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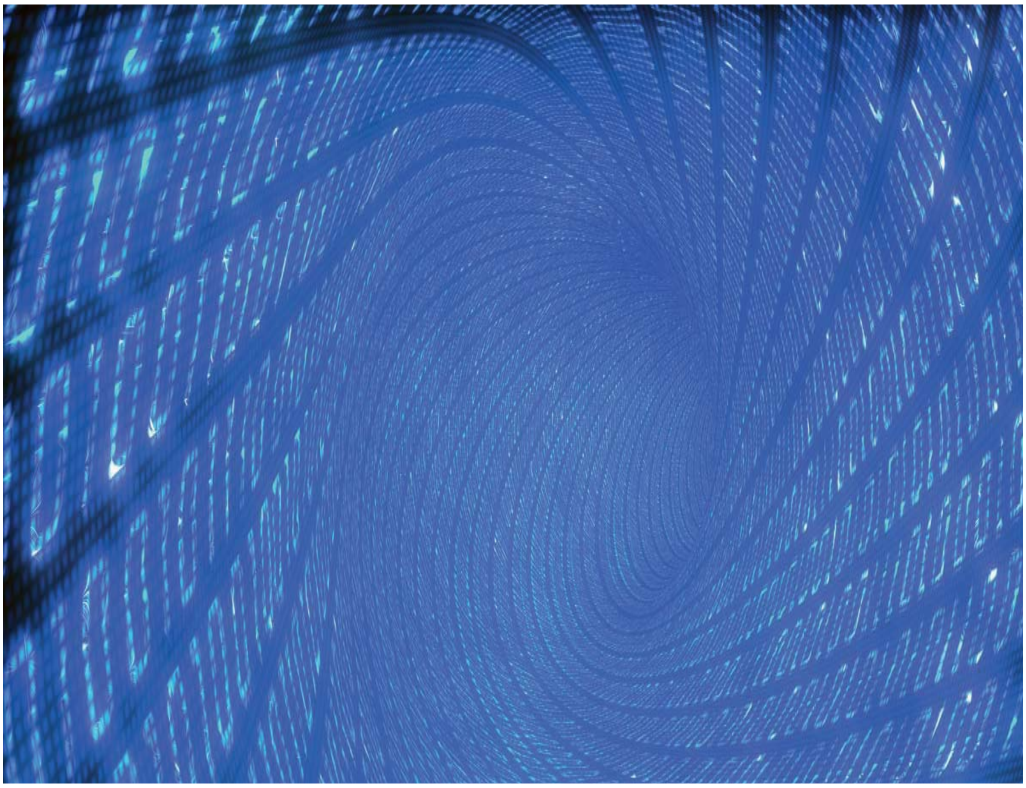

Project no: 34732

D3.5 Methods and models for relating wood properties and storage conditions to process efficiency and product quality

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Intelligent distributed process utilization and blazing environmental key

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D3.5

Methods and models for relating wood properties and storage conditions to process efficiency and product quality

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1 Executive Summary

This deliverable describes methods and models for relating wood properties and storage conditions to process efficiency and product quality in general and with emphasize on traceability (at different levels) and the digital information chain all in the context of the Indisputable Key project.

The objectives of this report are to provide methods and models which can be used to improve monitoring, understanding, valuation, automatization and decision making with respect to reduced process costs, reduced environmental load and increased product values of wood supply chains. One prerequisite to fulfil the objectives is to “start smart” and continue to work smart, and smart will usually be equal to based on knowledge and analyses.

Increased economic gain, possibilities for more profitable work and improved environmental concern can all be influenced by wood properties and storage conditions. The main impacts of log properties and storage conditions can be divided into three main fields: **a)** impact on process efficiency, **b)** impact on proportions of products and product quality classes and **c)** delivery accuracy in relation to stock management, business agreements and contracts.

The quantified economic and environmental impact of wood properties on the outcomes of the value chain should be balanced as cost/benefits step by step through the chain. Some of the wood properties can be measured or predicted by harvesters' or by high resolution inventory measurements. The impacts of some of these log properties have already been roughly estimated. Log diameter and log length will have impact (**a, c**) on yield and productivity. Distances between branch whorls (internode lengths) will have impact (**a, b, c**) on the value of blanks aimed for window frames. Basic density will have impact (**b, c**) on strength (C-classes) of structural timber. Sound knots will have impact on the quality of interior panels (**b, c**). Heartwood content will have impact on durability (**b, c**) and kiln drying (**a**) etc. Some properties will have impact on the value of by-products. The impacts of some of these properties have been investigated earlier, with respect to different specific processes and products. Such information can be used to identify the most important properties to focus in the production chains. However for many properties the impacts are still not analysed or estimated by other means.

The work with simulations (“Sawmill to secondary manufacturer simulation tool” D3.7 Chapter 7) for the SWSC can give us indications of the impact and values of some log properties but only if they are directly or indirectly included in the model. Possible impact from remaining properties and validation of the results from simulations, have to be evaluated by studies of the real production, preferably by means of traceability.

Traceability is about digital and physical traceability in combination. In this document we present a step by step description of the modern wood supply CTL system as it look like both in general and in the additional context of the IK project. Our conclusion is that an economic introduction of the IK system architecture should start with statistical traceability like the control logs from the Quality control system for harvesters. A statistical sample of traceable individuals will bring much further knowledge and basis for important considerations concerning the accuracy of measurements and predictions of wood properties and where and how to utilize wood properties in the most economically and environmentally efficient way. The results from the most recent analyses (second release) show a good correspondence between simulated predicted log properties and measured (harvester and 3D frame at sawmill) and predicted properties of sample logs from production files in the Swedish Wood Supply Chain.

2 Background and objectives

Native stem and log properties in the forest, methods and techniques for characterising, selecting, felling, bucking, forwarding, piling, loading, transporting, unloading and stockpiling at sawmill will all directly or indirectly be related to process efficiency or product quality or both.

The objectives of this report are to provide methods and models which can be used to improve monitoring, understanding, valuation, atomization and decision making with respect to reduced process costs, reduced environmental load and increased product values of wood supply chains.

3 Introduction

Increased economic gain, possibilities for more profitable work and improved environmental concern can all be influenced by wood properties and storage conditions. The main impacts of log properties and storage conditions can be divided into three main fields:

a) process efficiency

b) proportions of products and product quality classes

c) delivery accuracy in relation to stock management, business agreements and contracts

In this report we have focused on methods and models that can relate wood properties and storage conditions to process efficiency and product quality in the context of Indisputable Key. In line with the project focus on traceability we have put focus on different means to improve process chain coherency with respect to solid wood products. Figure 1 shows a typical outline of a forest to final products chain also indicating the divergence of products coming from harvesting of a typical harvesting object. In the following we have gone into details concerning supply chains (referring to case 7.1 – 7.4 in tables 3-5, D3.2 Existing models and model gap analyses for wood properties) similar to the Swedish Wood Supply Chain (SWSC), i.e. case study 7.1 Sveaskog - Setra Malå - Norsjö wood (Scots pine). However many of the methods and models presented and their possible impact on process efficiency and product quality are to a considerable extent valid for the cases 7.3 ESAS (Norway spruce) and 7.4 Raunion (Norway spruce) as well. An overview of the cases has been presented in e.g. D3.1 “Initial analysis of drivers and barriers” and the impact of wood properties, existing models and model gaps have been presented in D3.2 “Existing models and model gap analyses for wood properties”. Once the logs (and poles) have arrived to the log reception there will be considerable costs for rejecting them from the ordinary production. The later in the chain unsuitable properties and damage from storage are detected the higher the cost.

Methods and models facilitating coherency include tools, supportive systems for planning and operative actions, and control systems. Models will also imply algorithms for predicting stem and log properties and their realised or potential impact on process efficiency and product quality. The effects of selection among harvesting objects, adaptation of bucking instructions, the level of sorting into different assortments and the forwarding, road-piling and haulage operations are all dependent on the possible impacts and costs of taking action in different links of the production chains. By full traceability of a limited but continuous flow of sample logs (e.g. in ordinary production routines integrated with the quality control system for harvester measurements), a considerable part of the drivers (See D3.1) of the traceability system as regards improvements of the forestry to industry integration can be achieved at a limited cost. We can foresee possible improvements of pre-harvesting information, like (air-born and terrestrial laser scanning) measurement technology on harvesters and in harvester felling heads. Furthermore we expect reductions of costs for efficient traceability. These factors will add value and reduce cost for more extensive use of traceability at all individual logs, also reducing cost for separate handling of different assortments, quality classes etc. aimed to be delivered to the same mill.

Methods and models for relating wood properties and storage conditions to process efficiency and product quality will also include a lot of subjects that are based on internal measurements and processes within a sawmill unit. Modern sawmill technology includes 3D frames providing high resolution measurements on geometric shape of logs(stems) and also a number of sawmills have installed X-ray frames (similar to tomography) for detecting internal log (stem) properties all aiming to improve production control at log conversion. In this report these parts will not be deeply described examples on how to use this kind of high resolution data for process improvements are given in D3.6 “Influence of processing conditions and wood properties on saw mill operation”.

In an attempt to calculate the “real” values of different logs in the SWSC, the average modelled value (indicated, not exactly real) selling or internal prices for boards, chips and bark of undamaged logs where by average 1113 SEK/m³s u.b.+ bark with a difference between means for diameter classes and assortments of between 858 and 1342 SEK/m³s u.b. + bark and the differences between logs were modelled to between 726 and 1520 SEK.

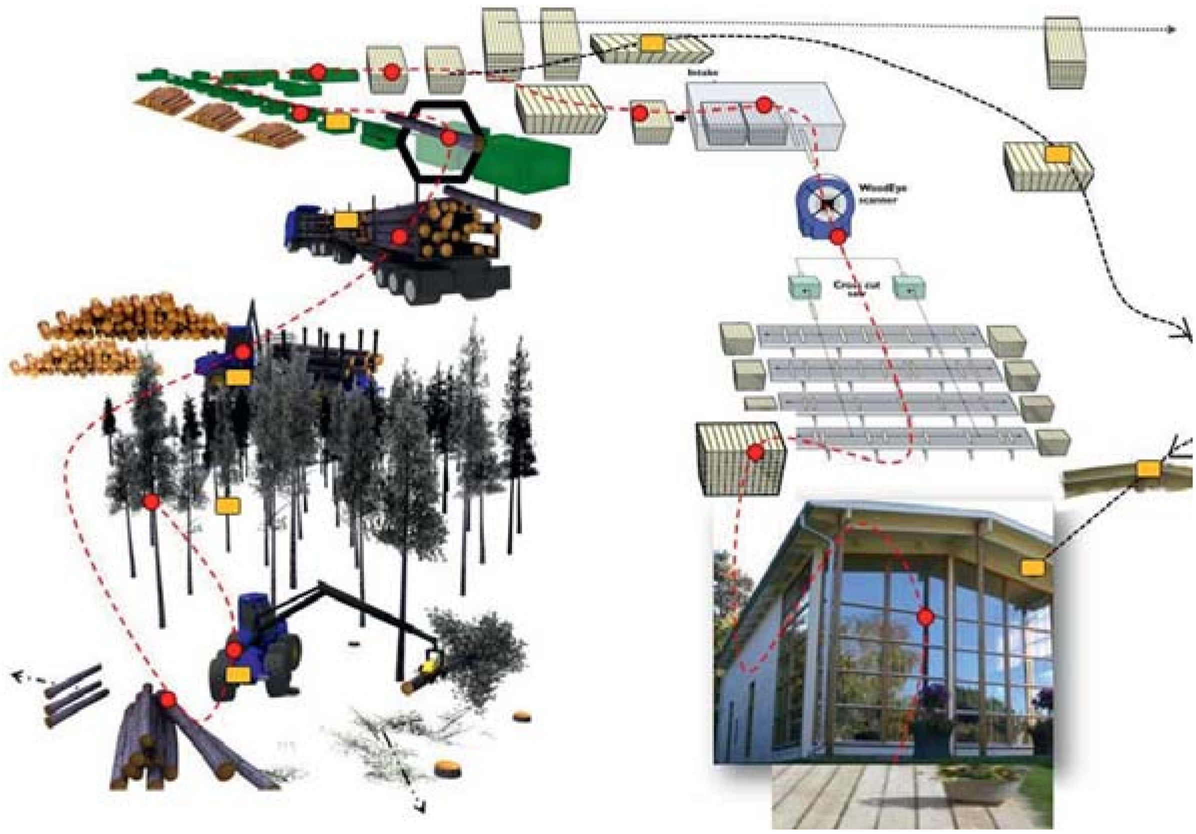


Figure 1. Outline of a forest to final products chain where a CTL harvester serves more than one customer (e.g. one–two wood industries, one pulp & paper industry, and an energy plant) and several different products from one harvesting object. Information should be connected to the physical flow from forest to industries. Traceability makes it possible to send high resolution feed back and improved specifications of well-founded demands and premium or deducted prices. (Computer animation components forestry to sawmill Peter Wilhelmsson, Drawings Wood manufacturing, WoodEye, House Träguiden)

4 Limitations

There are both technical and economical limitations concerning methods and models for relating wood properties and storage conditions to process efficiency and product quality. In general the cost for measuring a property with a certain accuracy at one stage in the chain should be justified by larger reduction of cost or increase of revenues elsewhere in the chain. Higher precision will usually increase cost. By means of traceability it will be possible to accumulate information instead of losing the history of a log every time it will be mixed with other logs. By means of information systems and statistical/mathematical models valuable information can be gathered at a very low cost. However the accuracy of predicted properties of wood has to be considered. For models based on statistic adaptations their validity may be dependent on the similarities between the materials used for development of the models and the environment (material etc.) where they should be applied. A considerable part of the models concerning wood properties have a deductive origin as a core combined with statistical tuning based on experimental studies. Such models may be more stable in different environments. However, validation of results from models and quality control of measurements is important when considering improvement of the value chains. The statistical sampling with full traceability, we will achieve by the IK development of the quality control system for harvesters (See 5.2.2) will be a very strong tool for both validations and further development and improvements of models. Such validation swill also be a basis for economic considerations when discussing investments in measurement technology.

5 Methods and models - forestry to log reception –

Figure 2. Outline of the main processes from harvesting to sawmill intake describing a chain to one of several customers/production units. (Animation components Peter Wilhelmsson)

The overall objective of Indisputable Key is how to meet the consumer’s expectations in the most efficient way. One prerequisite to fulfil the objectives is to “start smart” and continue to work smart (Figure 2). In the following we are taking the reader step by step through “best practice” based on the current level of knowledge, available technology and additional possibilities which have been developed since the start of Indisputable Key.

5.1 Methods previous to harvesting

5.1.1 Offering the possibilities from forestry

Starting the physical production chain with making optimal decisions and doing the right thing with respect to customer demands, balancing delivery alternatives, selection, bucking (i.e. cross-sectional cutting of stems to logs), sorting and haulage and at the same time using the logging and truck fleet in the most efficient summarise the objectives of a forest wood supply organisation. In the following we will use the term bucking simulation which typically will be performed as follows:1) Representative individual trees are described by breast height diameters and total tree heights. 2) The demand for logs of specific diameters lengths and applicable quality traits are specified by a pricelist or apportionment matrices. 3) The value of produced logs (Cut To Length) and/or fitness to apportionment demands can be compared and optimized.

A key to success in this work, as being a player at the wood market, is detailed information on individual trees within a database of harvesting objects available for harvesting. The possibilities to fit the demands of different industry customers may then be communicated between forestry and industry. This communication, including offering the possibilities from forestry in relation to clearly expressed and preferably also valued specific specifications from industry customers will at least in theory improve both efficiency (lower cost per unit final product) and the potential total value of end products, always keeping in mind that parties along the production chains are players at a currently altering market. By traceability the importance of present knowledge can be analysed and validated. Traceability at different levels will also provide possibilities to gain new knowledge and higher levels of details as regards the value of different wood material properties for different processes and the importance of different actions at the beginning of the chain.

5.1.2 Trends of customers orders/preferences

The customer, i.e. a sawmill, pulp mill, energy plant or similar, has certain demands that can be of varying specificity. Current sawmill demands usually covers total volumes, species, diameters, lengths, delivery times, industry stock levels etc, but we could also imagine a wider scope where for example wood properties like internode distance, heartwood content etc are also included. If the demands are well described and somewhat suitable for the type of forest resources available in the region, there are opportunities to work with matching the customer demands with the available forest resources to obtain the best solution for all parties. By different means of traceability the customers order and production reports can be much better compared. In the following we will follow the chain from forest to sawmill.

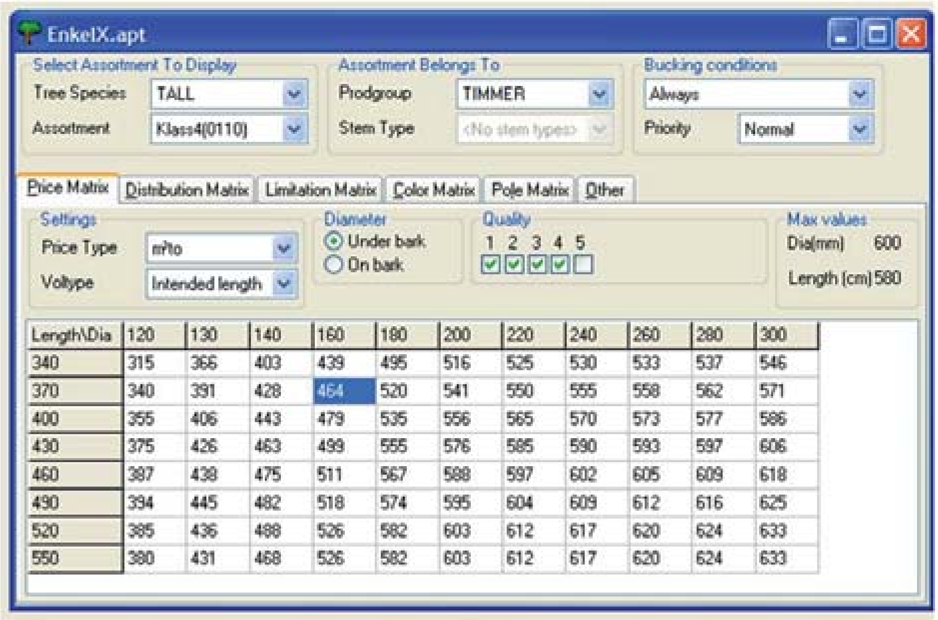
5.1.3 Forest inventory measurements

Before harvesting, trees at a potential harvesting object may be sampled according to a forest inventory routine. Typically this will result in information on standing volumes, proportions of different species, average breast height diameter, tree height, stem size and tree age. New techniques for forest inventory by air-borne laser scanning, will provide height and breast height diameter of all individual trees within a harvesting object, and thereby improving the projections.

5.1.4 Selection of harvesting objects

To bring out the full potential of the wood to be harvested, demands and customer orders should be carefully matched with information from inventories/of the forest resources. The difference between the estimated total incomes of the final products and the total costs spent along the production chains should in principle be maximised with respect to given restrictions. Economic and environmental valuation of wood properties can be performed by bucking simulations based on strict demands like basic assortment requirements, number of logs per diameter and length class, and penalty costs for different kinds of deviations. Wood properties having a statistical impact on the proportions of different products and quality classes may also be valued by a value index giving a premium for desirable properties and a deduction of inferior properties in comparison with “norm values”. Such a system for consistent but flexible value of bucking alternatives can be continuously improved by means of traceability.

In order to achieve the best matching of logs from harvesting in relation to customers orders, the bucking simulation tool developed at Skogforsk – Aptan (a part of TimAn2 described in D3.7) – can be used to construct a price list (Figure 3) based on the parameters which are handled by the harvester computer software. The Aptan tool can also be used to compare the result of bucking based on different price lists and to make projections of alternative yields of a harvesting object.



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 3. Screen shot of a Price Matrix (SEK) for Pine (Tall) saw logs from a bucking simulation. Each (competing) assortment is defined by a price matrix or fixed prices per volume unit. The bucking simulation can be strictly controlled to perform the highest value according to the pricelist or to fulfil demands given as required apportionments of specific log lengths and log diameter combinations within specified limitations of accepted losses in price (value to forest owner). At the present stage, log number from stump will be registered but only the proportions of the sound knot quality (Quality class 2) can be automatically classified by the bucking system. Other quality classes are seldom registered at harvesting but can be judged by the harvester operator if requested. The reliability of such judgements has been shown uncertain.

The output of the bucking simulation is a pri-file (StanForD), including information about each individual log produced. Based on the data in the pri-file, a number of properties can be calculated for each log using the Pri-analyses tool (described in D3.2) that contains a number of models predicting wood properties. By evaluating the outcome of harvesting in each of the objects simulated, the most suitable object(s) can be chosen for each customer.

In some cases, logs with more specific properties (e.g. long internode distance suitable for wood component manufacturing by finger-jointing) could be worthwhile sorting out even in smaller volumes from several objects and transported to one customer. In this case, a cost-benefit analysis should be performed in order to determine the case for transporting more specific logs over longer distances to achieve a better total yield of the industrial process.

5.2 Methods at harvesting

Harvesting methods are continuously developed. Since the start of the project in 2006 many parties in Swedish (and other Scandinavian) forestry supply chains have now developed their information systems considerably. This includes digital harvesting object directives (Figure 4) (Arlinger 2008). Some of the drivers are customer needs for improved accuracy in deliveries concerning, log dimensions, log types and time of delivery. There are also drivers based on the needs to improve quality of feed back to forest owners as well as for an increased use of harvester measurement as a basis for paying forest owners as well as progressive work to increase productivity and decrease costs.

Figure 4. Digital harvester object directives can now be presented on screen in the harvester and forwarder computers according to StanForD-standardisation. This enhance traceability at the pile level and is a tool for atomised communication as harvester production reports linked to forwarding operations and reports.

5.2.1 The harvester measurement systems

Harvester measurements are keys to the bucking and property characterisation systems. The more accurate the harvester measurements the better logs will fit customer requirements and the 3D-scanner measurements at the sawmill reception. Improved non-contact measurement technique in the harvester felling head (Andersson et al 2008) may make harvester measurements of individual log characteristics from a specific harvesting object to fit measurements by 3D/X-ray scanners at the sawmill reception at a meaningful level of certainty.

At harvesting, the diameter is measured every 10 cm along the stem, and the data is stored in the harvester computer. Today, diameter measurements are made with sensors that are in contact with the stem, which might cause e.g., unwanted debarking and inaccurate measuring. In the future, measuring systems utilizing non-contact techniques might be used to improve measuring. The length of the log is determined by measuring how far the log has been fed through the harvester head. To determine the length of the stem, all logs from the stem need to be added and a projection can be made to determine the length of the top.

The volume of each log is calculated both over and under bark using section-wise calculations. The volume under bark is determined using specific bark functions (Hannrup, 2004) to adjust for the predicted thickness of the bark in each log. In Sweden the volume measured by harvester should diverge less than 5.5 % at a wood lot of at least 10 m^3s, then coming down to less than 3 % from the true volume at 400 m³s total volume or more (VMR 2007-04-15a, page 8).

In Sweden, the wood measuring council regulates and controls scaling for payment between different parties. According to agreed rules they require that harvester teams, should obtain at least 55 % of the diameter measurements within ± 4 mm (as compared to an external auditor) and at least 70 % of the length measurements within ± 2 cm, before they will be certified to start operations. (VMR 2007-04-15b).

5.2.2 Selection of stems and cross-sectional cutting

Modern harvesters are equipped with computers which are utilized for automatic bucking decisions. At harvesting, the harvester head is used to grip the stem, which is subsequently cut. After felling, the stem is fed through the harvester head and de-limbed. During de-limbing, the stem diameter is collected every 10 cm, and a prognosis of the so far unmeasured part of the stem is made, given models in the computer software and corrected by diameters from previously harvested stems in the same object. Based on the measured diameters, a number of bucking alternatives are determined, and the optimal one (with respect to the current price list) is selected. The operator can also make manual (forced) cuts if damages or other defects are observed.

5.2.3 Sorting and marking logs

The logs are arranged in separate piles for each assortment. In order to facilitate the work for the forwarder operator, logs in assortments that may be hard to keep apart, e.g. small timber dimensions and pulpwood, are marked with one specific colour per assortment by the harvester. The paint is applied automatically (or manually by the harvester operator), using a feature at the harvester head. The paint is usually bleached during storage in forest and at road side, so that the colour coding cannot be used for sorting at the sawmill. One way to get an efficient and low cost labelling of a pile might be by bringing clearly colour and transponder marked logs at the top of each loaded pile. These logs should then be loaded as the first and the last log fed from the pile into the 3D-scanner.

The more detailed type of marking by RFID tags or ink based coding systems which are developed in the Indisputable Key project can be used to trace logs all the way from the forest and through the industrial process at the sawmill (Figure 5). When used extensively the marking must be automatically attached to the log. Low frequency marking, for example manually controlled sample logs, may however be done manually, even though they would preferable be automatically marked, especially if the frequency of marked logs for different reasons should be occasionally or permanently increased.

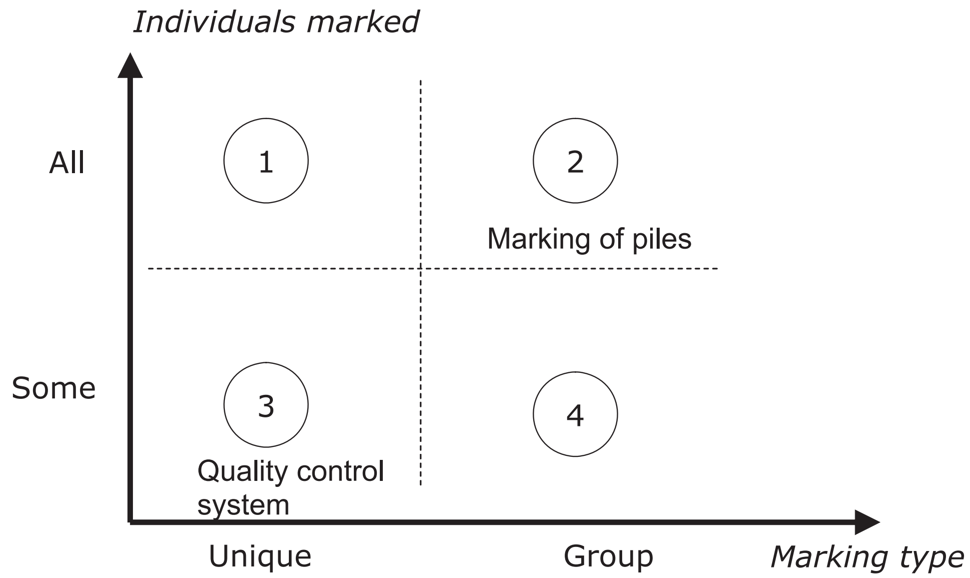


Figure 5. Illustration of different levels of marking logs (D3.1). Marking the logs measured according to the Quality control system (se below) will provide much information on a small but valuable statistical sample of individual logs for a low cost. Marking of piles with a "start" and a "stop" log at the beginning and end of a pile at unloading at the log reception will keep track of large batches of wood for a low cost.

5.2.4 Quality control measurements

The IK integration of traceability into the new quality control system for harvesters is a break-through. The quality control system has been developed by Skogforsk in collaboration with the forestry sector, SDC (IT organization owned by the Swedish forestry sector) and the timber measurement bodies. In order to make sure that harvester measuring of length and diameter are within acceptable limits, a system for quality control has been developed. The system is based on a randomly selected sample of stems (usually 1-2 stems per day and team) that is measured manually by the harvester operator. When the operator gets an indication from the harvester computer that a control stem is selected (usually done when the second log is about to get cut), the rest of the stem is prepared and logs are placed so as to facilitate measuring. The stm-file (according to StanForD data standard, including information about the stem that has been collected by the harvester) is transferred to a digital calliper that is used for measuring the control logs. The logs are then measured manually by the operator and data is stored in a ktr-file in the digital calliper. When the operator returns to the harvester, the ktr-file is transferred to the computer. At the next occasion for production reporting from the harvester, the ktr-file is also sent.

The control measurements are monitored by an independent auditor, who also makes field inspections at a few occasions annually. During the field inspections, a few stems are control measured to insure that length and diameter is measured correctly and that the harvester lives up to the demands of the timber measurement bodies.

Bringing the IK traceability solution with the manual axe-applicator into the quality control system (Figure 6) has now been successfully demonstrated. We regard this as a very cost–effective way to gain much of the possibilities discussed in D3.1 Initial analysis of drivers and barriers by quality statistics from low frequency but well structured sampling.

Figure 6. The Quality certification (control) system has just recently being operationally applied into Swedish forestry (Arlinger & Möller 2006). In Indisputable key we have added traceability to this system. It will provide a quick and cost-efficient introduction of traceability still achieving many of the identified benefits on a statistical basis.

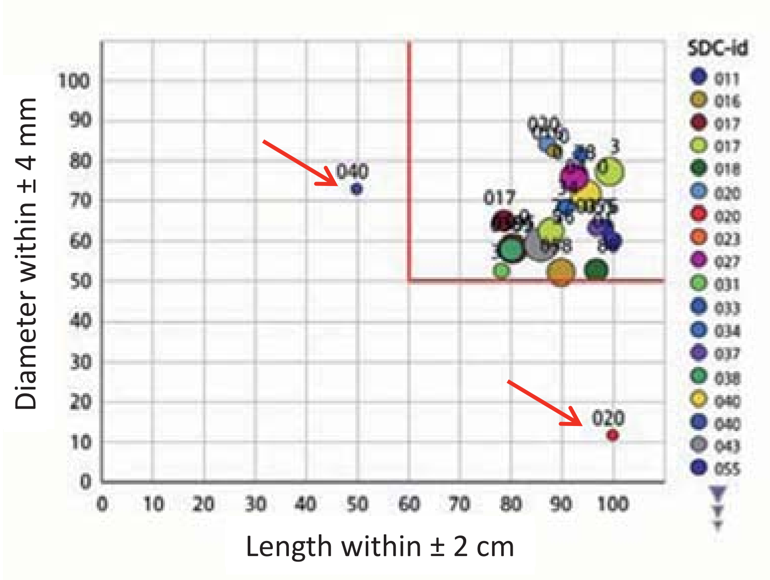


Figure 7. Quality control measurements from 18 different harvesters (SDC, Sweden). The area of each circle is proportional to the number of measured control stems. The position of each circle shows the percentage of harvester measurements within +/- 4 mm (diameter, y-axis) and +/- 2 cm (length, x-axis) when compared with manual callipering. Arrows indicating inacceptable accuracy of length (harvester 040) and diameter (harvester 020) measurements respectively.

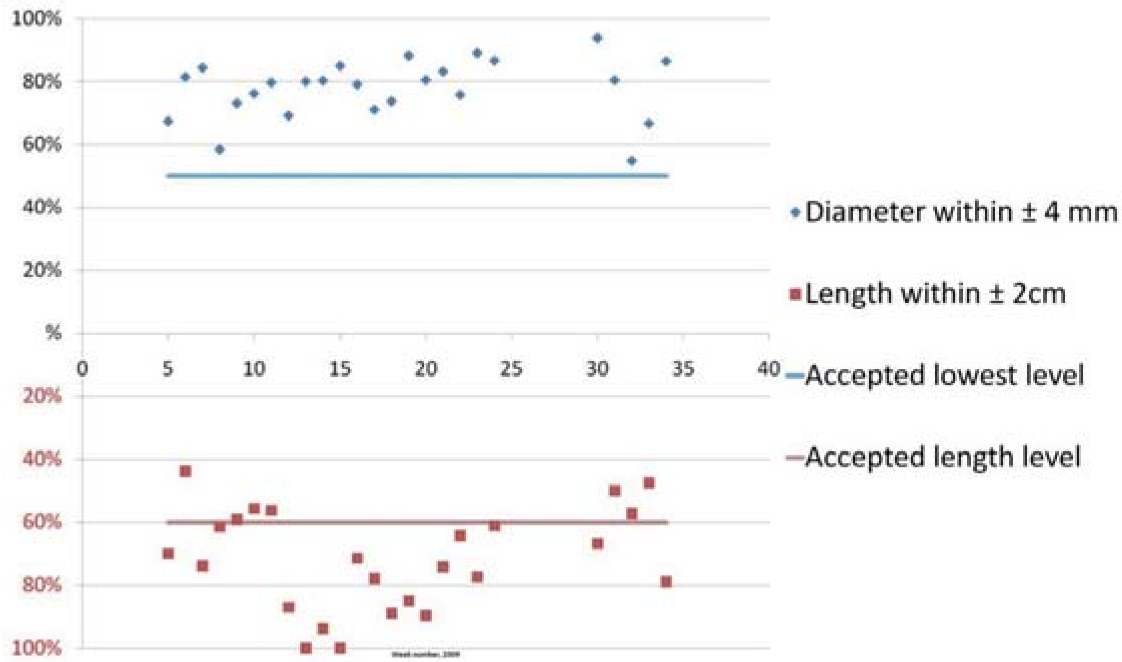


Figure 8. Detailed picture of statistics from the Eisab harvester, week 4-34 , 2009(X-axis). This harvester has been a reference machine for the SWSC case study. Diameter measurements have been above acceptable level all weeks while there have been a few occasions of problems with the length measurements. However the number of control logs within each dot are limited. This may result in some “extreme” values that should not be taken as evidential.

5.2.5 Forwarding

Once the logs are on the ground, the forwarding work begins. The complexity (and thereby cost) of the forwarding operation is very much determined by the number of assortments produced. If there are many smaller assortments, the forwarder operator needs to spend more resources keeping the assortments apart. The forwarder is therefore dependent on good marking of the logs in the forest. To make the forwarding procedure efficient the number of assortments must not be too many within one load. If the destination is the same for all assortments this will simplify the handling at forwarding. If several destinations are planned within the same harvesting object, individual traceability will not solve the problem to keep the logs separated into different piles.

5.2.6 Stacking at roadside

The forwarder brings the logs to roadside, where they are arranged in piles by assortment. The piles are marked with paper tags in order for the transporter to be able to identify assortments and their final destination. The forwarded volumes are reported, usually once per shift but more frequent reporting is possible when requested. In the IK solution this is done electronically by prl-files (StanForD) or when not available through a voicemail system.

5.2.7 Information from harvesting object to sawmill customer, logistics organisation and forest owner

In the IK system all production information from the logging operations (harvesting, forwarding and stacking to roadside) will be reported to the specific customers, to the organization working with operational logistics and to the supplier (forest owner) without delay. Different parties and customers in the supply chain will benefit from different information. Table 1-4 show the information we can measure or calculate (predict, estimate) and distribute from the forestry operations. Lot of this information is measured and calculated at the individual log level, but without individual traceability it can only be handled as statistical distributions at the pile level. As many of the predictions have a considerable prediction (or measurement) error the value of individual traceability will be reduced making pile level traceability economically feasible. However as measurement technology become less expensive and provide higher accuracy, the arguments for individual traceability will be strengthened.

5.2.8 The current situation of the IK project

No data is available from whole forest to industry chain as of December 2009. Therefore it has not been possible to carry out validations of statistical functions or the whole chain of methods as described previously within the IK-project.

The pre-existing tools for analysing data (primarily pri- and ktr-files) have been developed in order to include traceability information. This means that the methods and tools described in chapter 5 are adapted to the IK traceability systems and can be run today whenever data from the whole chain is available.

Table 5 shows a structure where the quantified economic impact of each of the quality parameters can be filled in when/if determined. Some of the figures have already been roughly estimated with respect of specific processes and products, while a majority are still not analysed or estimated by other means. The work with simulations (“Sawmill to secondary manufacturer simulation tool” see D3.7 Methods and Algorithms for Holistic Supply Chain Management and Multivariate Statistical Analysis of Supply Chain Data, Chapter 7) for the SWSC can give us indications of the impact and values of some log properties but only if they are directly or indirectly included in the model. However possible impact from remaining properties and validation of the results from simulations, have to be evaluated by means of traceability. If the economic weights with respect of a) Impact on process efficiency b) Impact on product/proportions/quality and c) Impact of delivery accuracy (table 5) can be determined for the most important properties with respect to a specific process and product, a modified selection index theory (e.g. Berlin et. al., manuscript) may be applied. The correlations (co-variances) between the different properties should also be determined and included.

Table 1. Description of ordinary (not extended) pri file.

Description
Assortment number.
Species number. The number refers to the order of the species in variable 120.
Diameter top, mm ob.
Diameter top, mm ub.
Diameter mid, mm ob.
Diameter mid, mm ub.
Diameter butt, mm ob.
Diameter butt, mm ub.
Middle diameter according to HKS measurement, mm ob
Middle diameter according to HKS measurement, mm ub
Forced cross-cut (break) at small end, code according to var300
Length, cm
Volume according to Var161.
Volume m3sob.
Volume m3sub.
Volume m3topob.
Volume m3topub.
Volume m3smi ob.
Volume m3smi ub.
Volume according to Var161 in dl (not m3).
Volume dl sob.
Volume dl sub.
Volume dl topob.
Volume dl topub.
Volume dl smi ob.
Volume dl smi ub.
Stem number.
Log number in stem 1st log =1, 2nd = 2 ...and so on ...

Table 2. Tree data in ordinary (not extended) pri file.

Description
Species
Stem number
Adaption of harvesting for retrieving bio energy assortments
DBH (on bark) measured at height according to var500_t1, mm
Stem type (Finnish PMP codes)
Operator number. The number refers to the order of the drivers in variable 212.
Latitude, integer as 0.00001 degrees
North or South
Longitude, integer as 0.00001 degrees
East or West
Altitude, meters above sea level

Table 3. Properties predicted (calculated) and added to extended dataset in IK-PriAnalysis. Observe that no relevant data from the original pri file is excluded from the extended dataset.

Name	Description	Unit
Dens	Basic density under bark, kg/m3s.ub.	kg/m3s.ub.
HeartDiam	Heart wood diameter, mm	Mm
Heart	Heart wood proportion, %	%
Mean_Dbl_ Barkthickn	Double bark thickness, mm	Mm
Late	Latewood proportion, %	%
AnnGrRing	Number of annual (growth) rings	No
FiberL	Fibre length, mm	mm*100
FiberWl	Fibre wall thickness, µm*100	µm*100
KDMax	Maximum knot diameter, mm*100	mm*100
KType	Proportion of green knots at surface, %	%
GreenDensUb	Green density under bark, kg/m3s.ub.	kg/m3s.ub.
BarkDens	Green bark density, kg/m3 (solid)	kg/m3
GreenLog	Sound knot log top cylinder only includes sound knots)	No
VolPriceDl	Volume accepted for valuation	Dl
VolSubDl	Solid volume under bark, dl	Dl
VolSobDl	Solid volume over bark, dl	Dl
ManCutCode	StanForD-code indicating whether log was cut manually by operator (0=automatic)	No
Mass	Calculated raw mass of log, kg	Kg
MeanDia_ob	Calculated average diameter for whole log, mm	Mm
MinAnnGrRing	Number of growth rings at small end of log (minimum)	Years
MaxAnnGrRing	Number of growth rings at large end of log (maximum)	Years

Table 4. Additional wood properties, environmental parameter and work load estimates added to a super extended dataset in addition to what comes out from TimAn2 and PriAnalysis respectively. Observe that no relevant data from the original pri-file and the extended dataset is excluded from the super extended dataset.

Parameter	Description	Unit
Dens12Fk	Density at 12% MC (by dry weight and by actual volume)	kg/m3sub
Knotwhorl	Longitudinal width of average knot whorls in the log	Cm
NetInternode	Average NetInternode = average knot-free distance between branch whorls	Cm
NetInternodeshare	Share of knot-free wood between branch whorls in percent of total length	%
Origsort	Original assortment by harvester or bucking simulation	No
MOR	Modulus of Rupture	MPa (N/mm²)
MOE	Modulus of Elasticity	GPa (kN/mm²)
Barkprocpb	Bark percentage based on volume over bark	%
ToDiaubclass	Log small end diameter class under bark	Varies
Carbonkgperm3Ub	Sequestrated carbon per m3 wood	kg/m3sub
CarbonkgLogUb	Sequestrated carbon in log excluding bark	Kg
Carbbarkkgm3Pb	Sequestrated carbon in bark	kg/m3sob
CarbbarkkgLogPb	Sequestrated carbon in bark per log	kg/m3sob
M3ObperTonCarbon	Required volume to sequestrate one ton carbon	m3fob.

Table 5. Economic and environmental impact of wood properties with respect of processes, products and accuracy in deliverance to sawmills' customers

Description of property	Impact on process efficiency	Weight[1)]	Impact on product/proportions/quality	Weight[1)]	Impact on delivery accuracy	Weight[1)]
Diameter top, mm u.b	40-60% yield of log vol, productivity	eDt	Yes	qDt	Yes, stock of products, dimensions	aDt
Diameter mid, mm u.b.	Yes, yield and productivity	eDm	Yes	qDm	Yes	aDm
Diameter butt, mm u.b.	Yes, yield and productivity	eDb	Yes	qDb	Yes	aDb
Length, cm	Yes, productivity	eLe	Yes	qLe	Yes, stock of products, lengths	aLe
Dens	Yes e.g. kiln drying	eBD	Yes e.g. proportions of C-class, surface req.	qBD	Yes, stock of quality classes	aBD
HeartDiam	Yes, e.g. kiln drying	eHDm	Yes, % change in prop durable boards	qHDm	Yes stock of durable products	aHDm
Heart (%)	Yes, e.g. kiln drying	eH	Yes, % change in prop durable boards	qH	Yes stock of durable products	aH
Mean_Dbl_ Barkthickn	Yes, affects measurem. accuracy	eBA	Accuracy sawing pattern, wane etc.	qBA		aBA
Late	See Dens	eLa	See Dens + visual properties	qLa	See Dens + visual properties	aLa
FiberL		eFl	Sawmill chips quality	qFl		aFl
FiberWl		eFW	Sawmill chips quality	qFW		aFW
KDMax		eKDm	Yes proportion of quality classes	qKDm	Yes stock of quality classes	aKDm
KType		eKt	Yes proportion of quality classes	qKt	Yes stock of products and quality classes	aKt
GreenDensUb	Yes e.g. kiln drying, speed, blunt	eGD	Yes, e.g result from kiln drying	qGD		aGD
BarkDens		eBD	Yes, Energy utilized from bark	qBD		aBD
Barkprocpb	Yes, energy	eBp		qBp		aBp
GreenLog	Yes, speed	eG		qG		aG
VolSubDl	See Diameter and Length	eVol	See Diameter and Length	qVol	See Diameter and Length	aVol
Mass	Cost of haulage	eM		qM		aM
AnnGrRing		eR	Yes proportion of quality classes	qR	Yes stock of products and quality classes	aR
MinAnnGrRing		eRmi	Yes proportion of quality classes	qRmi	Yes proportion of quality classes	aRmi
MaxAnnGrRing		eRma		qRma		aRma
Dens12Fk		eD12	Yes, e.g. required surface prop.	qD12	Yes stock of quality classes	aD12
Knotwhorl	Yes, when cutting knot whorls	eKnW	Yes proportion of quality classes	qKnW		aKnW
NetInternode	Yes, when cutting knot whorls	eNI	Yes, 1-2% difference in board value/cm	qNI	Yes stock of adapted boards	aNI
MOE		eMOE	Yes, e.g. proportions of C-class	qMOP	Yes stock of quality classes	aMOA
MOR		eMOR	Yes e.g. proportions of C-class	qMOR	Yes stock of quality classes	aMOR
M3ObqerTonCarbon		eCar	Information	qCar	Information to customers	aCar

[1)] Weights= Economic (or environmental) weights which should be determined and expressed in value indices i.e. make the system more economically efficient (used for optimisations).This table should be considered for each mill and product/(mix of products) covering the most important properties (not all). OBSERVE: Correlations between variables should also be considered!

6 Methods and models - log reception and forward -

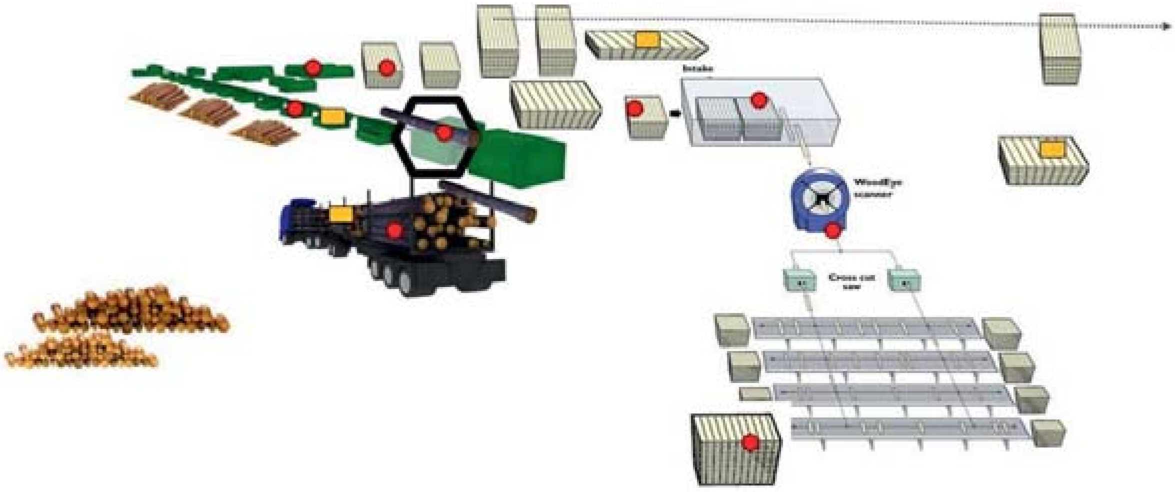


Figure 9. Outline of the main processes from sawmill reception to secondary wood manufacturing.

The paradigm of work going on concerning methods and models within the sawmill is briefly described in D3.2 and concerning some exemplified details in D3.6. In the SWSC chain the efficiency in producing knot free blanks and finger-jointed wooden frames is focused. In this process special interest is put on the distances between branch whorls in the growing trees and width of branch whorls. This is expressed as the net internode length in logs and centre boards. When used for finger–jointing this parameter may add value to the centre boards between 1 and 2 % per centimetre above average and a deduction of the same magnitude when inferior to the average.

7 Storage conditions from forest to final product

Storage usually means a capital cost. It may also be uncertain if the stored wood is optimal in relation to customers' demands. It also includes a risk for damage caused by drying out, stain, debarking problems and finally cracks and deformations (Figure 10). But storage also provide a buffer for different disturbances in harvesting capacity, problems with thawing roads, bad weather and rapid increase in demands of wood at the market. Accepted differences and buffering capacity of stored roundwood will also simplify efficiency in logging operations when strictly isolated. When looking at the total system it might be different. The information systems built by StanForD in connection with papiNet can assist the storage management considerably. Delivery reliability from the forest may sometimes be hard even though only volumes of sawlogs per month are reflected without any other requirements. If diameter and length and specific combinations of these and wood properties as long internode distances, sound knots, heartwood etc. are taken into account and the time scale is stressed down to weekly based plans, difficulties will rapidly increase. Solutions may be hard but will be considerably easier to overview if forest inventories and bucking simulations previous to harvesting are practiced and harvester reporting of pri-files (harvester production messages) are systematically compiled and the results currently taken into consideration. Coordinated production control of the harvesters by flexible pricelists will also improve the possibilities to keep the need for large and as regards content of logs not optimised stores.

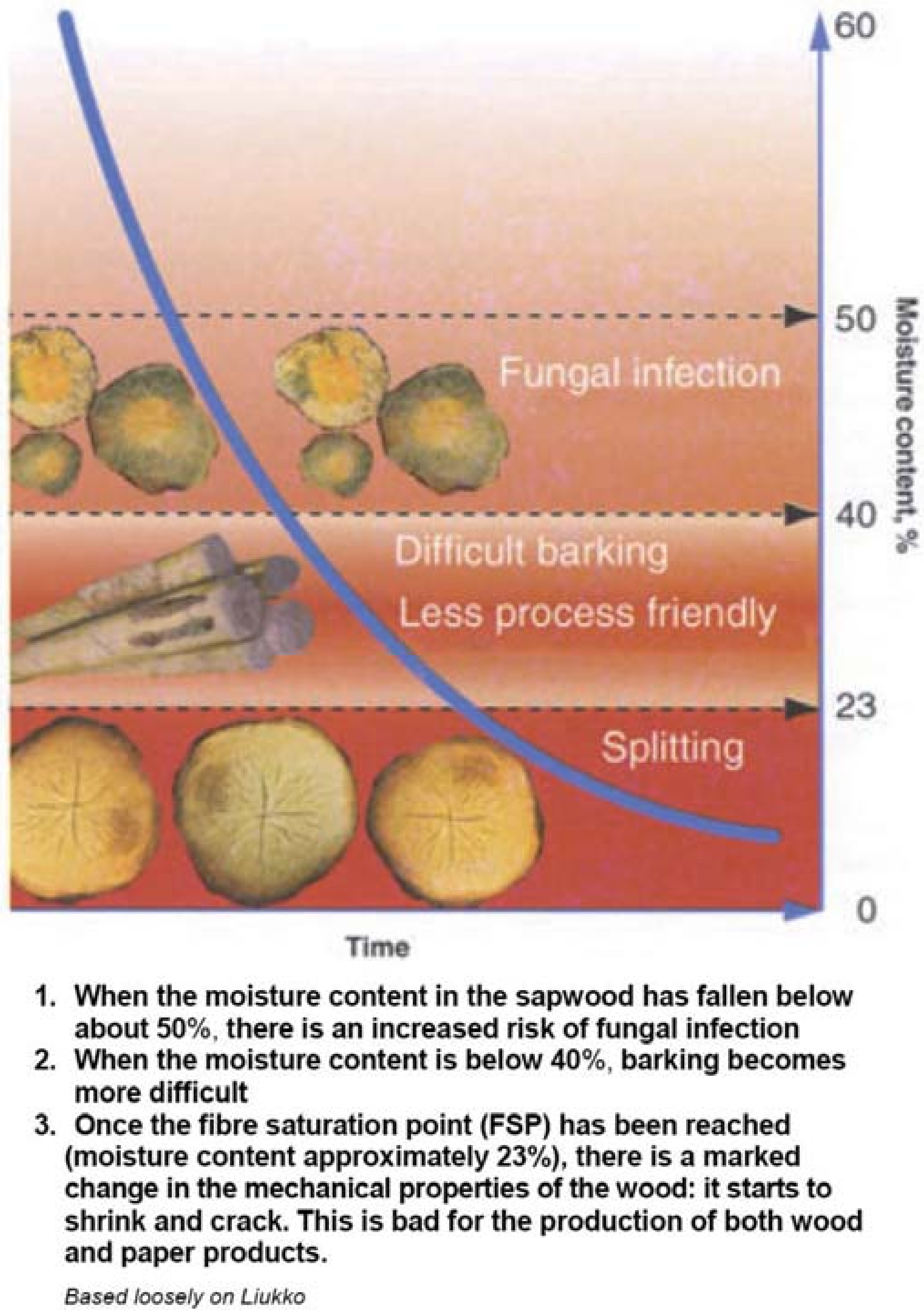


Figure 10. A schematic view of the negative consequences of loss in moisture content when storing logs. (Persson et al 2002). Moisture content in sapwood should be kept well above 50 % to avoid risks for loss in value.

7.1 Storage of logs in the forest

7.1.1 Freshness control

Wood can be regarded as fresh as long as its properties are not negatively affecting production and product quality as compared to newly harvested wood. The moisture content of wood can be used as an indicator of freshness at shorter-term storage (1-3 months) or storage of frozen wood.

Depending on the season and local weather variations, the harvested wood dries out with varying velocity. The logistical plans are made out of assumptions about how fast the drying happens, which gives a maximum number of days before the wood must be delivered to the industry if quality shall be maintained.

By using a model for wood freshness in a short term perspective defined as critical loss in moisture content (Wilhelmsson et al. 2005), a more refined projection of the wood freshness can be made. This can be used to facilitate the prioritizing of transports of harvested wood, especially during dryer periods. The model bases the calculations on a drying rate function (Persson et al 2002) and information about accepted degree of drying, time of harvesting and forwarding, position of the harvesting object and degree of wind/sun exposition of the wood. Output from the model is the critical handling time, i.e., maximum number of days from harvesting to delivery to industry to maintain demanded freshness. The model makes general assumptions about typical weather situations at a given time of the year, however, there’s an opportunity to fill in actual weather data concerning average temperature and relative humidity.

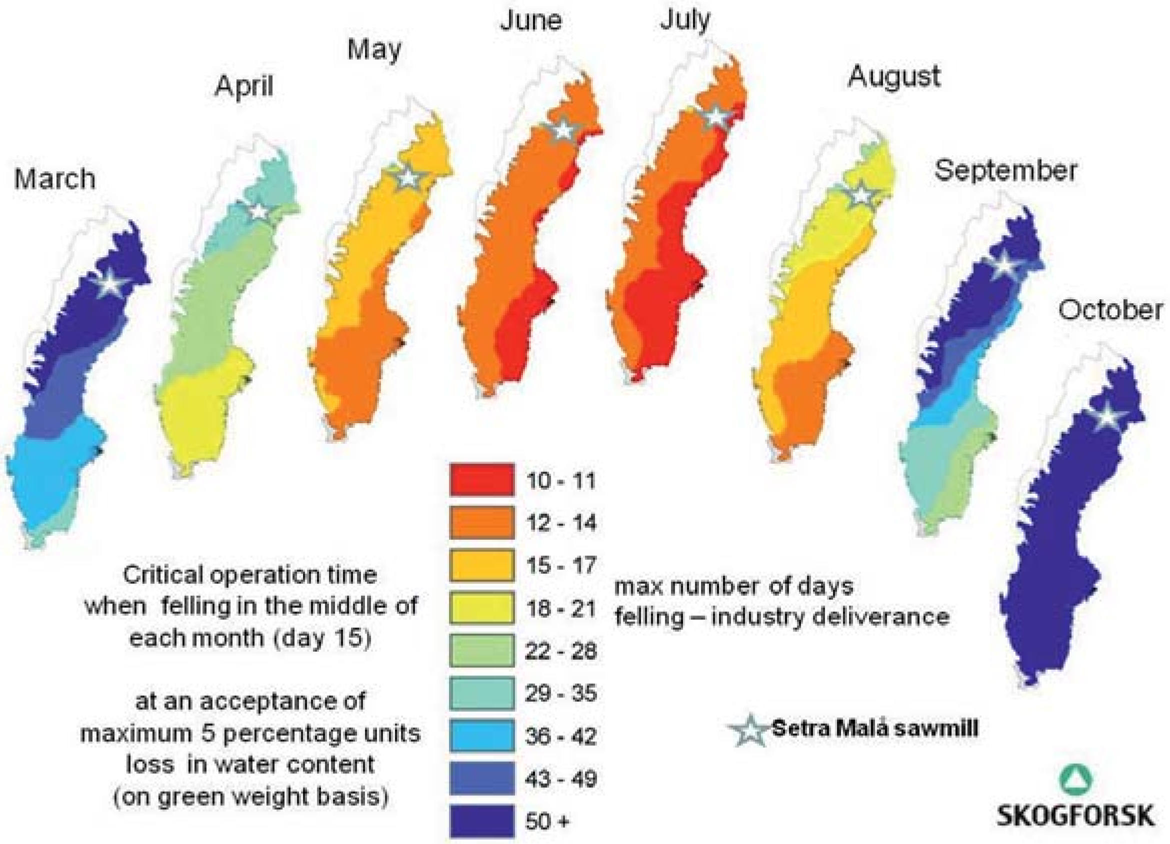


Figure 11. Critical operation time for a maximum of 5 percentage units loss in moisture content (MC) on the green weight basis. Calculated for Sweden by the tool Skogforsk TorkCalc (Wilhelmsson et al. 2005). By the digital chain starting with production files from harvesters, forwarding and pile information plus ordinary current weather statistics (temperature and relative humidity) the IK system can be fed by estimated moisture content in supplied and stored logs. The TorkCalc program can also be used for rough estimates of the following drying rates when logs are stored without sprinkling at the log yard.

7.2 Storage conditions and time of storage in the saw mill

7.2.1 Storage in the log yard without sprinkling

The time of storage at the log yard before damages will appear (Figure 10), is dependent on the climate, and hence, the season will be of essence. In a cold winter climate almost no change in moisture content and biological activity will take place. The TorkCalc tool has been originally developed for small stacks before forwarding and for piles at road-side. However if the stock-piles at the sawmill is not sprinkled we assume that the drying rates of logs can be roughly calculated with the TorkCalc tool or its basic drying function (Persson et al 2002) in that environment as well (Figure 11). By a sample of traceable logs from the quality control system whe suggest that this assumption should be further tested. This is one of many examples of what can be achieved by a combination of software and digital chains combined with traceability.

7.2.2 Storage in the log yard with sprinkling or water storage

Traditionally, logs were stored immersed in water at Nordic softwood sawmills. This has changed to mostly land based storage under sprinklers, nowadays. In the growing season on the other hand, damage can occur within a short period of time (Figure 11). That is why, today, most softwood logs are sprinkled with water in the period April-September in the Nordic countries (Liukko 1997; Myhra 1998). The amount of water sprinkled is often connected to the climate to avoid excessive use of water, and the aim is to keep the moisture content (on dry weight basis) in the sapwood above 100 %. This keeps the risk of attack from insects and fungi down to a minimum, in addition to keeping the logs free from cracks (Myhra 1998).

Many investigations have been done over the years on storage of logs in the log yard and how this influences various wood properties. An increased permeability will occur in timber stored for a sufficient period of time in water, due to bacterial attacks on the parenchyma cells and the pores in the cell wall (Myhra 1998). The time for this to occur will depend on the season and the climate. Boutelje et al.(1979) found the following maximum storage periods in the warm season, in order to avoid increased permeability, for spruce and pine respectively:

Pine in water storage:	2 weeks
Pine sprinkled:	10 weeks
Spruce in water storage:	6 weeks
Spruce sprinkled:	17 weeks

Later investigations have shown shorter intervals for sprinkling before increased permeability occurs. Holappa (1990) investigated the permeability in pine logs after two, six and ten weeks. She found no increased permeability after two weeks, 15 %, 36 % and 21 % logs with increased permeability in butt logs, middle logs and top logs respectively after six weeks, and about 50 % of the logs had increased permeability after ten weeks of sprinkling. Edvardsen (1995) found occurrence of increased permeability already after three weeks under sprinkling for both spruce and pine, and longer sprinkling intervals than six weeks gave more damage to pine timber than that of spruce.

The increased permeability in water stored logs makes impregnation easier (Boutelje et al. 1977; Boutelje et al. 1978; Boutelje and Jonsson 1976) and increases the retention of the treatment. The adsorption will increase as well (Elowson et al. 2003). The increased permeability of water storage gives a higher uptake of stains and thin primers. However, the adhesion, appearance and lustre of covering paint look reasonably unaffected as long as the priming has the right degree of filling (Boutelje et al. 1979). For gluing, no effects of water storage have been found (Boutelje et al. 1976).

A slightly increased tendency to checking after drying is indicated by Boutelje and Ihlstedt (1978), but other factors in the drying process are much more important. Against fungal decay, water stored timber show a decreased resistance (Boutelje and Nilsson 1985), while against insect attacks, water stored timber show larger resistance than timber stored on land (Boutelje and Rasmussen 1985).

The practical applicability of knowing how long the logs have been stored both in the forest and on the log yard would be in the shape of avoiding trying to make products that are impaired by long log storage. A typical example is special claddings as the "Kaunapanel" manufactured by several Swedish sawmills, and the "Eidskogkledning" manufactured by ESAS". A special regime in the manufacturing of this cladding is imposed, and includes a requirement for log freshness in the season between March and November. The requirement is a maximum storage time of logs of 4 weeks from harvesting to transport to the mill, and maximum 14 weeks of sprinkling in the log yard before sawing.

For other products, like timber meant for impregnation, a long storage time could be beneficial.

7.2.3 Storage after sawing prior to drying

Temnerud (1991) investigated timber dried immediately after sawing, stored for one week unprotected at the mill yard, stored one week inside in a storage hall or stored one week under water sprinkling. The occurrence of checks and cracks were twice as high for the timber stored unprotected for a week, compared to the timber dried immediately. The timber stored in the storage hall or under sprinkling had the same occurrence of checks and cracks as the timber dried immediately after sawing.

Berg (1998) found that the relative length of checks (i.e. length of checks compared to total timber length) increased with almost 50 % for every day timber was stored at the mill yard between sawing and drying. This will depend on the outside climate. The connection between occurrence of checks and storage after drying is hard to establish, probably because the drying schedule has such a strong influence. She found that 25 % of the checks occurring after drying were initiated during storage before drying. Calculations of loss in value due to storage of eight days between sawing and drying sums up to 21 SEK/m3 sawn timber. The calculations were done based on sawn timber prices in 1998 on the different grades of Nordic Timber (Anonymous 1994). If the sawmill also is grading higher grades for carpentry, the loss was estimated to 84 SEK/m^3.

Also on this aspect requirements in the production of "Eidskogkledning" at ESAS are imposed. The timber should be put in to the kiln before three days have gone since the sawing. In general no timber should be stored very long between sawing and kiln drying, perhaps apart from the fact that you will get some "drying for free" in the boards, but this is lost in the increased downgrade due to checking in most periods of the year.

7.2.4 Storage of kiln dried timber before dry sorting

At this stage, the possible degradation depends mostly on the moisture content (MC) of the sawn timber. Timber dried to "shipping dry", i.e. some 20-23 %, and protected from direct exposure of rain, will remain sound. However, at this stage, the timber is still on sticks and influenced by circulating air of varying humidity, bringing about fluctuations in MC that might influence the end use properties. Normally, in inland Scandinavia, the MC will fluctuate between some 10 % in early summer and 20 % in early winter with a maximum weekly sorption rate of 0.5 to 1.0 %-points (Gjerdrum 2008). Sorption alone, without the presence of fluid water, will not bring kiln dried timber to a MC vulnerable for fungal degradation.

7.2.5 Storage as sawn and planed timber

Timber stored without sticks, which is customary after the dry sorting, is much less exposed to drying in a normal outdoor climate, but if the moisture content (MC) is below 13-14 %, some protection towards outdoor climate should be imposed (Tronstad 2006). Haave (2004) investigated timber dried to 13 % MC and the development in moisture content on timber packages exposed to a Nordic climate with different extent of plastic covering. He found that wrapping with plastic on five sides of timber packages is recommendable if the moisture content is below 16 %. Most professional producers of glulam, which normally has a moisture content of 10-14 %, has taken this fact into consideration and store lamellae in storage with climate control, avoiding adsorption in the timber (Tronstad 2006). Further on, producers of wood products for interior use in dwellings produce their product with MC's as low as 6 %. This is the case for certain wood flooring and parquet, and for such products, only totally air tight packaging is feasible to avoid product deterioration.

Sunlight is another important factor that must be avoided, since this will degrade the wood surface in terms of colour change and surface inactivation (Nussbaum 1999). The first is not desirable in appearance products like panelling and flooring (Anonymous 2008; Tronstad 2006), the latter is of essence in painting and gluing (Nussbaum 1999).

In all storage of timber, the packages must be stored in a way that the pieces in the package are not subjected to deformation. This will be avoided if packages are placed on even surfaces, giving no strains on the timber pieces in any direction (Anonymous 2008).

For products to be surface treated or glued the time from mechanical processing, i.e. planing, to treatment should be as short as possible (Nussbaum 1999). In glulam production this is imposed as a requirement for maximum time from planing to gluing of 24 hours in the standard EN 386 (CEN 2001). ESAS has requirements of maximum 4 days storage between planing and surface treatment on the "Eidskogkledning", while the "Kaunapanel" is to be surface treated within 60 hours after planing.

7.2.6 Moisture content in timber products

The moisture content level of various timber products vary depending on the climate they are used in (Tronstad 2006). Wood is hygroscopic and will obtain an equilibrium with its surroundings depending on the relative humidity and temperature called the equilibrium moisture content (EMC). The most suited moisture content in production of a wood product is then the average of the EMC a product will attain throughout an annual cycle. Depending on the climate in an area, this will vary, and in some parts of the world the EMC will vary very strongly throughout an annual cycle. This is particularly present in places with large differences in outside temperature during a year.

8 Other specific case perspectives

The general presentation of methods and models in this report describes the CTL-harvesting and forwarding system supplying sawmill and consecutive wood manufacturers in the Swedish Wood Supply Chain (SWSC) or similar. Some of the cases are quite different from this like the ScanPole case in Norway and the Oak barrel production in France. Both cases are briefly described in D3.1 and D3.2. Below the specific conditions of treating and storing poles as well as the specific needs and problems of log/pole sorting are presented.

8.1 System design ScanPole - log sorting and MC modelling

The objective for the case study Installation ScanPole included increasing the knowledge and improving the system for predicting final product outcome.

8.1.1 MC modelling

The Scots pine is widely used for pressure-treated transmission poles. Prior to preservation treatment, all capillary water must be dried off. Natural seasoning in open-air predominates, which implies that most drying takes place during the dry spring and warm summer seasons. The inventory of drying poles represents considerable value in a company's balance sheet and risk of downgrading. There is risk both for keeping higher inventory than optimal and for treating poles that would not be sufficiently dried. Knowledge of drying times during the annual seasons has been insufficient. The study was set up to work out a model for pole drying, based on a description of the pole itself and climatic observations during drying (Salin and Gjerdrum 2009). The model is based on general physical rules for wood drying and is valid for debarked logs stacked in well ventilated piles, intended for easy drying.

The model has then been applied to predict optimal drying times for various pole types and climatic conditions, for roofed or sheltered pole inventories, for assisted drying, etc. (Gjerdrum and Salin 2009).

8.1.2 Log geometry

Log shape and dimension parameters are most important traits for pole quality. For this reason, poles are always sorted after debarking. The geometric shape, in particular out-of-roundness and the taper for pole logs, was observed and analysed (Halvorsen 2008, Gjerdrum 2009). Observations were made on barked poles with calliper, 2D scanner and 3D scanner. The local variation in diameter can be indicated by a standard deviation of 3 to 5 mm for repeated observation in almost the same location, and the same magnitude for actual diameter profile deviation from a smoothed profile. In a 3D scanner, the amount of observed data is huge, making it a challenge to analyse, verify and calibrate the equipment. Nevertheless, the accuracy seems acceptable for observations on barked logs. The results have been implemented into the sorting algorithms. The RFID technology might find uses in permanent applications, but it is still rather work demanding and expensive to set up, and the commercial profit has so far not been identified for *ad hoc* experiments.

9 Improved strength grading from logs to centerboards

The strength of wood is varying very much within logs, between logs from the same tree, between trees and between sites. The practical application of differentiation wood according to strength properties is done as strength grading. The rules and requirements for this strength grading is stated in standards. The result of this strength grading is timber with strength classes where the specific strength properties in the classes are defined in the standard EN 338 (CEN 2003).

However, due to reliability factors in structural design, and the fact that variation in strength properties also varies within the strength classes, the strength values obtained in these classes are conservative, and hence low. The grade yield is also dependent on the accuracy of the grading system, and higher accuracy increases the yield in the higher strength classes. There is a large potential in getting timber with higher strength if the systems for strength grading is improved, and the later years different approaches have been explored.

Differences in strength and grade yield in strength grading between regions has been investigated by Chrestin (2000). He found that Norway spruce timber from the mountainous regions in northern Sweden had lower values for mechanical properties, while timber from central Sweden and some parts of southern Sweden had higher values for mechanical properties. Within a procurement area for a medium sized saw mill Øvrum (2007) showed that there is a great variation in yield of strength grades from Norway spruce timber from different stands even in stands in very close proximity to each other. An assessment of the forest quality before logging showed very good correlation with the yield in high strength classes and indicates a possibility of pre-sorting in the forest. To be able to exploit the result of these findings a logistic system has to be implemented which either allocates all the logs from each stand to different saw mills, or by marking the logs that are not suitable/suitable for strength grading. The latter could involve a traceability system concept.

At the saw mill several investigations has been done on making models for the strength properties in boards based on log parameters measurable with existing equipment (Brännström et al. 2007; Jäppinen 2000; Oja et al. 2001). Jäppinen (2000) found that through a pre-sorting of logs based on variables from a 3D scanner the yield of glulam lamellas could be improved significantly. Oja et.al. (2001) found that data from an X-ray logscanner could give good indications about the stiffness in the centre boards graded by a Cook-Bolinder machine. Brännström et.al. (2007) found that an X-ray logscanner predicted the strength in centre boards with the same accuracy as a standard strength grading machine (Goldeneye 702). The implementation of systems based on sound measurement in logs and correlations to strength in boards has also been investigated for Nordic softwood (Edlund et al. 2004; Edlund et al. 2006; Lindström et al. 2009) and have showed promising results. This approach is further investigated in the Gradewood-project (Lycken 2008). This latter techniques has been used for grading logs from plantation forests in Australia and New Zealand (Carter et al. 2006), and grading veneer logs in North America (Anonymous 2005; Wang et al. 2004) for several years.

Within the frames of Indisputable key Hannrup et al. (manuscript to be submitted to scientific journal) have developed new models for predicting centreboard modulus of elasticity (MOE) and modulus of rupture (MOR) on Norway spruce logs at harvesting (Appendix A). The models are developed from a material that was gathered within the EC project “Improved spruce timber utilization”. For a material description see e.g. Kliger & Johansson (1996). The material consists of sample trees from 12 stands covering a large part of the latitudinal range of Sweden. The presented models should be considered preliminary as the development of the models is still ongoing. Their relevance for pine is not known. Typical application of the models may be to characterise strength properties both previous to harvesting by bucking simulation or by harvester production messages (files). As basic density and largest knot diameter are not measured neither previous to harvesting, nor in the harvester felling heads, modelled basic density (e.g. Wilhelmsson et al 2002 combined with Wilhelmsson 2006) and modelled knot diameter (Moberg, 2006) may be used. It should be observed that one can expect lower degree of explanation if modelled input parameters are used instead of measurements of high accuracy.

A system where the boards are graded in logs, i.e. before they are sawn, will require a detailed traceability system similar to the one introduced in SWSC-case, or alternatively many bins for logs sorting and a sophisticated logistic system to divide the different strength classes of logs.

10 Examples of IK information - log properties from forest operations

The different measurements currently made in harvester felling heads or determined by the harvester operator (table 1-2), and properties possible to predict by these measurements combined with gatherable stand information (table 3- 4) are described in chapter 5. Figures 12-14 show three examples of predictable results from simulated Cut To Length harvesting based on measurements of 600 representative sample plots in Västerbotten (Swedish National Forest Inventory, SLU). Similar results can be calculated on the basis of real harvester production files (pri).

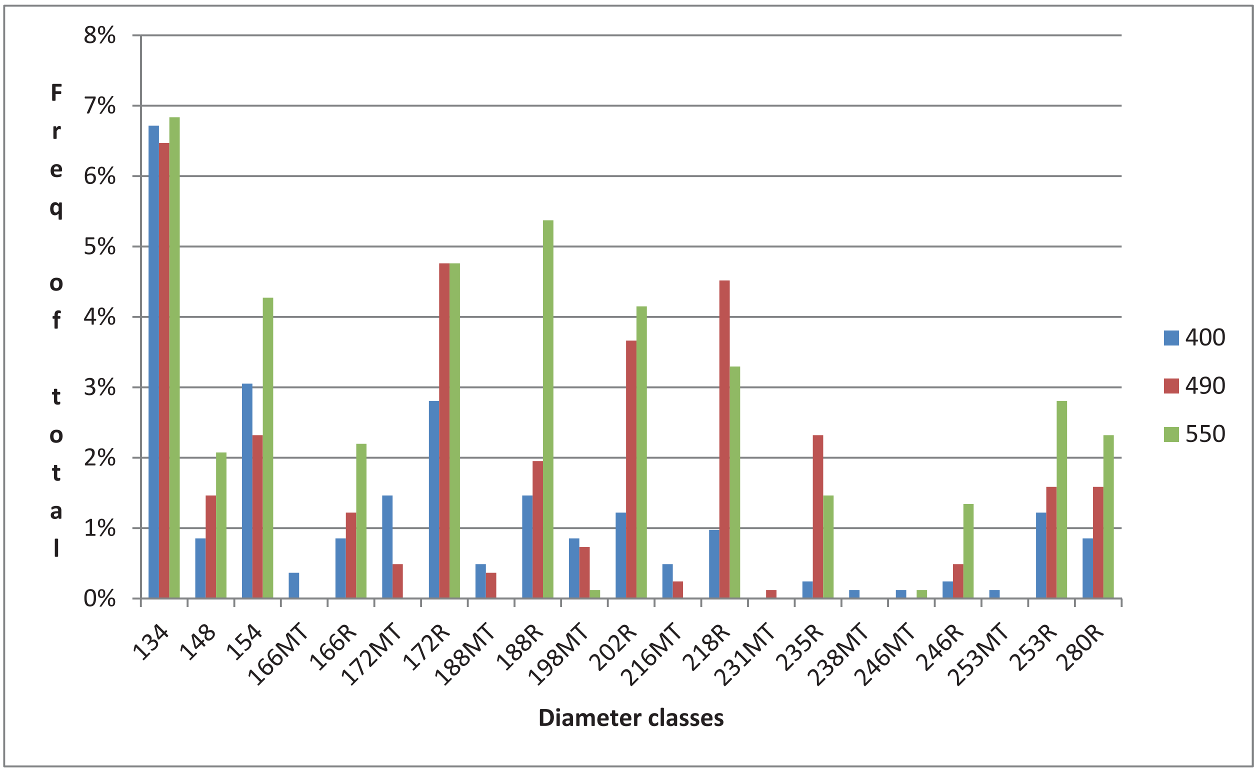


Figure 12. Results from IK bucking simulation with TimAn2 for predicting geometrical properties (diameter classes over three length classes (400, 490 and 550dm) of the logs. After harvesting the harvester production message (pri-file) can be used for a similar report of operational production to be used for production planning at the sawmill and planning of subsequent harvester production. It can also be used for comparisons between simulated and realised results from harvesting.

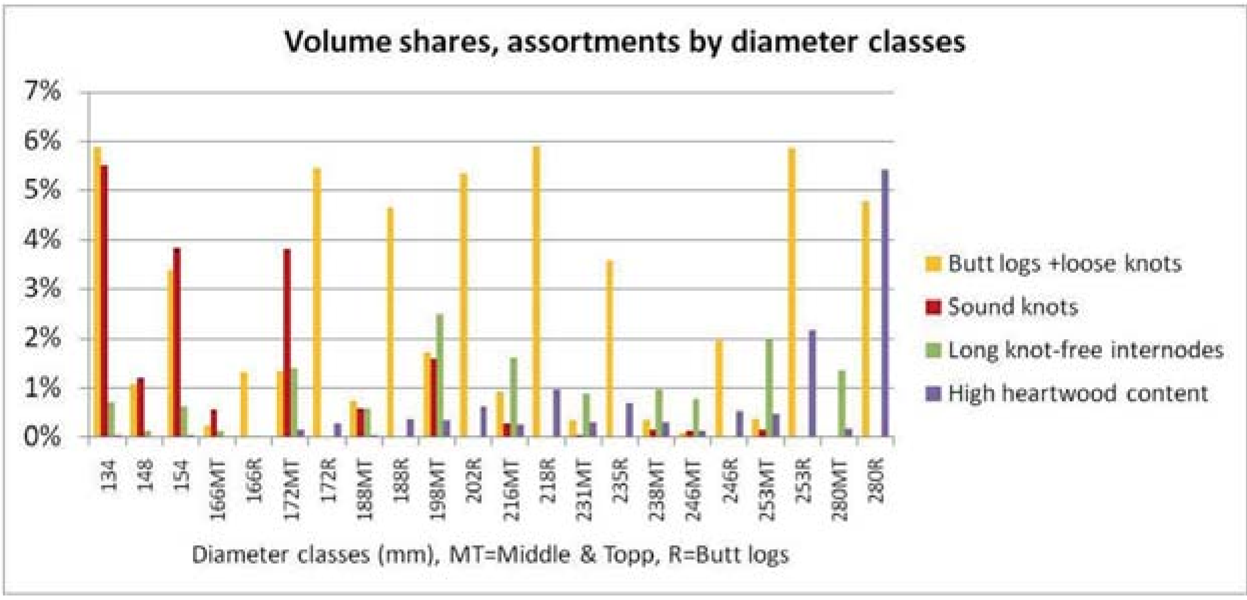


Figure 13. Results from bucking simulation with TimAn2 controlled by diameter and length followed by Pri-analyses for predicting properties Example from simulated harvesting of plots from the National forest inventory in Västerbotten for SWSC scenarios.

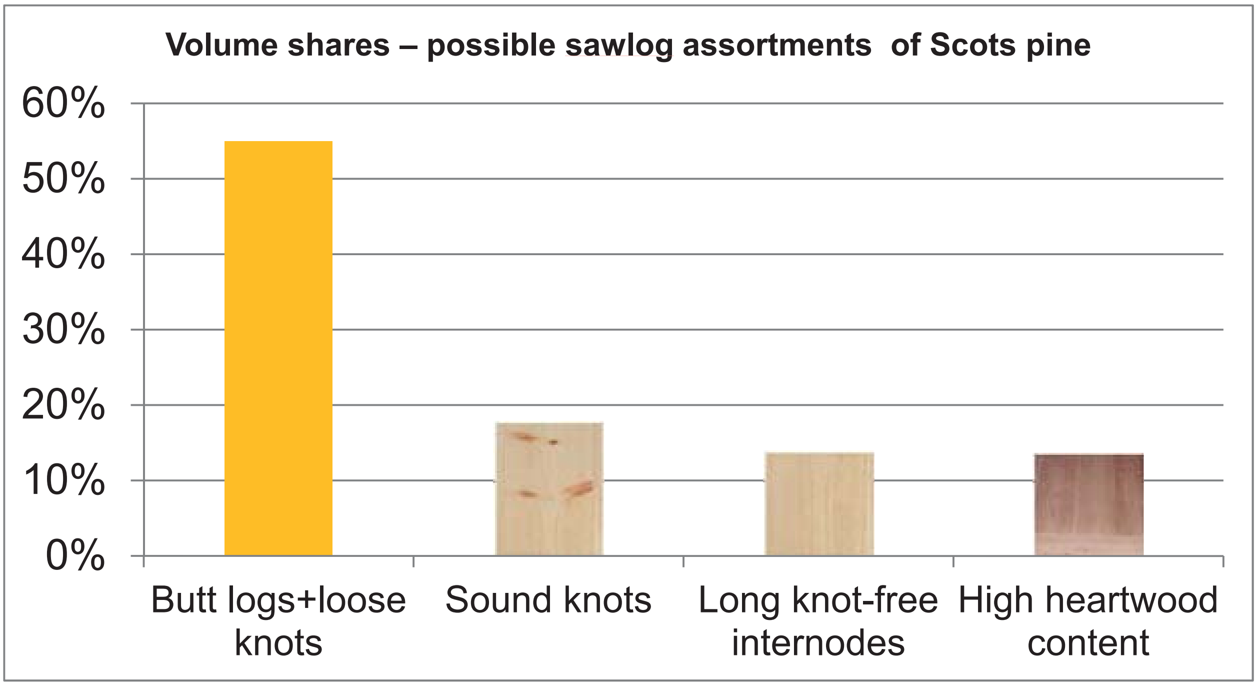


Figure 14. Results from bucking simulation with TimAn2 controlled by diameter and length followed by Pri-analyses for predicting properties Example from simulated harvesting of plots from the National forest inventory in Västerbotten for SWSC scenarios. Simulations based on representative sample trees makes it possible to estimate the proportions of logs suitable for different wood products.

11 Discussion and conclusions

The cost for wood raw material delivered to a sawmill is the dominating part of the total cost (D3.4 Economic and environmental inventory) in manufacturing of wood products. Based on production statistics and analyses by prediction models it is also evident that the raw material properties have a large variation. Consequently there is much money and considerable reductions of environmental load to gain if a larger proportion of this variation can be controlled and utilized in an efficient way. The accuracy of models and measurements and the variation within sawlogs have both to be considered when designing where and how crucial decisions should be taken.

One of the keys to higher production efficiency and improved products is to “start smart” and take knowledge based decisions all the way through the production chains. This can be achieved by digital and physical traceability in combination. In this document we present a step by step description of the modern wood supply CTL system as it look like both in general and in the additional context of the IK project. Our conclusion is that an economic introduction of the IK system architecture should start with statistical traceability like the control logs from the Quality control system for harvesters. A statistical sample of traceable individuals will bring much further knowledge and basis for important considerations concerning the accuracy of measurements and predictions of wood properties and where and how to utilize wood properties in the most economically and environmentally efficient way.

Another economically feasible use of traceability is marking of individuals representing and keeping track of piles. An efficient application of pile marking has to be further considered and developed.

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12.1 References to deliverables from Indisputable key

D3.1 Initial analysis of drivers and barriers. Editors: Lars Wilhelmsson, Skogforsk, Sweden and Erik Furusjö, IVL, Sweden Contributing participants: Erik Furusjö, Åsa Nilsson, Martin Erlandsson, IVL, Sweden; Jarl-Gunnar Salin, Anders Lycken, SP, Sweden; Elisabeth le Net, Fahrudin Bajric, AFOCEL, France; Didier Pischedda, Robert Golja, Marcel Lienafa, and Stephane Nicosia, CTBA, France; Lars Wilhelmsson, Staffan Berg, Skogforsk, Sweden; Peder Gjedrum, NFLI, Norway; Kimmo Piispa, LappUnit, Finland, Eivind Skaug, Knut Finstad, NTI, Norway. Deliverable, Indisputable key, 41p.

D3.2 Existing models and model gap analyses for wood properties. Responsible: Jean-Denis Lanvin & Fahrudin Bajric, FCBA, France. Participants: Lars Wilhelmsson, Lennart Moberg, John Arlinger, Johan Möller, Skogforsk, Sweden, Jan Bramming, NTI,Norway, Urban Nordmark, Sveaskog, Sweden. Deliverable, Indisputable key, 56p.

D3.4 Economical and environmental inventory. Responsible: Martin Erlandsson, IVL, Sweden (main author). Collaborative authors: Fahrudin Bajric, Estelle Vial, FCBA, France. Staffan Berg, Lars Wilhelmsson, Skogforsk, Sweden. Mats Almemark, Sara Nilsson, IVL, Sweden. Industrial partners involved: Urban Nordmark, Sveaskog, Sweden. Bo Andersson, SETRA, Sweden. Ralf Signarsson, Norsjöfönster, Sweden. Martin Nyström, Rottne, Sweden. Nathalie Bonin, Laurent Rizet, Ducerf, France. Emmanuel Pawliez, RolPin, France. Olli Raunio, Raunio, Finland. Stian Skarpnord, Scanpole, Norway. Deliverable, Indisputable key, 97p.

D3.6 Influence of processing conditions and wood properties on saw mill operation. Responsible: Anders Lycken, SP, Sweden. Participants: Johan Oja, SP, Sweden; Ylva Steiner and Audun Øvrum, Norsk Treteknisk Institutt, Norway; Kimmo Piispa, Lappeenranta University of Technology, Finland. Deliverable, Indisputable key, 33p.

D3.7 Methods and Algorithms for Holistic Supply Chain Management and Multivariate Statistical Analysis of Supply Chain Data. Responsible: Klara Westling, IVL, Sweden. Participants: Klara Westling, Anders Björk, Håkan Fridén, Linda Åmand and Åsa Nilsson, IVL, Sweden; Lars Wilhelmsson, John Arlinger, Maria Nordström, Gert Andersson, Karin Westlund, Diana Vötter, Skogforsk, Sweden. In appendix B also: Patrik Flisberg and Mikael Rönnqvist, associated to Skogforsk, Sweden. Deliverable, Indisputable key, 105p + appendix 20p.

13 Appendix A. Model overview

Table 6a. Models introduced in the Pri-analyses and additional SAS-tools (Skogforsk) for predicting log properties at harvesting. These could be utilized in all cases served by CTL harvesters. (Here cases 7.1 and 7.4 are considered, other cases presented below) Input data based on production files from harvesters and general stand information. **PG=Primary Goal, ++ = of large relevance**, + = of some/or potential relevance. Models available, Y=Yes, or ± figures indicating Standard Error (SE) at the single log level when relevant and estimated (unit given in column "Property"). (Based on table 6

Property	**Case study 7.1 Setra Malå Norsjö windows**	**Case study 7.4 Raunion**	**Possible accuracy (if input parameters are accurate) ±SE**	**Development since finalization of D3.2**
Green density at felling, kg/m³fub	+	+	Spruce ± 70, Pine ± 50	Applied
Green density at haulage	+	+		Applied to calculations of cost for haulage in SWSC
Basic density (radial average), kg/m³fub	**++**	++	Spruce and pine ± 26	Applied into value indices in the SWSC
Moisture content, %	**++**	**++**	Loss in MC% SE ± 3.8% Also dependent on green density at felling (see above)	Applied into drying models in simulations (D3.5 & D3.7)
Heartwood diameter (mm)	++	++	Pine ± 17 Spruce ± 20	Applied into value indices in the SWSC
MOE (MPa)	+	++	Spruce 1670	New models developed. (Hannrup et al) To be submitted for Scientific publication
MOR (MPa)	+	++	Spruce 11.05	New models developed. (Hannrup et al) To be submitted for Scientific publication
Mean annual ring width	+	+	Function of accuarcy in diameter and n.o. rings	Applied into SWSC
Internode length (cm)	PG	+		Applied into value indices in the SWSC
Maximum knot diameter at surface, (mm)	+	+	Spruce and Pine ± 6	Applied into value indices in the SWSC
Average knot diameter at surface, (mm)	+	+	Spruce and Pine ± 5	Currently not used
Number of knots/whorl	+	+		Currently not used

Table 6b. Continuation of 6a, Models introduced in the Pri-analyses and additional SAS-tools (Skogforsk) for predicting log properties at harvesting. (for further information see table head 6a).

Property	**Case study 7.1 Setra Malå Norsjö windows**	**Case study 7.4 Raunion**	**Models available**	**Development since finalization of D3.2**
Sound knots distance from pith (cylinder)	++	+	Y	Applied into value indices in the SWSC
Log position in stem	++	PG	Measured	Applied into value indices SWSC
Bark thickness	+	+	Y	Applied into value indices SWSC
Basic density along radius	PG	+		Considered in new models MOE/MOR
Microfibril angle	+	+		No
Spiral grain	+	+		No
Knot diameter (average knot), mm	+	+	Y	Currently not included
Knot index	+	+		Currently not
Chip characterisation	+		Y	Done by density in value indices in SWSC
Chemical characterisation	+		Y	Carbon sequestrated included in SWSC
Energy values of components	+		Y	Included by dry mass in SWSC
Economic valuation of log properties based on calculated impact (Based on ideas shown in table 5)	**+++**			**Developed for SWSC** **See appendix C**

Table 7. Models of specific interest for implementation or further development in the Norwegian cases. **PG=Primary Goal, +++ of very large relevance**, ++ = of large relevance, + = of some relevance

Property	Case study 7.2 Scanpole (pine) (Pole production)	Case study 7.3 ESAS (spruce) (Eidskogkledning)	Models available (suggested origin indicated)	Development since finalization of D3.2
Mean annual ring width	+	++	Sweden	Applied in Pri-analyses
Annual ring width along radius		**PG**	Norway, more analyses necessary	No
Basic density, log average	+	++	Sweden	Applied in Pri-analyses
Basic density along radius		**PG**	Norway, more analyses necessary	No
MOR stems	**PG**		Finland	New models for boards developed . (Hannrup et al)
MOE stems	+		Finland	New models developed. (Hannrup et al)
Moisture content of stem	**PG**		Sweden	New models developed for poles Gjerdrum & Salin, 2009.
Heartwood diameter	++		Sweden	Applied in Pri-analyses
Resin pockets		**PG**	Only descriptive statistics available	Most common in middle logs (logs 2-3 in spruce stems). Temnerud (1996)
Sound-knot cylinder		**PG**	Norway, Øyen 1999	Applied in Pri-analyses
Knot diameter		**PG**	Sweden and Norway Øyen 1999	Applied in Pri-analyses
Reaction wood		**+++**	Only descriptive statistics available	No

14 Appendix B. Detailed model descriptions MOE/MOR

Modulus of elasticity. General information.	
Model description supplied by	*Skogforsk, Hannrup et al. (manuscript)*
Model	*Modulus of elasticity (MOE)of centerboards in Norway spruce*
Objective and description	*The model predict mean MOE of the centerboards in a log*
Reference	*The model is developed from a material that was gathered within the EC project "Improved spruce timber utilization". For a material description see e.g. "Kliger & Johansson 1996. Final report from subtask A1.4 Mechanical properties of battens: 21 pp". The material consists of sample trees from 12 stands covering a large part of the latitudinal range of Sweden. The presented model should be considered preliminary as the development of the model is still ongoing.*
Algorithm	*Additive function, see below.*
Calculation steps	*The mean MOE of the centerboards of a log is predicted from the volume weighted log basic density and the position of the log within the tree i.e. the distance from the butt end of the butt log to the centre of the log.* *In those cases there is no information of the basic density it is predicted from the model developed by Wilhelmsson et al. (2002), see also a description of that model in Deliverable 3.2. A procedure to calculate volume weighted log average of basic density is described in the latter report.*
Program code	*To be implemented in e.g. Pri-analyses.(Delphi-code)*

Model result. Modulus of elasticity (MOE)				
Variable	Unit	Expressed as integer or floating	Max/Min	Description
MOE	*MPa*			MOE of the centerboards of a specified log along the stem.

Variables of the model. Modulus of elasticity				
Variable	Unit	Integer or floating	Max/Min	Description
C		*Floating*		Intercept
bd	*kg/m*^{3}	*Floating*		Basic density
h	*cm*	*Floating*		The distance from the butt end of the butt log to the centre of the log.

Modulus of elasticity Coefficients functions	
Variable	Coefficient
C	-8070.69
bd	57.08
h	-1.65
R^2	0.44
RMSE	1670
Bias	-

SAS-code MOE

MOE = -8070.69 + 57.08*bd – 1.65*h

Modulus of rupture. General information.	
Model description supplied by	*Skogforsk, Hannrup et al. (manuscript)*
Model	*Modulus of rupture (MOR) of centerboards in Norway spruce*
Objective and description	*The model predict mean MOR of the centerboards in a log*
Reference	*The model is developed from a material that was gathered within the EC project "Improved spruce timber utilization". For a material description see e.g. "Kliger & Johansson 1996. Final report from subtask A1.4 Mechanical properties of battens: 21 pp". The material consists of sample trees from 12 stands covering a large part of the latitudinal range of Sweden. The presented model should be considered preliminary as the development of the model is still ongoing.*
Algorithm	*Additive function, see below.*
Calculation steps	*The mean MOR of centerboards of a log is predicted from the volume weighted log basic density and the maximum knot diameter within the log. In those cases there is no information of the basic density it is predicted from the models developed by Wilhelmsson et al. (2002) Models for Predicting Wood Properties in Stems of Picea abies and Pinus sylvestris in Sweden* *Scandinavian. Journal of Forest Reseacrh 17:4 pp 330-350. See also a description of the models in Deliverable 3.2. A procedure to calculate volume weighted log average of basic density is described in the latter report.* *In those cases there is no information of the knot diameter it is predicted from the model developed by "Moberg L. 2006 Predicting knot properties of Picea abies and Pinus sylvestris from generic tree descriptors. Scandinavian Journal of Forest Research 21 (Suppl. 7): 48-61". The model is also described in Deliverable 3.2.*
Program code	*To be implemented in e.g. Pri-analyses.(Delphi code)*

Model result. Modulus of rupture (MOR)				
Variable	Unit	Expressed as integer or floating	Max/Min	Description
MOR	*MPa*			MOR of the centerboards of a specified log along the stem.

Variables of the model. Modulus of rupture (MOR)				
Variable	Unit	Integer or floating	Max/Min	Description
C		*Floating*		Intercept
bd	*kg/m^3*	*Floating*		Basic density
kd_max	*mm*	*Floating*		The maximum knot diameter within the log

Modulus of rupture Coefficients functions	
Variable	Coefficient
C	-21.54
bd	0.23
kd_max	-0.77
R^2	0.26
RMSE	11.05
Bias	-

SAS-code MOR

MOR = -21.54 + 0.23*bd – 0.77*kd_max

15 Appendix C. Economic valuation of logs (SWSC) from a sawmill product perspective

System analysis and attempts to valuate product quality have been performed based on bucking simulations and additional predictions of wood properties. Some preliminary results of the total gross value of logs when developed to different products are presented in figures 15-17 (cost are also modelled but presented in D3.7). The average modelled “real” value (indicated, not exactly real) selling or internal prices for boards, chips and bark of undamaged logs where by average 1113 SEK/m³s u.b.+ bark with a difference between means for diameter classes and assortments of between 858 and 1342 SEK/m³s u.b. + bark and the differences between logs were modelled to between 726 and 1520 SEK. Figure 18 show information on carbon sequestrated in different types of logs as a background for environmental analyses.

A SAS-program has been developed (Wilhelmsson, 2010). Significant details of this valuation per diameter class adapted to SWSC are given below.

```
DO;        /* Below Specify Yield of solid volume (Class bottom) per
diameter class */
if ToDiaubclass="134" then Yield1=0.415;
if ToDiaubclass="148" then Yield1=0.457;
if ToDiaubclass="154" then Yield1=0.469;
if ToDiaubclass="166R" then Yield1=0.48;
if ToDiaubclass="166MT" then Yield1=0.47;
if ToDiaubclass="172R" then Yield1=0.505;
if ToDiaubclass="172MT" then Yield1=0.505;
if ToDiaubclass="188R" then Yield1=0.521;
if ToDiaubclass="188MT" then Yield1=0.516;
if ToDiaubclass="196R" then Yield1=0.518;
if ToDiaubclass="202R" then Yield1=0.519;
if ToDiaubclass="198MT" then Yield1=0.535;
if ToDiaubclass="218R" then Yield1=0.524;
if ToDiaubclass="216MT" then Yield1=0.547;
if ToDiaubclass="231MT" then Yield1=0.54;
if ToDiaubclass="235R" then Yield1=0.555;
if ToDiaubclass="238MT" then Yield1=0.558;
if ToDiaubclass="246R" then Yield1=0.536;
if ToDiaubclass="246MT" then Yield1=0.556;
if ToDiaubclass="253R" then Yield1=0.576;
if ToDiaubclass="253MT" then Yield1=0.604;
if ToDiaubclass="280R" then Yield1=0.536;
if ToDiaubclass="280MT" then Yield1=0.521;

END;
/* OBS! Dessa rader är patchar för att klara beräkningar där
0*Netinternode-MNetinternode annars blir "missing" med hjälpvariabeln patch
```

```
respektive Mpatch för att inte ev. verkliga nollvärden ska sättas till .
vid återkonverteringen i slutet av blocket */
if Netinternode=. then Patch=0;
if MNetinternode=. then MPatch=0;
if Patch=0 then Netinternode=0;
if MPatch=0 then MNetinternode=0;
/* OBS! Sätts tillbaka till . längst ned i detta block */


/* Pricing of logs to Industry 1 */
Baseprice1=1900; /*SEK per m3s assuming that Yields are including shrinkage
*/
Residueprice1=220*Dens/MSpDens; /*SEK per m3s*Dens/MSpDens*/
Pulpwbase=280; /*SEK per m3s*/
Barkprice1=120; /*SEK per m3s*/
if species=1 AND length=340 then Baseprice1=Baseprice1*0.90;
if species=1 AND length=370 then Baseprice1=Baseprice1*0.94;
if species=1 AND length=400 then Baseprice1=Baseprice1*0.95;
if species=1 AND length=550 then Baseprice1=Baseprice1*0.85;

/* Below Specify alternative values of properties */
if Species=1 AND ToDiaubclass="134" then
DO;
Baseprice1=Baseprice1*0.95;
ValueAdd1_1=.;  /* Set to . if the assortment is invalid
(0.02*Baseprice1)*(Netinternode-MNetinternode)+1*1*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0)*(KDmax-MKDmax); */
ValueAdd1_12=.;
if KTYPE>10 then
ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 70 */
else ValueAdd1_2=.;
/* All logs            */
ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */
if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */
else ValueAdd1_4=.;
END;

if species=1 AND ToDiaubclass="148" then
DO;
Baseprice1=Baseprice1*0.95;
```

```
ValueAdd1_1=.;  /* Set to . if the assortment is invalid
(0.02*Baseprice1)*(Netinternode-MNetinternode)+1*1*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0)*(KDmax-MKDmax); */

ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/* All logs            */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="154" then

DO;

Baseprice1=Baseprice1*0.97;

if Netinternode>=17 AND Dens12Fk>=460 then

ValueAdd1_1=(0.02*Baseprice1)*(Netinternode-MNetinternode)+1*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0)*(KDmax-MKDmax); /* Set to . if the
assortment is invalid */

else ValueAdd1_1=.;

if Dens12Fk>=460 AND KDmax<=1300 then

ValueAdd1_12=1*(Dens12Fk-MDens12Fk)+0*(Heart-MHeart)+(-0.05)*(KDmax-
MKDmax); /* Set to . if the assortment is invalid */

else ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="166R" then

DO;
```

```
Baseprice1=Baseprice1*1;

ValueAdd1_1=.;/*(0.02*Baseprice1)*(Netinternode-MNetinternode)+1*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0)*(KDmax-MKDmax); /* Set to . if the
assortment is invalid */

;

if Dens12Fk>=460 AND KDmax<=1300 then

ValueAdd1_12=1*(Dens12Fk-MDens12Fk)+0*(Heart-MHeart)+(-0.05)*(KDmax-
MKDmax); /* Set to . if the assortment is invalid */

else ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="166MT" then

DO;

Baseprice1=Baseprice1*0.9;

/*if Netinternode>=17 AND Dens12Fk>=460 then */

ValueAdd1_1=.;/*(0.0*Baseprice1)*(Netinternode-MNetinternode)+1*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0)*(KDmax-MKDmax); /* Set to . if the
assortment is invalid */

/*else ValueAdd1_1=.; */

if Dens12Fk>=460 AND KDmax<=2000 then

ValueAdd1_12=(-25)+1*(Dens12Fk-MDens12Fk)+0*(Heart-MHeart)+(-0.05)*(KDmax-
MKDmax); /* Set to . if the assortment is invalid */

else ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-50)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */
```

```
else ValueAdd1_4=.;
END;
if species=1 AND ToDiaubclass="172R" then
DO;
Baseprice1=Baseprice1*1;
ValueAdd1_1=.;
if Dens12Fk>=460 AND KDmax<=1300 then
ValueAdd1_12=1*(Dens12Fk-MDens12Fk)+0*(Heart-MHeart)+(-0.05)*(KDmax-
MKDmax); /* Set to . if the assortment is invalid */
else ValueAdd1_12=.;
if KTYPE>10 then
ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */
else ValueAdd1_2=.;
/*All logs */
ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */
if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */
else ValueAdd1_4=.;
END;
if species=1 AND ToDiaubclass="172MT" then
DO;
Baseprice1=Baseprice1*1;
ValueAdd1_1=.;
if Dens12Fk>=460 AND KDmax<=2000 then
ValueAdd1_12=(-25)+1*(Dens12Fk-MDens12Fk)+0*(Heart-MHeart)+(-0.05)*(KDmax-
MKDmax); /* Set to . if the assortment is invalid */
else ValueAdd1_12=.;
if KTYPE>10 then
ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */
else ValueAdd1_2=.;
/*All logs */
ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */
if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */
else ValueAdd1_4=.;
END;
```

```
if species=1 AND ToDiaubclass="188R" then
DO;
Baseprice1=Baseprice1*1;
ValueAdd1_1=.;
if Dens12Fk>=460 AND KDmax<=1300 then
ValueAdd1_12=1*(Dens12Fk-MDens12Fk)+0*(Heart-MHeart)+(-0.05)*(KDmax-
MKDmax); /* Set to . if the assortment is invalid */
else ValueAdd1_12=.;
if KTYPE>10 then
ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */
else ValueAdd1_2=.;
/*All logs */
ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */
if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */
else ValueAdd1_4=.;
END;


if species=1 AND ToDiaubclass="188MT" then
DO;
Baseprice1=Baseprice1*1;
ValueAdd1_1=.;/*(0.0*Baseprice1)*(Netinternode-MNetinternode)+1*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.05)*(KDmax-MKDmax); /* Set to . if the
assortment is invalid */
if Dens12Fk>=460 AND KDmax<=2000 then
ValueAdd1_12=(-25)+1*(Dens12Fk-MDens12Fk)+0*(Heart-MHeart)+(-0.05)*(KDmax-
MKDmax); /* Set to . if the assortment is invalid */
else ValueAdd1_12=.;
if KTYPE>10 then
ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */
else ValueAdd1_2=.;
/*All logs */
ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */
if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */
else ValueAdd1_4=.;
END;
```

```
if species=1 AND ToDiaubclass="196R" then

DO;

Baseprice1=Baseprice1*1;

ValueAdd1_1=.;

ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="202R" then

DO;

Baseprice1=Baseprice1*1;

ValueAdd1_1=.;

ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="198MT" then

DO;

Baseprice1=Baseprice1*1;

ValueAdd1_1=.;/* Set to . if the assortment is invalid */

ValueAdd1_12=.;

if KTYPE>10 then
```

```
ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="218R" then

DO;

Baseprice1=Baseprice1*1;

ValueAdd1_1=.;

if Dens12Fk>=460 AND KDmax<=1300 then

ValueAdd1_12=1*(Dens12Fk-MDens12Fk)+0*(Heart-MHeart)+(-0.05)*(KDmax-
MKDmax); /* Set to . if the assortment is invalid */

else ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="216MT" then

DO;

Baseprice1=Baseprice1*1;

if Netinternode>=17 AND Dens12Fk>=460 then

ValueAdd1_1=(0.02*Baseprice1)*(Netinternode-MNetinternode)+1*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0)*(KDmax-MKDmax); /* Set to . if the
assortment is invalid */

else ValueAdd1_1=.;

if Dens12Fk>=460 AND KDmax<=2000 then

ValueAdd1_12=(-25)+1*(Dens12Fk-MDens12Fk)+0*(Heart-MHeart)+(-0.05)*(KDmax-
MKDmax); /* Set to . if the assortment is invalid */
```

```
else ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="231MT" then

DO;

Baseprice1=Baseprice1*1;

if Netinternode>=17 AND Dens12Fk>=460 then

ValueAdd1_1=1*(Dens12Fk-MDens12Fk)+0*(Heart-MHeart)+(-0)*(KDmax-MKDmax); /*
Set to . if the assortment is invalid */

else ValueAdd1_1=.;

if Dens12Fk>=460 AND KDmax<=2000 then

ValueAdd1_12=(-25)+(0.0*Baseprice1)*(Netinternode-
MNetinternode)+1*(Dens12Fk-MDens12Fk)+0*(Heart-MHeart)+(-0.05)*(KDmax-
MKDmax); /* Set to . if the assortment is invalid */

else ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="235R" then

DO;

Baseprice1=Baseprice1*1;

ValueAdd1_1=.;
```

```
if Dens12Fk>=460 AND KDmax<=1300 then

ValueAdd1_12=1*(Dens12Fk-MDens12Fk)+0*(Heart-MHeart)+(-0.05)*(KDmax-
MKDmax); /* Set to . if the assortment is invalid */

else ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="238MT" then

DO;

Baseprice1=Baseprice1*1;

ValueAdd1_1=.;

ValueAdd1_12=.;/* Set to . if the assortment is invalid */

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="246R" then

DO;

Baseprice1=Baseprice1*1;

ValueAdd1_1=.; /* Set to . if the assortment is invalid */

ValueAdd1_12=.;

if KTYPE>10 then
```

```
ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="246MT" then

DO;

Baseprice1=Baseprice1*1;

ValueAdd1_1=.; /* Set to . if the assortment is invalid */

ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="253R" then

DO;

Baseprice1=Baseprice1*1;

ValueAdd1_1=.; /* Set to . if the assortment is invalid */

ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */
```

```
if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="253MT" then

DO;

Baseprice1=Baseprice1*1;

ValueAdd1_1=.; /* Set to . if the assortment is invalid */

ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>48 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="280R" then

DO;

Baseprice1=Baseprice1*1;

ValueAdd1_1=.; /* Set to . if the assortment is invalid */

ValueAdd1_12=.;

if KTYPE>10 then

ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */

else ValueAdd1_2=.;

/*All logs */

ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */

if Heart>50 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */

else ValueAdd1_4=.;

END;


if species=1 AND ToDiaubclass="280MT" then
```

```
DO;
Baseprice1=Baseprice1*1;
ValueAdd1_1=.; /* Set to . if the assortment is invalid */
ValueAdd1_12=.;
if KTYPE>10 then
ValueAdd1_2=70+0*(Netinternode-MNetinternode)+0.5*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.01)*(KDmax-MKDmax); /* Sound knots + XX
e.g. 35 */
else ValueAdd1_2=.;
/*All logs */
ValueAdd1_3=(-0)+0*(Netinternode-MNetinternode)+2*(Dens12Fk-
MDens12Fk)+0*(Heart-MHeart)+(-0.02)*(KDmax-MKDmax); /* Loose knots - YY
e.g. 35 */
if Heart>50 then ValueAdd1_4=(-0)+200+0*(Netinternode-
MNetinternode)+2*(Dens12Fk-MDens12Fk)+10*(Heart-MHeart)+(-0.02)*(KDmax-
MKDmax); /* Loose knots - YY e.g. 35 */
else ValueAdd1_4=.;
END;


/* OBS! Dessa rader är patchar för att sätta tillbaka (återkonvertera)
Netinternode och MNetinternode till . där detta värde gäller (se början av
blocket*/
if Patch=0 then Netinternode=.;
if MPatch=0 then MNetinternode=.;
/* OBS! slut patch */


/* Calculation of per log values */
if species=1 AND (sort NE 3) OR (sort NE 4) then
Logvalue1_1=Sawnvol1*(Baseprice1+ValueAdd1_1)+(Residuevol1*Residueprice1)+(
Barkprice1*Barkvol);
Logvalue1_12=Sawnvol1*(Baseprice1+ValueAdd1_12)+(Residuevol1*Residueprice1)
+(Barkprice1*Barkvol);
Logvalue1_2=Sawnvol1*(Baseprice1+ValueAdd1_2)+(Residuevol1*Residueprice1)+(
Barkprice1*Barkvol);
Logvalue1_3=Sawnvol1*(Baseprice1+ValueAdd1_3)+(Residuevol1*Residueprice1)+(
Barkprice1*Barkvol);
Logvalue1_4=Sawnvol1*(Baseprice1+ValueAdd1_4)+(Residuevol1*Residueprice1)+(
Barkprice1*Barkvol);
/* Calculation of log values per m3fub + bark  */
Logvalue1_1m3=Logvalue1_1/(VolsubDL/10000);
Logvalue1_12m3=Logvalue1_12/(VolsubDL/10000);
Logvalue1_2m3=Logvalue1_2/(VolsubDL/10000);
Logvalue1_3m3=Logvalue1_3/(VolsubDL/10000);
Logvalue1_4m3=Logvalue1_4/(VolsubDL/10000);

----------------------------------------------------------------------------
```

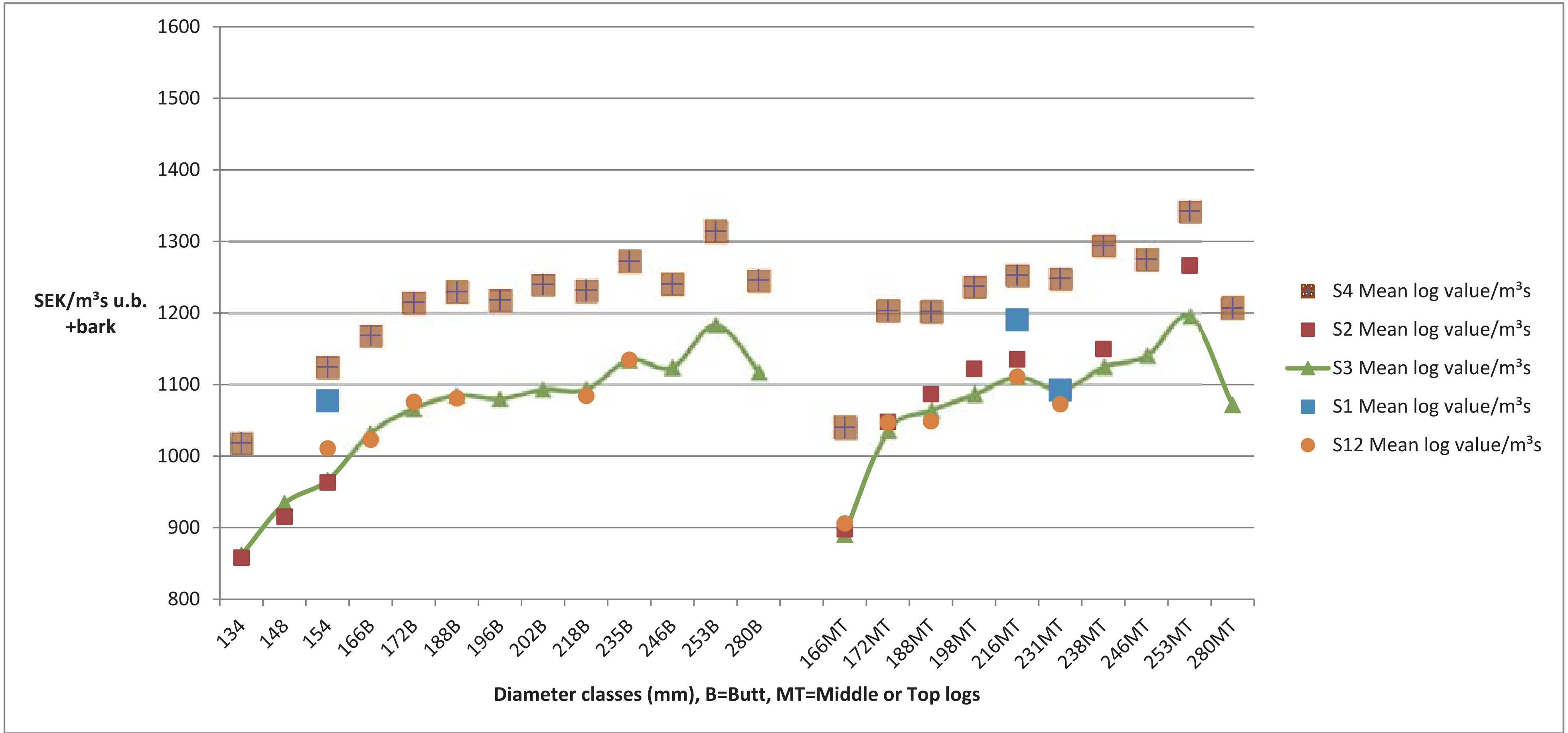

Figure 15. Example of modelled results from economic valuation (details indicated in the SAS-code above) of logs from a sawmill product perspective. Class averages include yield, log length preferences and calculated impact of wood properties. The assortments are based on Pine logs in the SWSC. S1= long internodes for e.g. window frame blanks. S12=Small loose knot/sound knot and medium density assortment for e.g. knotty furniture blanks. S2=Sound knot boards for e.g. interior panels gluelams, etc.S4= Boards with high heartwood content for e.g. improved durability in e.g. duckboards outdoor constructions floors etc. S3 ordinary boards sorted into common quality classes. By-products like chips and bark are also included.

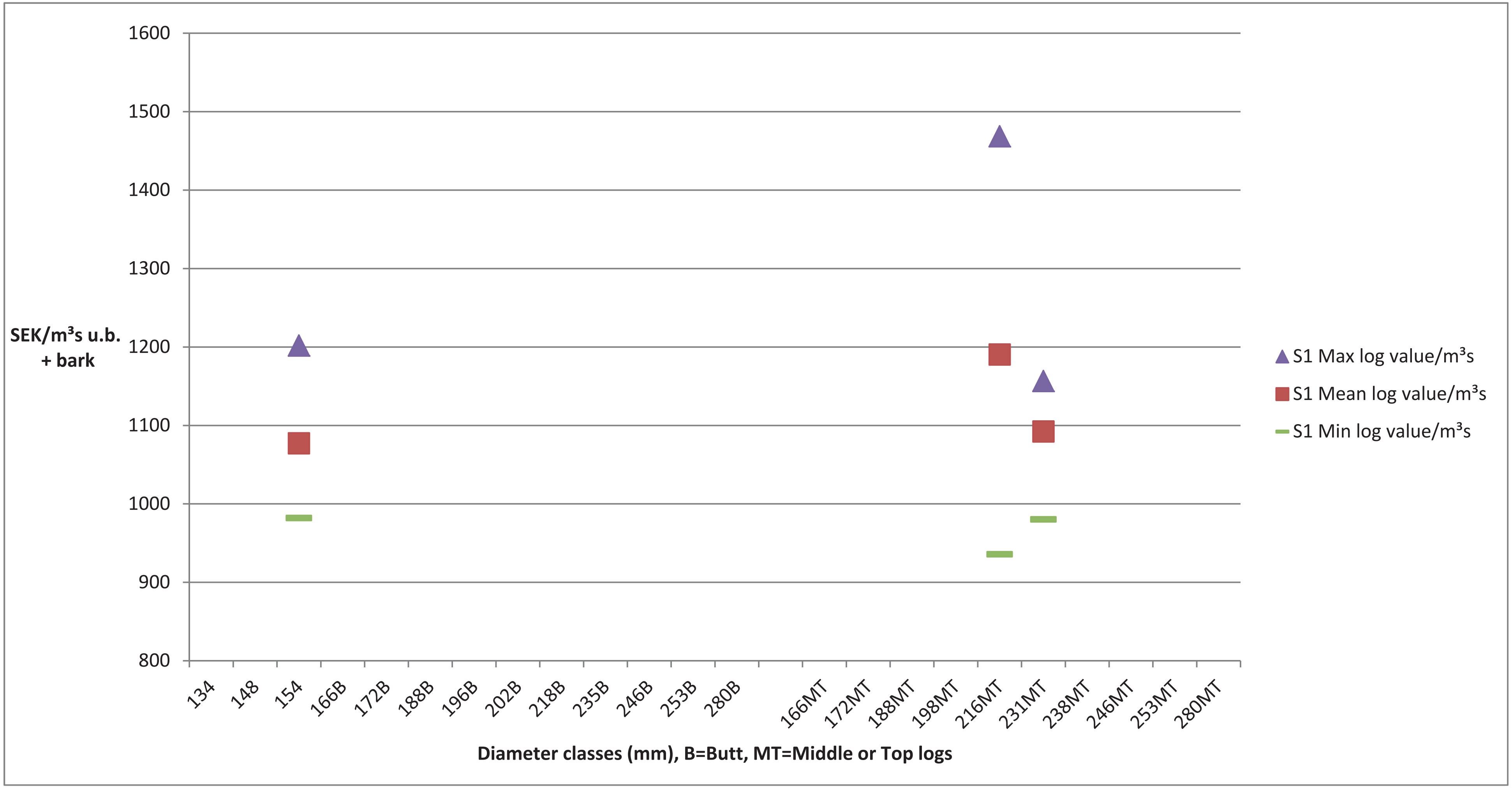

Figure 16. Example of modelled variation in pine log values (SWSC) suitable for S1= long internodes for e.g. window frame blanks (Only produced from a few specific diameter classes). Differences caused by differences in modelled internode distances (distances between branch whorls = 2% value added or lost per cm difference from diameter class average and a threshold value of 17 cm) and wood density (±1 SEK per kg deviation from diameter class average and a threshold value of 460 kg/m³ at 12% MC. By-products like chips and bark are also included. Remark: No effects of log damages, bows, splits, scares or decay are included. Such defects will decrease log values considerably below the values above.

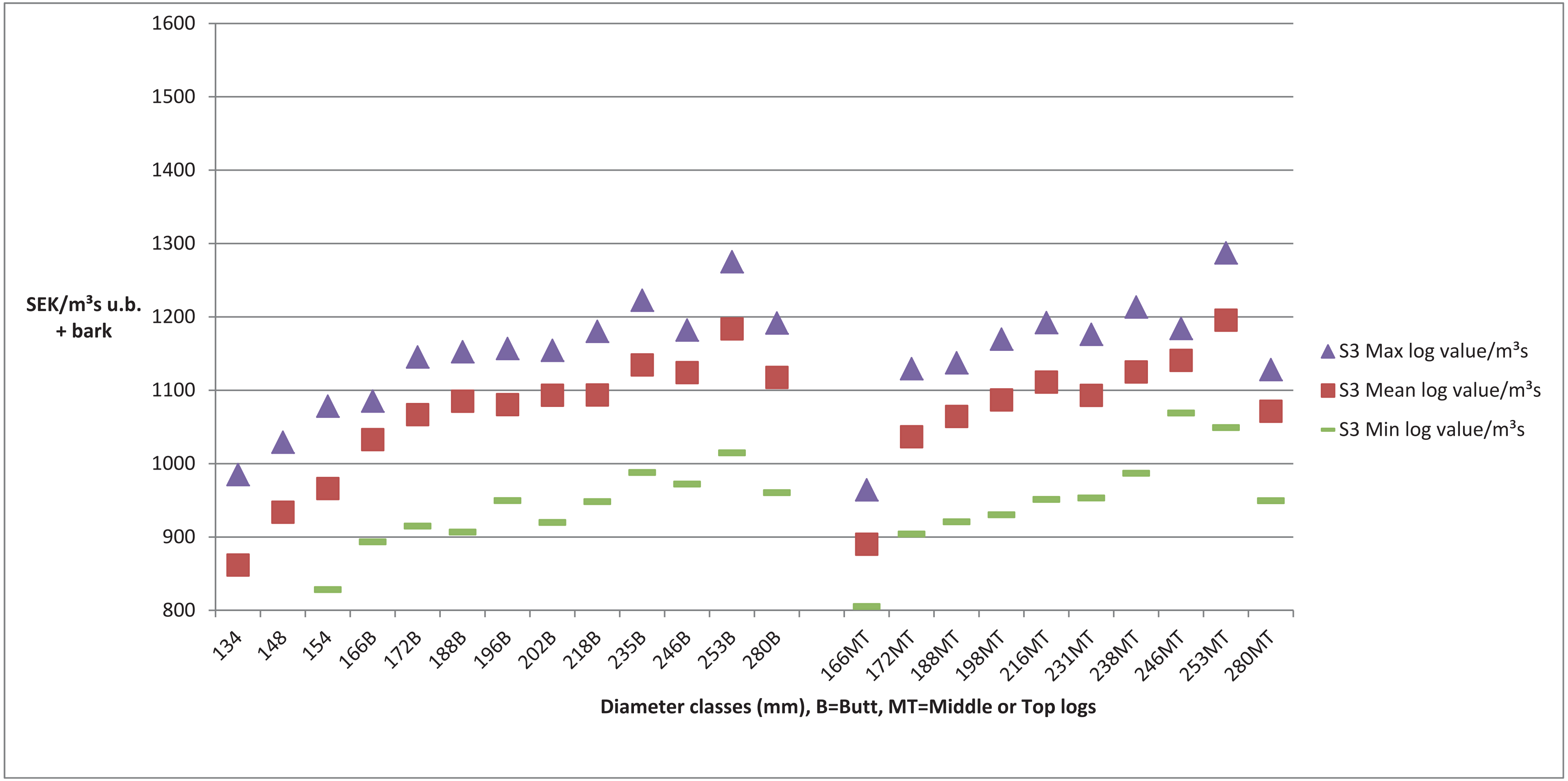

Figure 17. Example of modelled variation in pine log values (SWSC) suitable for S3 ordinary boards sorted into common quality classes. Differences in values within diameter classes are based on differences in predicted densities and knot sizes (Details in SAS-programme above). By-products like chips and bark are also included. Remark: No effects of log damages, bows, splits, scares or decay are included. Such defects will decrease log values considerably below the values above.

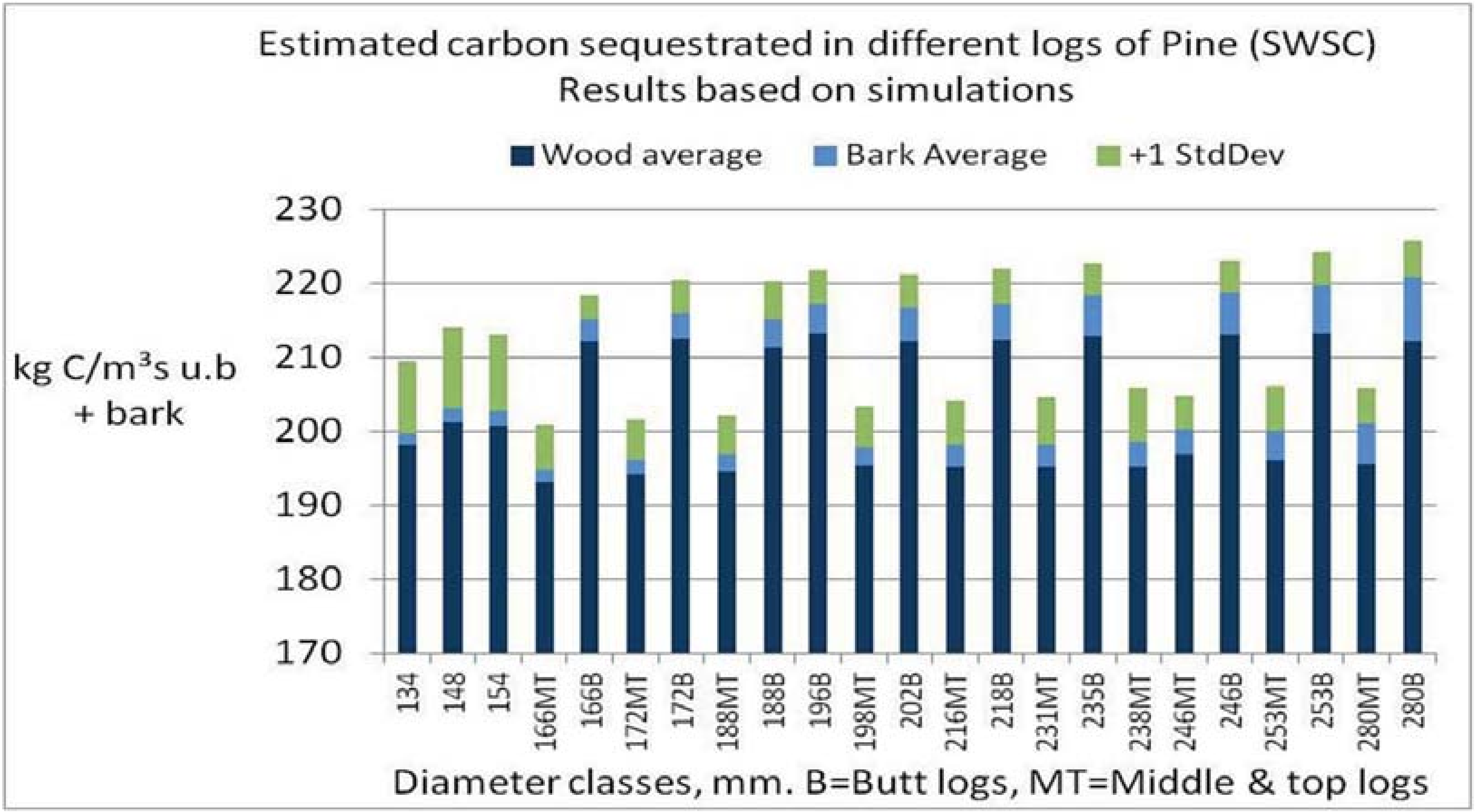

Figure 18. Predicted amounts of carbon sequestrated in sawlogs of different diameter classes to Setra-Malå. The amount of carbon stored in the final wood products can then be calculated from the yield of sawn boards.

16 Appendix D. Results from the quality certification system for harvesters

Figure 19 shows the power of traceable logs for detection of the measurement accuracy in harvesters and 3D-frames at sawmills.

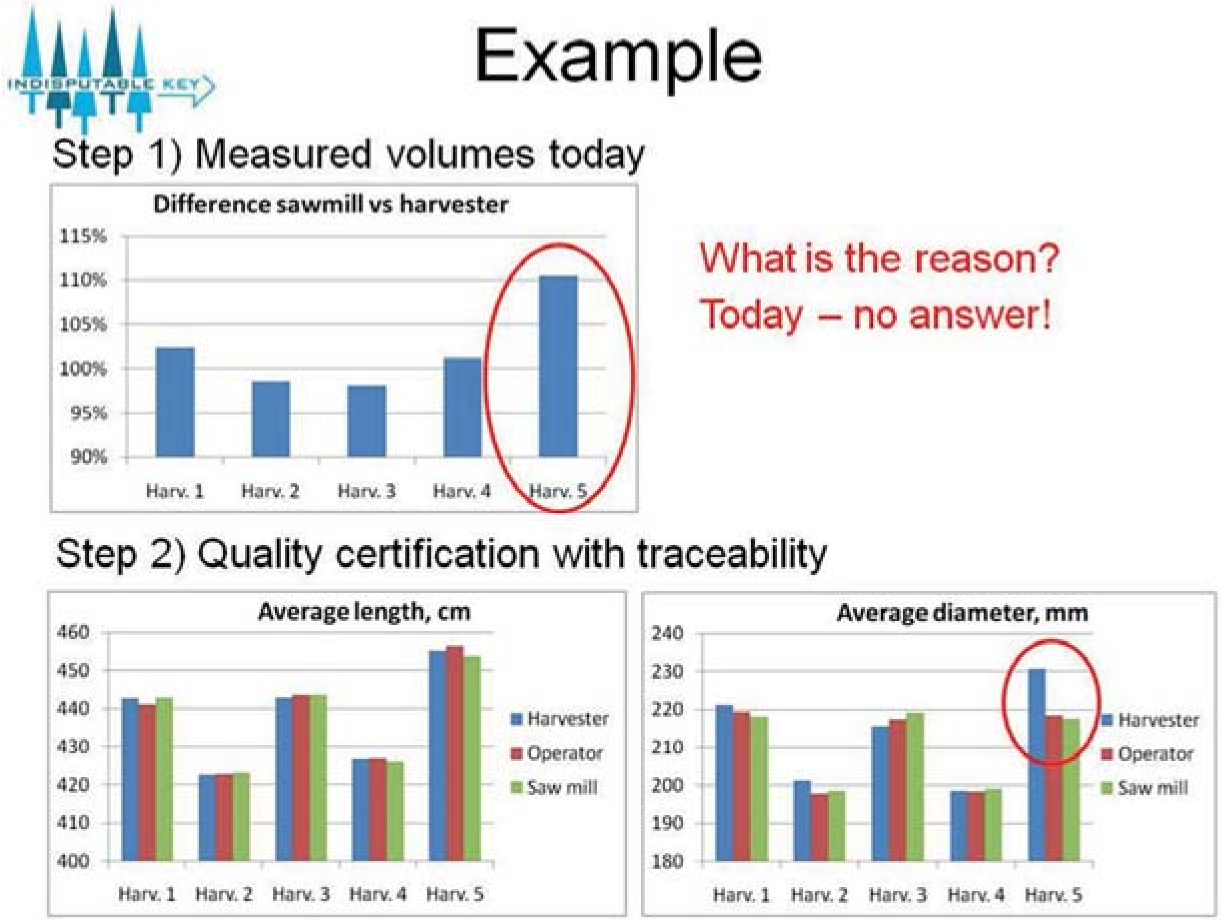

Figure 19. Results from traceable control logs (KTR-files combined with 3D frame data) in the SWSC, measured by five harvesters (Sveaskog), control measurements (caliper) by their operators and the 3D-frame at saw intake in Malå.

Figures 20 to 31 show the similarities between simulated bucking of sample trees and real production from the Quality certification systems (ktr-files).

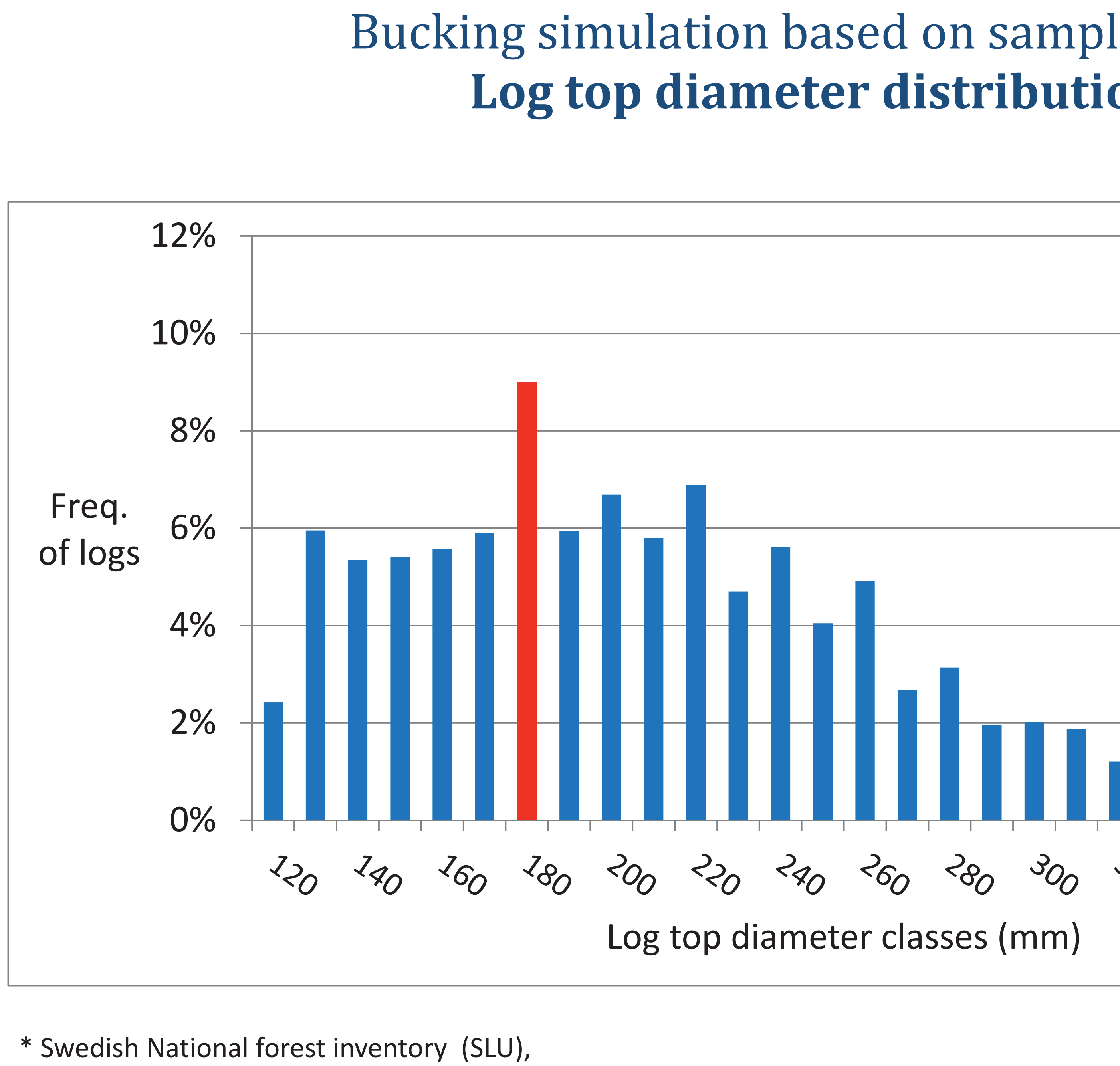

Figure 19. Log top diameter distribution based on simulations

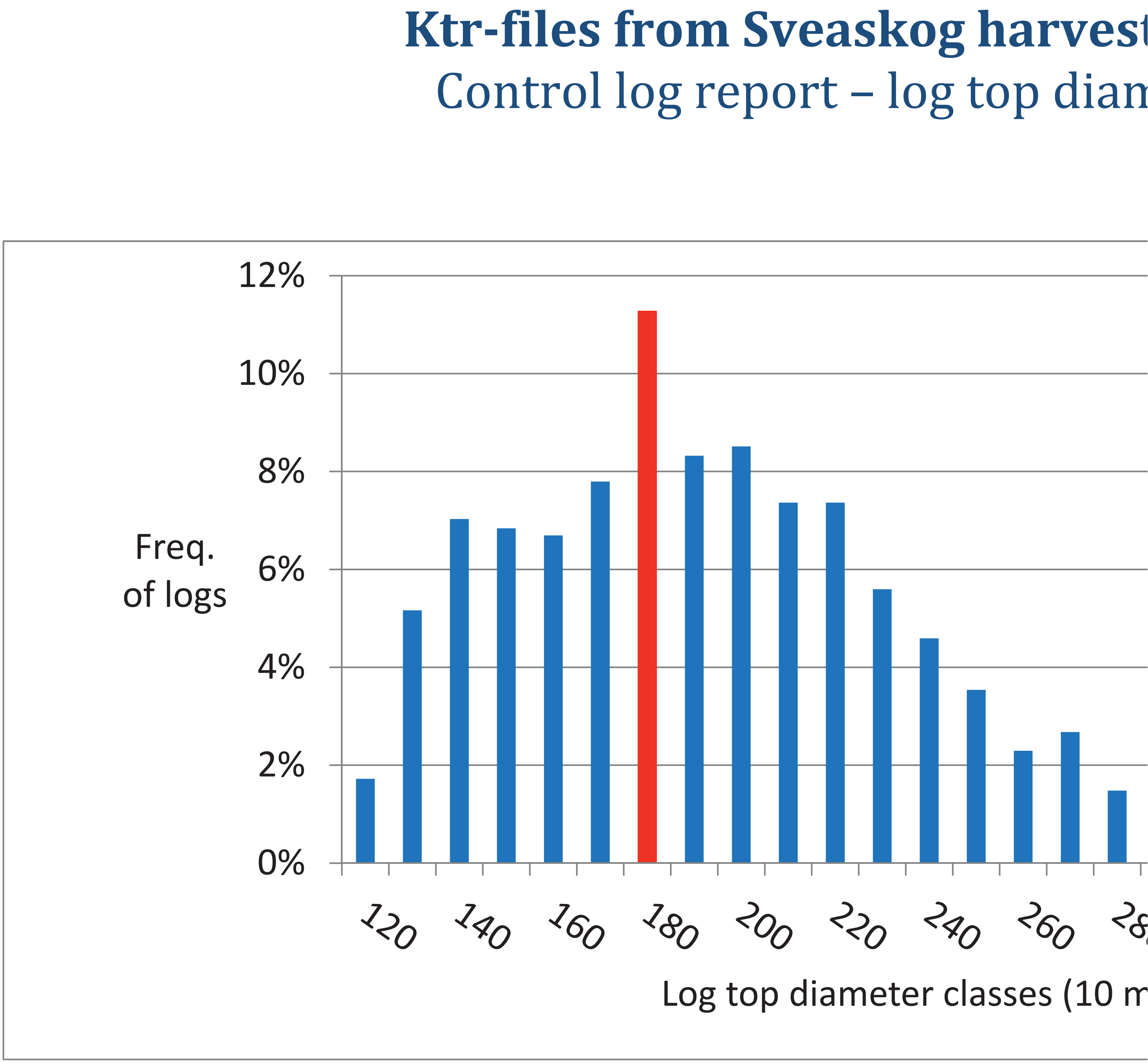

Figure 20. Log top diameter distribution based on KTR-files (Random sample of real production)

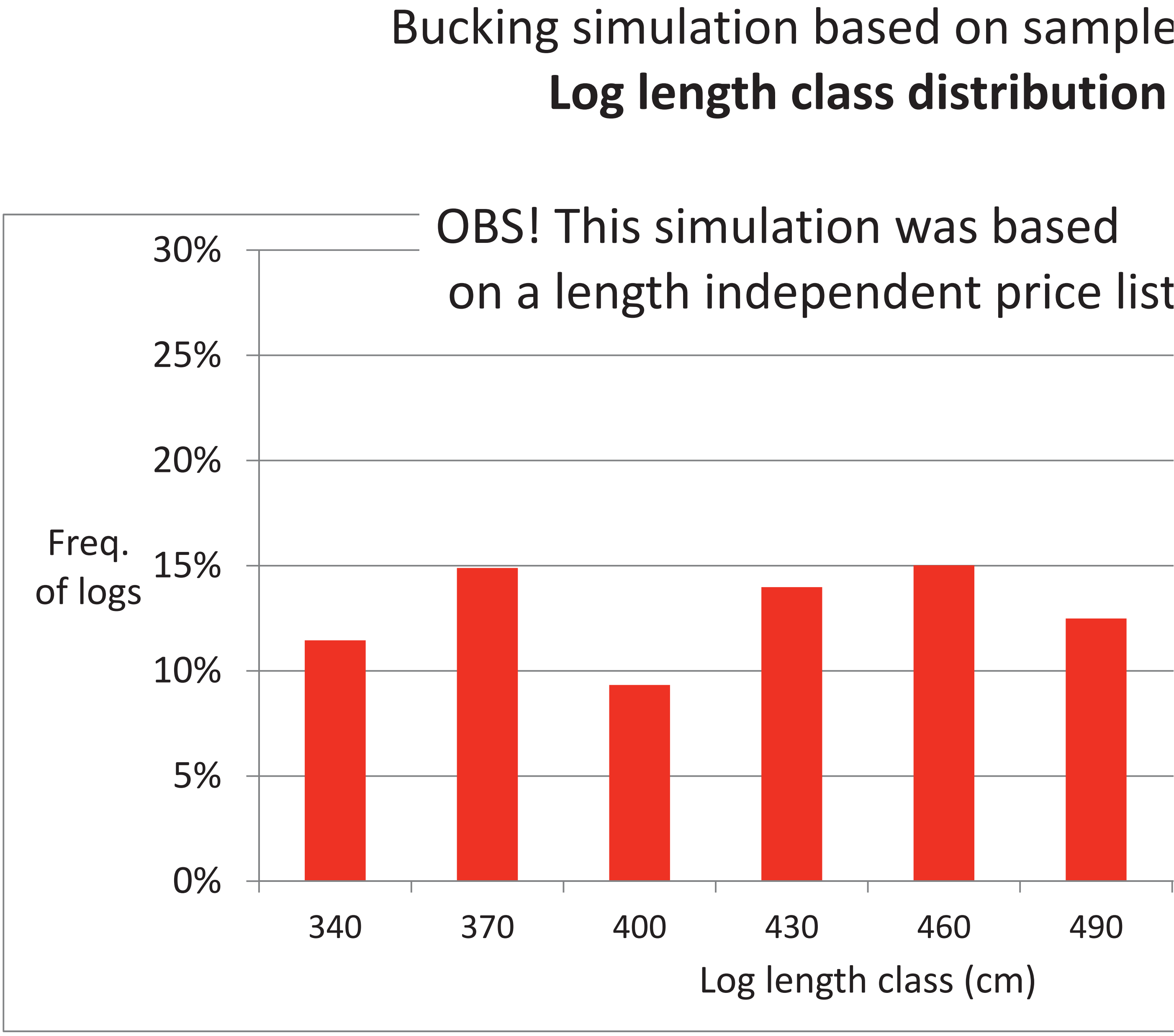

Figure 21. Log lengths within diameter class 180 mm according to bucking simulation based on a length neutral price list.

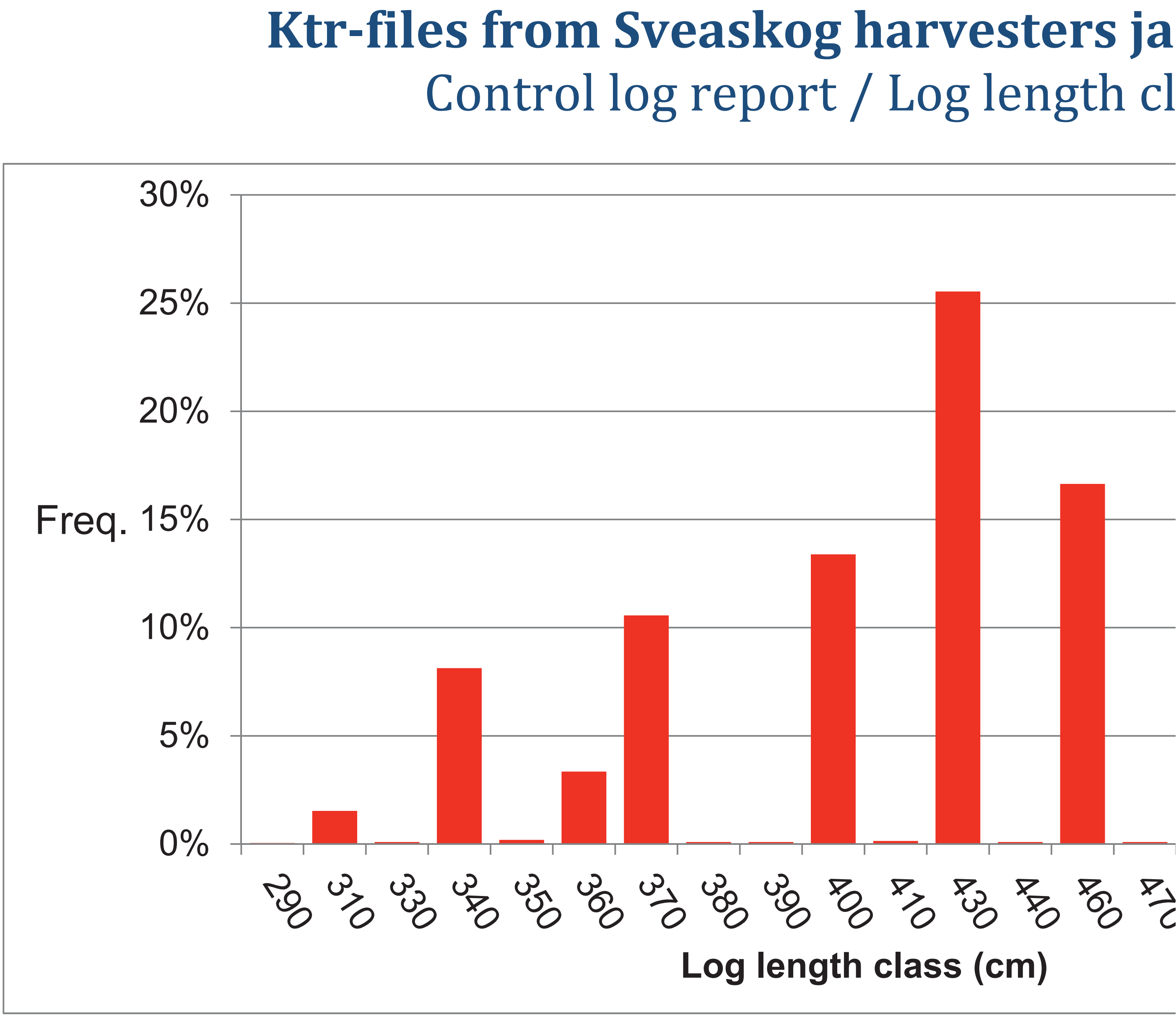

Figure 22. Log lengths within diameter class 180 mm according to KTR-files (Random sample of real production) when bucking was controlled by length preferences (not length neutral)

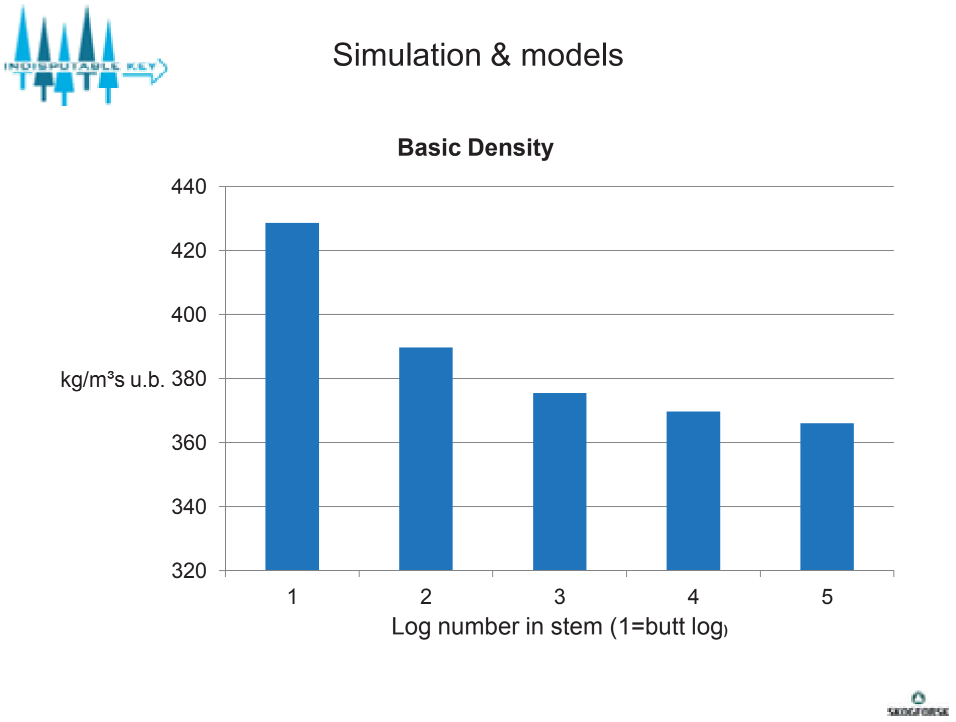

Figure 23. Predicted basic density of log types based on bucking simulation simulation of sample plots

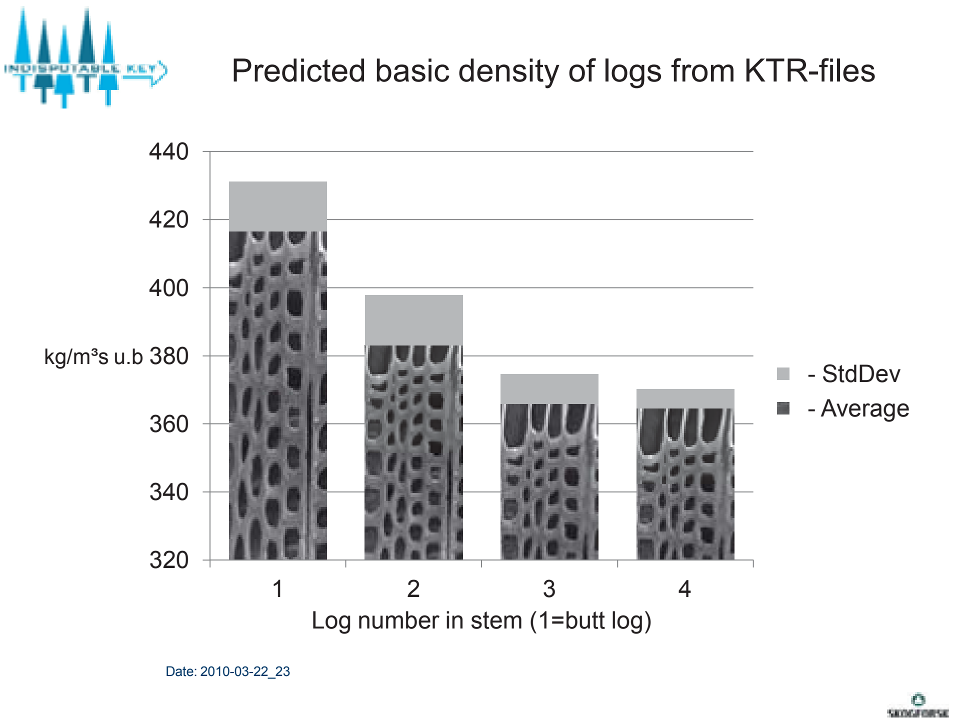

Figure 24. Predcited basic density of log types based on KTR-files (Random sample of real production at Sveaskog)

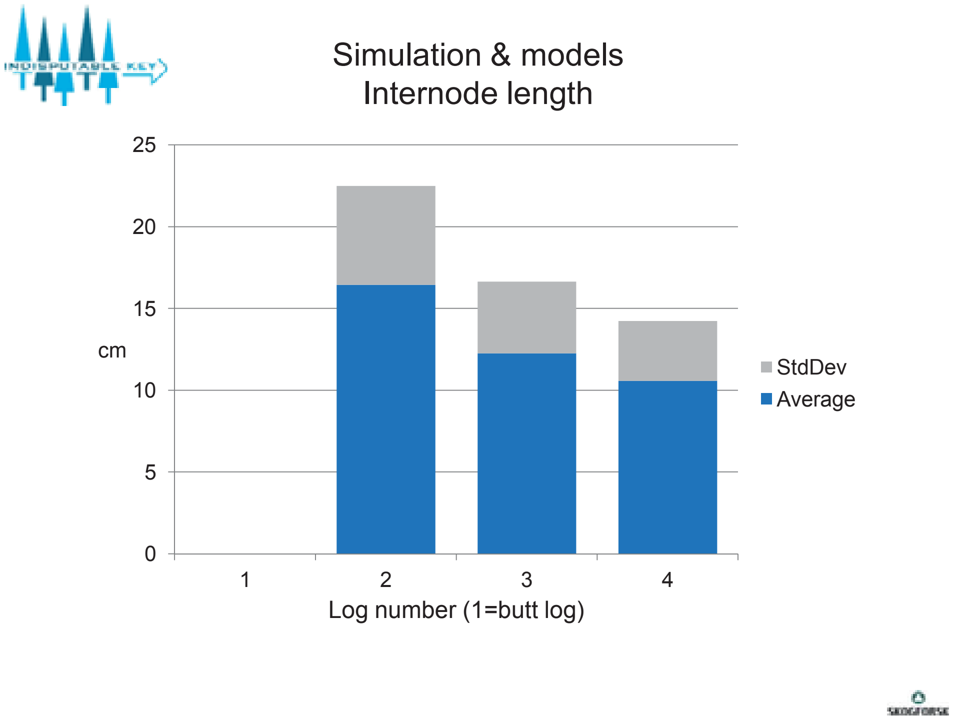

Figure 25. Predicted internode lengths of log types from bucking simulations of sample plots.

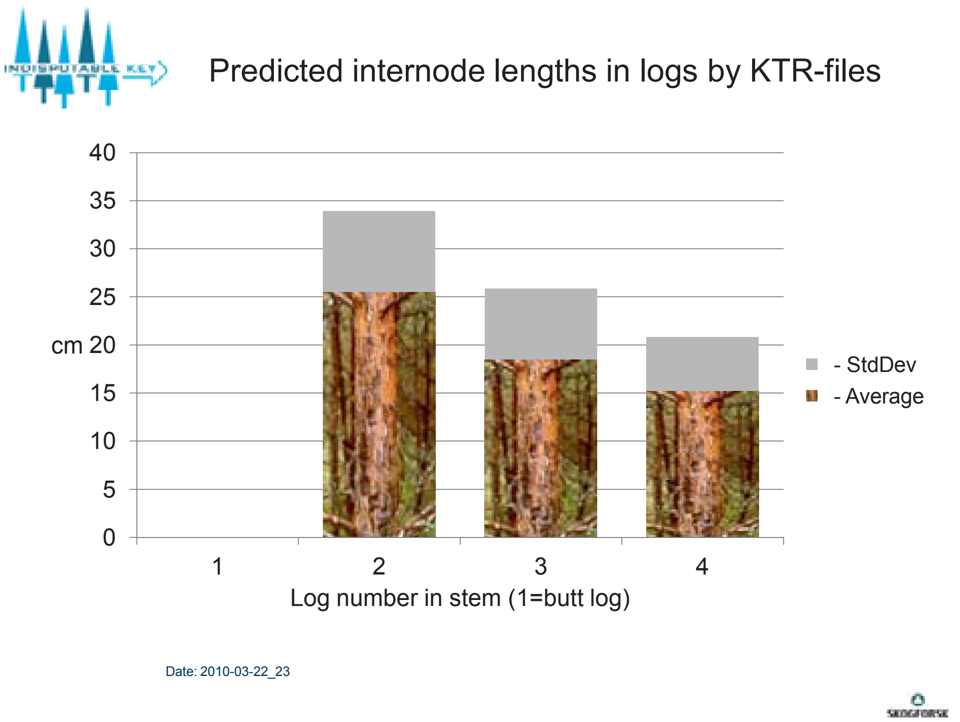

Figure 26. Predicted internode lengths of log types based on KTR-files (Random sample of real production at Sveaskog)

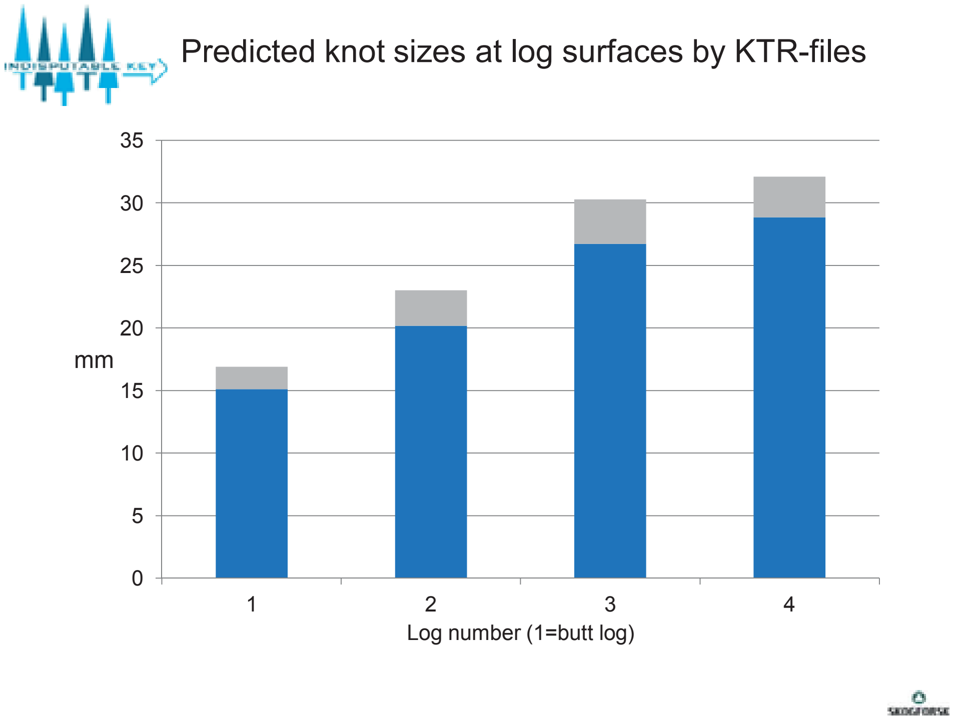

Figure 27. Predicted largest knot sizes per branch whorl in log types based on bucking simulations of sample plots.

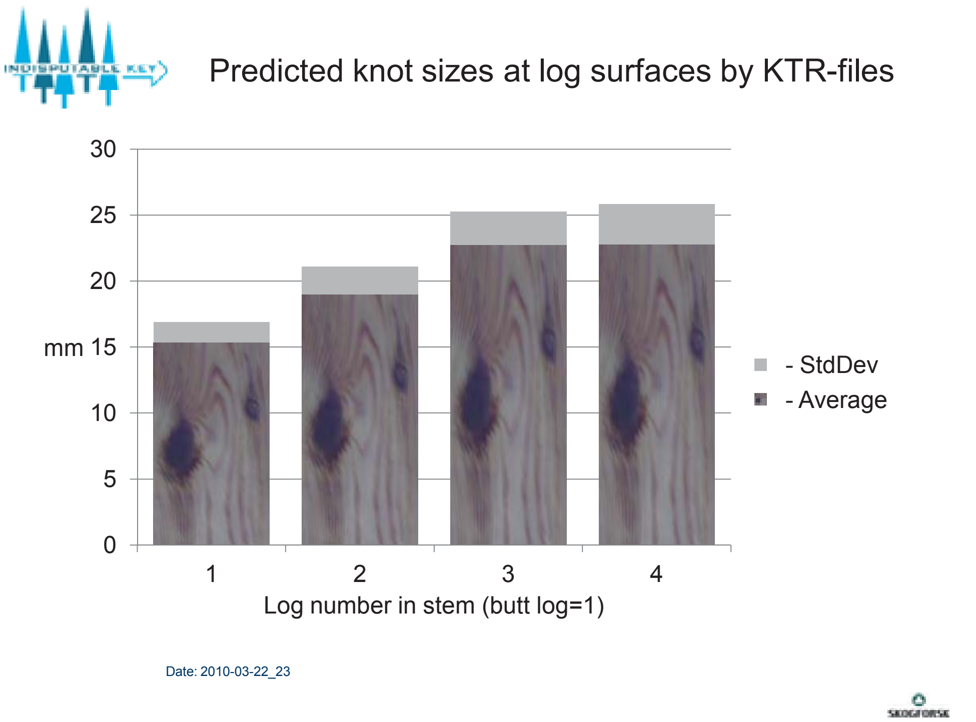

Figure 28. Predicted largest knot sizes per branch whorl in log types based on KTR-files (Random sample of real production at Sveaskog).

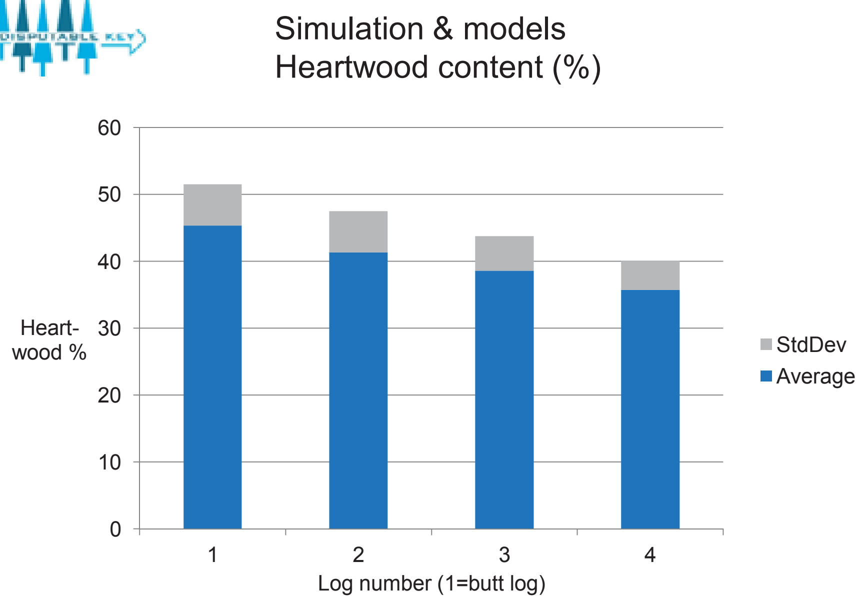

Figure 29. Predicted heartwood content in log types based on bucking simulations of sample plots.

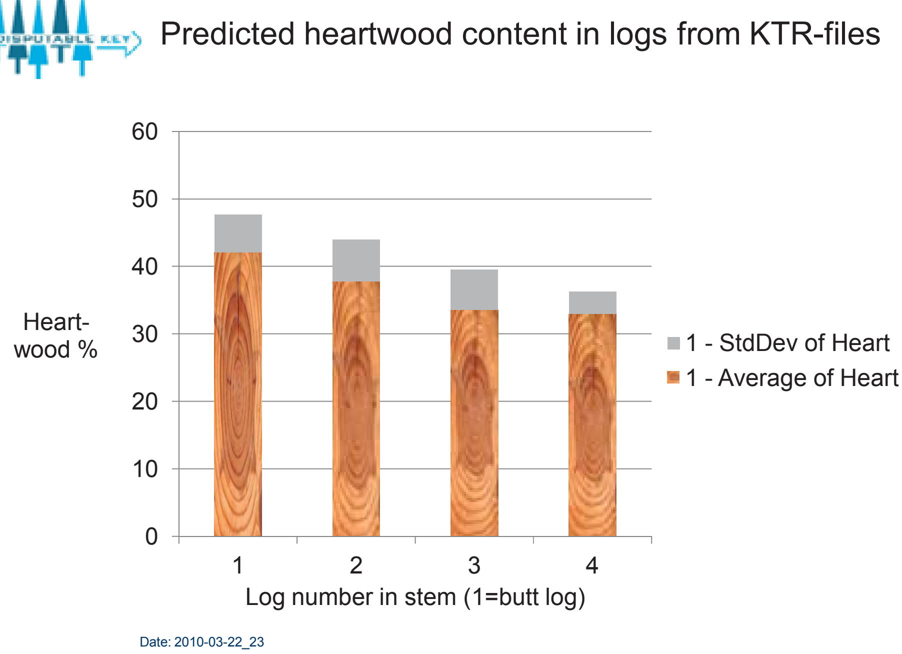

Figure 30. Predicted heartwood content in log types based on KTR-files (Random sample of real production at Sveaskog).