of x-ray technology will become increasingly common for sawmills. In the near future, especially in Finnish sawmills, it is expected that pine logs will be processed using knowledge on heartwood content and knot whorl interspaces gained by x-ray technology. Advanced x-ray technology in form of computed tomography is also expected to increasingly contribute knowledge of internal log behaviour as complete 3D reconstruction that can be used for flexible sawing pattern adjustments.

8. Conclusion

Within this research, it has been revealed that European FWC's are very diversely structured and organised. It is clear from the Finnish case that a common data exchange standard between acting stakeholders is of great benefit. All working forces are thus bundled to achieve the best entrepreneurial success of the sawmill. As first value creator, any down streamed FWC action should be in line with sawmill demands for optimal business success.

By means of standardised data exchange, the sawmill is, on the one hand, able to react flexibly according to changing market conditions and adjust harvester bucking instructions to demand and, on the other hand, can easily control work progress and expected raw material to be delivered in the vicinity. Data exchange is additionally based on GSM, a network that allows access to all acting stakeholders promptly, which simplifies tactical planning and execution.

Germany is also providing a standard for electronic data exchange, but based on the internet (ELDAT). Data can be downloaded or be sent via email. Main user groups here are forest enterprises and sawmills. Executive entrepreneurs acting in forest stand are not directly linked to that information channel, but can receive information before they transpose sawmill orders. Despite this advanced channel of data exchange, it is still common to exchange information as paper tally sheets, which represents breaks in media, surplus interfaces and slows down data exchange. Data is collected redundantly and resources on personal and material are not used most efficiently.

At the moment, information from forest enterprise on wood quality does not contribute significantly to breakdown planning and optimisation. A measurement unit in front of a sawmill bucking station and head saw provides more detailed data than what is provided by forest enterprise.

Improvement potentials could clearly be revealed through log quality information prior to felling actions. Currently, sawmills are most commonly restricted to information from estimations or rough forest inventory data prior to fellings, dealing with condensed data sets such as log volume or log amounts. Quality features of potential logs are excluded completely as decision support for material allocation. It is foreseeable that in the near future the sawmilling industry will request more quality data prior to felling actions, which can be used for tactical and strategic planning. This was clearly demonstrated by interviewed forest owners for deliverable 3.1. The data concerned will include geometrical behaviour of logs, quality parameters and timing. The former two criteria may be available using novel remote sensing technologies such as TLS and ALS and their combined interaction potential.

The comparison of both national FWC's also showed that industrial demands on roundwood characteristics with respect to product specifications are transposed differently. For example, Finnish sawmills have the potential to define individual sets of parameters that can be respected in bucking instructions. In consideration of applied clear cut harvest regimes and the need to consume all standing trees, this potential on parameter definition is rarely used. Primarily, there are few restrictions on quality parameters, which could be, for example knots and rot. In the case of spruce it is usually disclaimed to differentiate to any log quality class. In contrast, German sawmills generally rely on sets of parameters defined in international (EN 1927, EN 1316), national (upcoming RVR) or state (HKS) grading rules. Quality parameters are ranked here according to their level of importance and defined in absolute values. Parameters such as knots (knot status, dimension and amount per linear meter), discolouration, rot, insect damages or spiral grain are taken into consideration. They are applied species wise or on species groups like spruce/fir or pine/larch with similar wood properties. Typically, 4 log quality grades are sorted from A to D, which is represent the decreasing requirement on roundwood quality. Within this research, it was impossible to assess which of these methods is more advanced for the transposition of industrial needs on products specifications to roundwood characteristics in forest stands. Both are applied and adapted to different harvesting (clear cut and selective logging) and forestry regimes and, therefore, in many cases cannot be compared.

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