TAMPEREEN
AMMATTIKORKEAKOULU

Maximizing A-Quality Scots Pine Bottom Log

Changes in Technical Quality of Log Parts

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Master´s Thesis
November 2017
Management and Economy in the International Forest Sector

TIIVISTELMÄ

Tampereen ammattikorkeakoulu
Metsäalan kansainvälinen Yamk-tutkinto

PETRI RYÖTI:
A-laatuisten mäntytyvien maksimointikoe: laadulliset muutokset tukkikappaleissa

Opinnäytetyö 50 sivua, joista liitteitä 4 sivua
Lokakuu 2017

Kilpailu sahateollisuuden vientimarkkinoilla on voimakasta ja markkinatilanteet ovat hyvin alttiita talouden muutoksille. Säilyttääkseen hyvän kilpailukykynsä on suomalaisen nykyaikaisen sahalaitoksen saatava raaka-aineensa halutun laatuisena ja taloudellisen toiminnan varmistavalla hinnalla. Sahalaitos voi parantaa kannattavuuttaan hankkimalla raaka-ainetta, joka tilavuuden, pituuden ja puun teknisen laadun puolesta täyttää parhaiten myytäväksi valmistettavien lopputuotteiden vaatimukset.

Tavoitteena tässä työssä oli selvittää millaisia laadullisia muutoksia tapahtuu mäntytukkirungon muissa osissa, kun rungon arvokkain tukkiosa maksimoitiin tekemällä ensimmäinen eli tyvitukki mahdollisimman pitkäksi. Työtä varten hakattiin UPM-Kymmenen omistamilta tiloilta vuosina 2014-2015 n. 40 000 mäntyrunkoa, joista noin puolet tehtiin asiakaslähtöisellä hakkuumatriisilla, eli mahdollisimman pitkänä. Näitä koepuita verrattiin ns. ”normaalimatriisilla” tehtyihin tukkeihin. Tukit kuljetettiin UPM Korkeakosken sahalle, jossa ne sahattiin ja lajiteltiin normaalin prosessin mukaan. Lajittelun yhteydessä röntgen-laitteella kerättiin tietoa tukeista tätä koetta varten. Tiedot analysoitiin Excelillä Pivot-taulukoinnin avulla.

Työssä havaittiin, että tukin tekninen laatu hieman huononi kokeessa käytetyllä hakkuumatriisilla. Tämä havainto saatiin mittauksesta, jolla selvitettiin latvatukin tyvellä ollutta kuivaoksa-aluetta. Pituusluokassa 488 cm oli keskimäärin 20 mm kuivaoksa-aluetta latvatukin tyvellä. Toisella laadullisista mittareista selvitettiin oksaton osa välitukissa ja tässä tapauksessa laatu oli hieman parempi kokeessa käytetyllä hakkuumatriisilla, eli arvokasta oksatonta osaa siirtyi vähemmän välitukkiin. Lisäksi havaittiin, että mahdollisimman pitkäksi tehtyjä ensimmäisiä tukkeja olisi työssä käytettyjen mittareiden mukaan voitu pidentää edelleen keskimäärin n. 220 mm. Työssä myös selvitettiin muita keskeisimpiä tukkien laatua kuvaavia tunnuksia, jakaantumista erilaisiin pituusluokkiin ja tukkien keskitilavuutta. Keskitilavuus nousi hieman käytetyllä koematriisilla ja keskipituus melko reilusti. Lisäksi UPM Korkeakosken sahan tavoittelemat tukkipituudet lisääntyivät huomattavasti, joilla aiemman tutkimustyön mukaan on sahan tulosta parantava vaikutus.

Tässä kokeessa laadulliset erot vertailu- ja koetukeilla jäivät verrattain pieniksi. Merkittävimmät erot syntyivät tukin koon kasvamisesta, sekä sahalle halutumpien tukkipituuksien lisääntymisestä. Tulosten perusteella olisi jatkossa hyvä tutkia vastaavan kokeen pohjalta taloudellisia muutoksia lopputuotteissa ja selvittää erilaisia puun laatuun perustuvia hinnoittelumalleja. Lisäksi työssä havaittuun A-laatuisen tyvitukin pidennyspotentiaaliin olisi hyvä järjestää jatkotutkimus.

Asiasanat: hakkuumatriisi, a- laatu, katkonta, saha, mänty

ABSTRACT

Tampere University of Applied Sciences
Management and Economy in the International Forest Sector

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Master's thesis 50 pages, appendices 4 pages
November 2017

Competition at the export markets of sawmill industry is strong and market situations are very susceptible to changes in the general economical situation. In order to maintain a good competitive edge a Finnish modern sawmill needs to obtain the raw materials as best for the mill at a competitive price. The aim of this study was to find out what kind of qualitative changes took place in the Scots Pine (*Pinus sylvestris*) logs on the other parts of the stem, when the first and the most valuable first log was made as long as possible. For this study nearly 40 000 pine saw logs was made from the forests of UPM Kymmene in 2014-2015. Half of them were made with customer based cutting matrix so they were maximized by length. These test logs were compared with logs made by the normally used bucking system. The logs were transported to UPM Korkeakoski sawmill, where they were sawn and sorted in standard process. Alongside sorting data for this study was gathered by an X-ray gauge. The data was analyzed in Excel with Pivot tables.

In this study a specially selected qualitative indicator was used to measure the dry branch area at top logs bottom end. It revealed that the technical quality of the logs was slightly inferior with cutting matrix used in the study. At length class 488 cm there was roughly 20 mm dry branch part at the bottom of top log. With another qualitative indicator which examined the knot-free part of the middle logs bottom end the quality was slightly better with customer based cutting matrix, that means less knot-free timber passing to the middle log. It was also noticed that the first logs could have been made even 220 mm longer in average with indicators used in the study. In the work some other key indicators of the quality of logs were also studied, divisions into various categories of lengths and average volumes of logs. Average volume rose slightly with customer based cutting matrix and the average length increased significantly. In addition, the most valuable log lengths for Korkeakoski sawmill owned by UPM Kymmene increased significantly. According to earlier research work the result has positive effects on the competitiveness of a sawmill.

In this study the qualitative differences with comparison and test logs were rather small. Significant differences were found from bigger size of test logs and increased the number of wanted length dimensions for UPM Korkeakoski sawmill. Based on the results of this study, in the future it would be good to examine on the basis of the corresponding test the economic changes in end products and find a variety of quality-based wood pricing. In addition, the detected potential in increasing the length of A- quality bottom log would be an interesting theme for additional study.

Key words: cutting matrix, a- quality, bucking, sawmill, pine

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1 INTRODUCTION

Finnish forest industry is proceeding into an unforeseen phase. Big investments are partly a reality and some of them are in planning state. Consumption of domestic wood is increasing in years to come and that rash of wood will include millions cubic meters of Scots Pine saw logs (Metsä Group Annual Review2014). Sawmilling is moving more and more towards customer based orientation, so need for sorting logs by qualities is becoming more significant. One way to decrease costs and make a difference in competitiveness in Finnish sawmilling is to find out the most valuable qualitative parts of timber already in forest end and coming up in value chain. Among the technical quality of logs the different lengths are also important to sawmills. Together with diameter some dimensions are more valuable than others as end products. When bucking small-diameter logs it causes losses for the sawmill and by increasing diameter and length sawing gets improvement (Malinen, Kilpeläinen, Wall, & Verkasalo 2006). When a forest machine is bucking up logs in forest to right measures and qualitative dimensions in every position of stem, it is easier for the sawmill have profitable value for products (Dems, Rousseau & Frayret 2013).

In Nordic countries common method in harvesting is cut-to-length (CTL). It means that timber is bucked into different assortments in forest. Modern harvester is guided by computer. Harvester constantly collects information from stems like diameters, lengths and tree species. Bucking is programmed by selected value functions which may be value matrix, division matrix or combination of them (Appendixes 1,2). For the stem to be cut optimally it should be measured in advance. By the collected data computed the harvester forms prediction of the stem. Final bucking is done by this prediction and the driver`s eye based qualitative evaluation.

Sawmills have their own objectives for timber. Usually the main factors are average volume, quality of timber and specially amount of A-quality from a log rash. When the average volume and the quality of the logs are close to the objectives for sawmills it is possible to target for good cost-effectiveness. When aiming to the maximum yield and volume of A-quality logs when bucking a Scots Pine stem one must remember that the diameter is not the only factor determining the cutting points of the stem. Sawmills have qualitative boundaries for saw logs and UPM Korkeakoski factors are found in Appendix

3. Some stems may have various failures like crooking, rotten part etc. Main factors for every Scots Pine stem are dry branch line and fresh branch line. Those lines divide logs into bottom-, middle- and top logs.

The objective of this study was to find out what kind of changes in technical quality take place in sawn logs, when most congenial dimensions were maximized by bucking the first logs as long as possible. Sawmill UPM Korkeakoski was suited for this study because there were an X-ray gauge available. The forest machine driver was informed to make first log (bottom log) as long as possible regardless what the harvester computer suggested. For this study from UPM Korkeakoski´s X-ray gauge was performed two parameters:

1. Dry branch part in top log bottom end
2. Plane wood area without branches in second log

When planning this study these parameters were considered to be the main indicators of the success of the bucking using the two different cutting matrixes. For the values of sawn end products it is prominent that plain wood area do not pass from first log into the middle log and dry branch part from middle log to the top log.

This study was defined to analyze the log parts only and changes in their technical qualities. It was very obvious that in some extent part of traditional log part of stem passed to the pulp wood part of the when using the cutting matrix performed in this work. The economic outputs of sawn products or felling sites were not topics of this study. Also pricing of the raw wood convenient to the method performed in the study was not a topic in this study.

2 QUALITY DEMANDS OF SCOTTS PINE SAW LOG

2.1. Quality grades of sawn timber

The quality, size and location of branches mainly determine the quality of the sawn timber. Due to the external characteristics of the log it is difficult to predict the quality of the sawn timber that is obtained from the log. Externally fully grafted log may contain large branches hidden by growth of a tree. Healthy branches are not a problem in sawn timber but dry and broken branches causes problems in quality of end products. Healthy branches remain caught in the timber, while rotten and the dry branches extend deep into the log and they appear as holes in the timber. Bends and skewness only appears as visible defects in sawn timber reducing value and limiting applications (Tavoitteena laadukas puuraaka-aine 1992, 14–15). Other factors influencing the quality of timber are cracks, resin grooves, bark cracks, bark scars, curves, crooked faultiness and reaction wood (RT21-10978 guide 2009, 9).

The refinement values of the logs change according to the quality of the logs. Roughly simplified with example ratio the value of dry branched middle log is 80. The value from average logs is 100, the value of the products from non-branched logs products will increase up to 120 (Tavoitteena laadukas puuraaka-aine 1992, 14).

Sawn timber is divided into four main qualities based on quality characteristics; A, B, C and D. The highest grade is A, which is further divided into A1-A4. In the lowest grade class D all defects are allowed as long as the sawn timber remains intact. It is also possible to sort the sawn timber by using combinations AB and ABC, which include incident part from production of each quality (Pohjoismainen sahatavara 1998, 16).

Subdivisions A1-A3 does not take into account healthy and dry branches of 7 mm or less. In grades A4 and C 10 mm and smaller healthy and dry branches are not taken into account. In A and B grades the branches must be firm. Sawn timber which iclude 15 mm or smaller loose branches or wholes is classified in quality C. The pieces containing more than 15 mm loose or branch holes are classified as D grades (Pohjoismainen sahatavara 1998, 26-32).

In addition to the main grades, ST (saw productive), VL (export quality) and KL (domestic quality) are commonly used. Saw productive is sawn timber with full edged timber, which can include different grades. Exports and domestic qualities are surface boards and are mostly partial-edged (Rakennepuutavara: Laatua rakentamiseen, 2012).

In addition to the ABC rating, we also often talk about the old u / s, kvintta (V) and seksta (VI) quality grades. The old grading u / s quality corresponds to the current A-grade, kvintta B grade and seksta C-grade (Rakennepuutavara: Laatua rakentamiseen, 2012). Furthermore to ordinary grades, special grades are also used (Pohjoismainen sahatavara 1998, 19). UPM + specialty timber products have been designed and manufactured to meet the challenging special needs of customers, especially in the carpentry and furniture industry. Special timber differs from standard sawn timber on the basis of sawing and drying methods, as well as length and quality.

2.2. Quality demands of saw logs

According to the measurement and quality requirements of UPM's Scotts Pine logs (2012), A-quality Pine bottom log has a minimum top diameter of 200 mm. The log should be straight, curving must not be more than 10 mm / rm evenly. On the bottom log curving is measured by the distance between the top and 1 m from the cutting point of the log. Curves or multi skewness are not accepted. A curve is considered when skewness is over 10 mm/meter. A-quality bottom log also distinguishes between the other saw logs having as little as possible healthy or dry branches with diameter not over 20 mm. Rotten, branch nodules, or boy branches are not allowed at the A-quality bottom log at all, unlike like other logs, such as B-quality bottom log, middle log, and top log. Dimensional and quality requirements also prohibit color failures, rotten (both soft and hard), resin grooves, maggot wholes, twin cores, top sprouts, root rivets, cut flutes, and vices and irregularities at the cutting surface. There must also be no foreign matter, soot, coal, chemicals, plastics, metal, stones, sand or other contaminants (UPM Metsä 2012).

2.3. Natural basic charasterics of Scotts Pine stem

The purpose of this thesis was to find out what kind of qualitative changes the maximizing of the first and most valuable log part, bottom log, causes in the middle and the top logs. Numerous studies have been carried out on bucking saw logs based on economic impacts. They were not exposed in this paper.

The Scotts Pine tree must ultimately be bucked off according to its basic characteristics, which are the dry branch limits and the fresh branch limits. The driver of the harvest machine shrinks the stem by eye sight, observing the quality of the logs and observing the aforementioned branches. Target distributions in the felling site drive´s the bucking and together with quality limits provide different log lengths to the final harvested result. When looking at the first log of the pine tree, it is known that the branchless part does not end indefinitely, but for example with 25 cm diameter of $Dbh_{1,3}$ m the dry branches begin in the southern of Finland at an average of about 4.1 meters (Hakkila, Laasasenaho & Oittinen 1972, 13). With the same size of stem the dry branch limit continues on an average height of 8.5 meters, and starting with the fresh branch part of the stem from that point (table 1).

On the same size stem (D1,3, cm 25) the thickest branches from 70% of the total height of the stem are on average 42.4 mm (Hakkila et al., 1972). With a tree of 19 meters in length this would be about 13.3 m from the cutting point and at the area of the fresh branches. According to the quality definitions, the fresh branches maximum of 60 mm in the middle and the top logs were allowed.

At the same time, the dry branch parts of smaller trees extend slightly to more than 10 meters from which fresh branches begin. Within the average dry and fresh branch limits, it would be possible to extend the first log so that the bucking points will fit to the natural cutting points of the Scotts Pine tree.

In normal Southern Finland Pine forests obstacle to extend the bottom logs may be the average dry branch limits which according to Hakkila et al. are about 4-5 m above the level of about 2-3 meters in variation. It is very likely that an extension can not be achieved in all types of felling sites, but it requires better quality than average.

A-quality logs are on average more robust. This is because they are often bottom logs. In B and C qualities, the average rigidity is offset. A-quality logs are often longer and with the loss of quality the length of the logs decreases (H. Hakala, 1992, 23).

TABLE 1. Tree height and the lower limit of living and dead branches by breast height diameter classes. Scotts Pine

Dbh, cm	Tree height, m		Lower limit of branches, m			
	South		Living branches		Dead branches	
	x	s	x	s	x	s
5	5,7	0,8	2,4	0,9	0,8	0,6
7	6,4	1,7	2,9	1,9	0,8	0,6
9	7,5	1,6	3,3	1,6	1,0	0,9
11	8,9	2,0	4,1	1,6	1,5	1,3
13	10,4	2,1	4,9	1,9	1,8	1,5
15	12,0	2,5	5,8	2,2	2,6	1,6
17	13,9	2,4	6,7	2,6	2,7	1,8
19	14,9	2,7	7,1	2,6	2,9	1,9
21	16,1	2,6	8,0	2,5	3,9	2,3
23	16,7	2,8	8,1	3,2	3,9	2,3
25	17,7	3,1	8,5	3,0	4,1	2,2
27	19,3	3,0	9,4	3,2	4,5	2,5
29	20,0	2,5	9,6	3,0	4,9	3,0
31	20,5	2,7	9,7	2,9	4,7	2,5
33	20,9	2,7	9,7	3,1	6,0	3,3
35	21,7	3,2	10,2	3,0	6,0	2,9

2.4. Value ratios of Scotts Pine Stems

The origin of the tree, the place of growth and the forestry history together affect the kind of forest that has developed. By virtue of their basic features, these forests may have a very different economical value. According to Matti Kärkkäinen (1986, 124), the branch limits have little economic significance for fiberwood and smaller stems. The importance of external quality is growing strongly when the stem becomes larger. When looking at the dry branch limits 2 m and 8 m and the largest stems are differences in the final product yield between these two limits 6,7 € / m3 (Kärkkäinen 1986).

2.5. UPM Korkeakoski sawmill

Korkeakoski sawmill is located in Juupajoki, about 60 kilometers from Tampere and 210 from Helsinki. There are about 70 employees working at the plant and it is grounded in 1960. Produced products are constant- and special Pine saw products. Producing capacity is some 330 000 m3/ year. Main markets are in North Africa, China and Japan. Raw material comes mainly from central Finland, objective for average volume of saw log is 220 l, and from supplied timber pursue is to have A- quality saw logs over 30%.
In saw log measuring there is two independent of each other main function:

1. Acceptance measuring and reporting
- volume and length of log from 3D gauge
- diameter with bark from 3D gauge
- pressed forest crocks by sorter
- disqualifications from log gauge measures

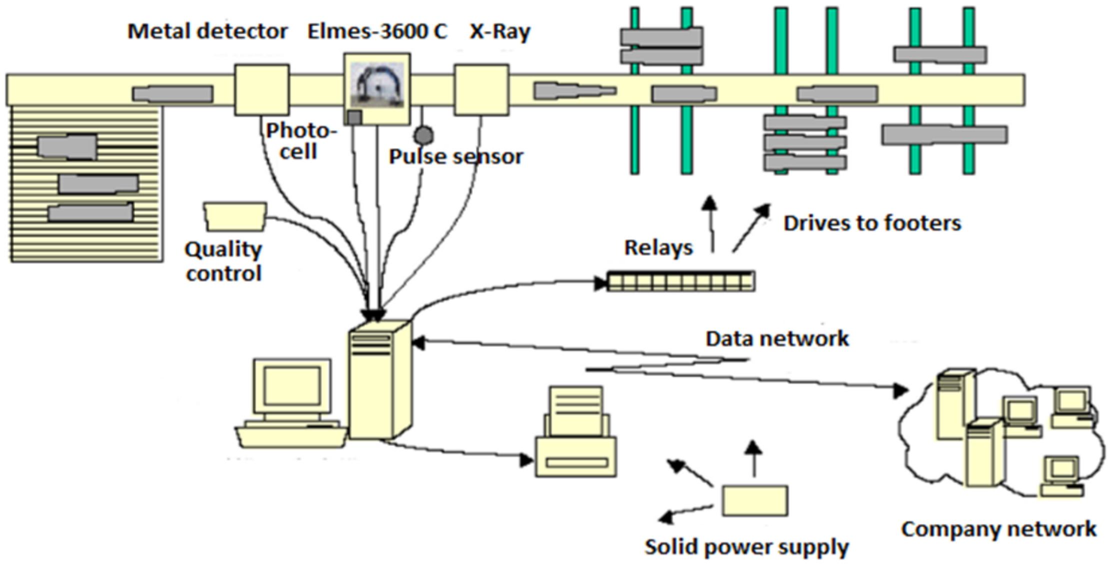
These are based on measurement law, Ministry of Agriculture and Forestry act and specifications of Natural Resources Institute Finland.

2. Sorting logs and reporting
- diameter without bark from X-ray
- interior quality of saw log from X-ray
- length from 3D gauge
- compartment- drive

These are based on productivity. At Korkeakoski mill log goes through a system which consists of eight lasers and three cameras. The system takes pictures from log with pulse of 20 ms. From these pictures 3D gauge makes three dimensional model of log, which consists circle information with 5 cm units and 360 pictures on each circle.

Log measuring system with digital cameras is a new way of measuring. It consists of smart cameras with embedded Linux computer with pre- processing the data. With this system is possible to get 15- times of data compared to old gauges, identify sway of logs during measurement and it has eventuality to draft sorting.

Wood-X Tomo200K is real time X-ray measuring system, which is able to help sorting logs by internal information of saw log. System produces comprehensive data of dimensions, density and defects of log. Four side X-ray pictures are processed automatically on calculation servers using developed inversion algorithms. Form and quality of log is possible to reconstruct and decode, results are sent to sorting system of Visiometric. Simplified picture of Korkeakoski sawmill production line in picture 1 (Toivonen 2016).



PICTURE 1, Korkeakoski sawmill production line (Toivonen 2016)

3 REVIEW IN TO FINNISH FOREST INDUSTRY

Taking quick glance to export statistics by year 2014, we can see that exported amount of sawn timber was roughly 7,5 Mill m3 and valued by 1 500 Mill € (Luke 2015). That is 2,7% of total value of goods exported from Finland in 2014. From that amount part of sawn Scots pine is around 3,8 Mill m3 and value 771 Mill €, which gives average unit price for Scots pine sawn timber 193 €/m3. Same values for Norway spruce sawn timber are roughly 3,2 Mill m3 and 648 Mill €, unit price 191 €/m3. Combining these figures to used amount of timber, we see that exported amount of sawn Scots pine is 39,5 % and Norway spruce 29,3 %. So meaning of sawn pine timber for exporting industry is significant (Luke 2015).

In the year 2014 Finnish forest industry used around 64 Mill m3 round wood. That is approximately same amount as in year 2013 (Luke 2015). Consumption of domestic wood increased 2 % ending to 55 Mill m3. Divided to industrial branches the biggest amount of wood was used by pulp industry, 29,5 Mill m3. Saw industry was next with consumption of 23,6 Mill m3. Sawn timber divided by tree species are Scots pine (*Pinus sylvestris*) 9,6 Mill m3, Norway spruce (*Picea Abies*) 10,9 Mill m3 and broad leaved trees 0,09 Mill m3. Saw industry is very important branch for Finnish forest owner, when nearly 70 % of earnings from stumpage prices come from sawmills, and by volume raw wood delivered to sawmills represent about 42 % of market loggings in Finland (Ylitalo 2013). When looking these figures one can conclude, that Finnish forest industry is in need of high quality timber assortments and it is willing to pay for good raw material.

While writing this report Metsä Group is building a big bio product mill in Äänekoski. Pulp production is planned to launch in the end of 2017. Bio product mill produces annually 1,3 Mill tons of pulp, from which 800 000 tons of long fibre pulp and 500 000 tons short fibre pulp (Metsä Group Annual Review2014). This mill is going to increase round wood consumption roughly 4 Mill m3 in Finland. From that amount of Scots Pine will be roughly 2,5 Mill m3 and birch 1,5 Mill m3. Procurement of 2,5 Mill m3 Scots Pine pulp wood from Finland means also that buying company gets some 1,25-1,9 Mill m3 of Pine saw logs.

At the same time UPM has invested to Kymi pulp mill and due that annual use of round wood will increase 800 000 m3 (Metsälehti 2014). In Varkaus Stora Enso has invested by turning old paper machine to pulp production line. This line will produce raw material for collocated cardboard and 310 000 tons of brown pulp. Together these new lines will increase use of round wood roughly 1,1 Mill m3 (Stora Enso 2014). Together these three investments will add consumption of round wood around 6 Mill m3. In addition to this there are plans for pulp mills to Kuopio and Kemijärvi. If all this would lead to real production, that would increase pulp wood procurement over 10 Mill m3, largely Scots pine. Thinking of total wood procurement that would mean increase of saw logs some 5-7,5 Mill m3.

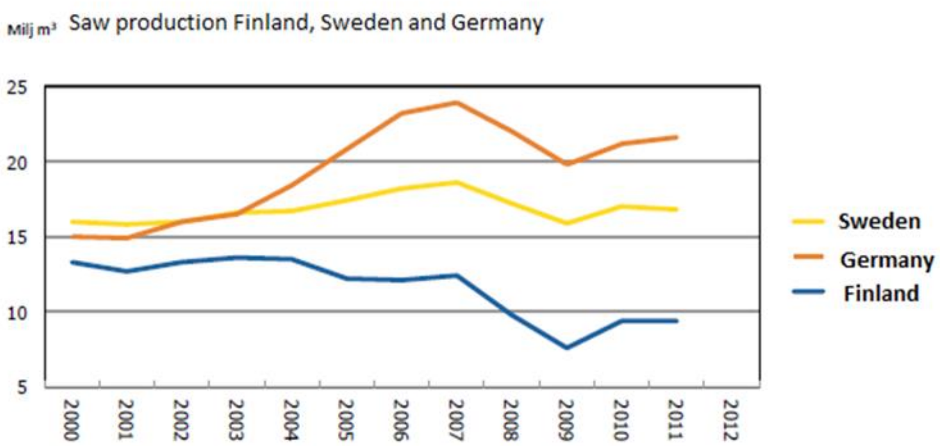
Pulp- and bio product mills require functional sawing industry. “If there are no sawmills, we can draw a line over every pulp investment” says CEO of Suomen Sahat Kai Merivuori (Kauppalehti 2015). At first this might seem, that is a provocative comment from leading man of Finnish saw industry, but it is impervious truth in essence. The cost structure of a pulp mill would not endure of using saw logs in boiling pulp.

When we estimate the challenge of this situation of increased amount of saw logs 3 million m3 roughly in year 2017, we can look at statistics of produced sawn timber years 1980-2014 (Peltola 2014). There is a variation being at the lowest on 1991 around 6,45 Mill m3, and the highest 13,32 Mill m3 in year 2000. In year 2014 Finnish sawmills produced sawn timber (Pine and Spruce) some 8,15 Mill m3. Looking at these numbers it may seem, that in Finland we have potential to increase sawmill production.

But there has been a lot of changes in sawmill business, and use of sawn products both domestic and exported since year 2000. Domestic use for sawn products were 2,89 Mill m3 in 1991, 4,97 Mill m3 in 2000 and then being descendent being 3,60 Mill m3 in 2013. At the same time Finnish saw production has been descending from year 2000, lowest level can be found from year 2009, 8 Mill m3 (Peltola 2014).

3.1. Main competitors on sawn product exporting markets

During this period of time the main competitors to Finnish sawmilling in Europe, Sweden and Germany have been able to increase their production (picture 2). Increment in Swedish sawmilling is not remarkable, but they have been able to keep the production level steady. But increase in German production is conspicuous, from year 2000 average 15 Mill m3 to peak level in 2007 some 24 Mill m3 and then steadily over 20 Mill m3 annually (EOS 2014). When looking how Germany has succeed to taking this leap in production, we find various reasons. Comparing Germany, Finland and Sweden cooperative of political actions concerning of competitiveness is advantageous for Germany (Ministry of Employment and Economy 2013). Biggest advantage Germany is getting, if saw plant is located at commodious investment support area, and it is producing electricity. According to surety and certificate prices support for Germany in 2013 was twice as high in Finland. On the other hand support for Finland was double compared to Sweden. Meaning of sulfur directive is in practice negligible to German saw industry, due the capacity of production. For Sweden and Finland impact is coarsely 3,5-4 €/m3 (Ministry of Employment and Economy 2013). Sulfur directive will increase costs of export around 10 %, and debilitates aims for increase Finnish export.



PICTURE 2. Saw production between Finland, Sweden and Germany
(EOS European Organisation of the Sawmill Industry 2014).

3.2. Finnish cutting edge in timber production

Geographical location is one thing that we can´t have an impact, so Finland will always be in a need to tolerate high transport costs in point of view of exports. Finnish forestry has long traditions in forest management, and it has produced good quality wood for industry. We have also become in to a situation, where in Finland we have more wood to harvest that forest industry is using. In the 90s the thinning area needed to manage was executed only by one third roughly (Korpilahti 1997). In this decade thinning area has been increasing, and it is clear that pulp plant investments in coming years will affect more increasing. Potential for thinnings and increased amount of pulp food procurement is available in Finnish forests due to VMI10 (Metla 2006). Through good forestry we will have good quality saw logs also in future.

In the markets Finnish sawn timber is known of good quality concerning both raw material and sawn timber. Good silviculture and our northern climate seems to produce good quality timber Verkasalo, Hautamäki & Kilpeläinen 2012). Regardless of tree species the qualities like strength, stiffness, measure- and form stability and endurance of weather conditions are the most important qualities of timber. In wood products that remain visible, the visual quality is represented especially with Scots pine, but also Norway Spruce in some cases. In this study was found that especially stiff qualities could be found very much from sawn timber in Finland, if they could be separated confidently from gridlock of sawn goods in practical sorting, and due that have added value in constructing markets (Verkasalo et al. 2012).

Other stronghold among quality of raw material in Finnish saw production has been customer based production. Prevalent cut-to-length method in harvesting gives possibility to change dimensions in timber quickly concerning the needs of a customer, if certain measures are more needed (Asikainen, Leskinen, Pasanen, Väätäinen, Anttila & Tahvanainen 2009). Different qualities and dimensions can be done with reasonably good quality in forest and supplied to factory. At sawmills we have comprehensive assortments in dimensions and qualities to have good reputation as sawn product provider.

While competition is hardening at saw production export markets and possibilities for Finnish saw producers to affect either markets of basic quality sawn goods, or demand at domestic markets are diminutive, there has been various of discussion of improvement of industry (Mutanen & Viitanen 2015).

One theme is aim to utilize high quality raw material specially Scots Pine saw logs according to new producing concepts, where modern measurement- and optimization technologies allows distinctive sawing. Outcome should be high standard optimization of produced saw products and components, simultaneously decreasing amounts of low value saw products (Usenius, Heikkilä, Song, Fröblom & Usenius 2010).
Technical Research Centre of Finland LTD (VTT) made a study together with Finnish forest cluster companies, where they developed production system concept which in production may significantly improve competitiveness of sawmills. System is based on measurable data of timber in refinement chain and saving the data for use and management in different phases of value chain. Measurement is done only once, while now it is done in several phases in refinement chain. According to the data saw log is sorted to specific log class and sawed with specific optimal sawing draft (Usenius, Heikkilä, Usenius, Makkonen & Väätäinen 2014).

There have also been studies where aim was to predict board values from saw logs based on 3 D scanning and X-ray scanning (Nordmark & Oja 2004). In that study computed logs with tomography were sawed according to simulation, which gave product value for each log. Predicted models for product value were adapted using partial least squares regression and x-variables, derived from the properties of the logs and their original stems, measurable with a 3D log scanner and the X-ray LogScanner.

3.3. Anterior research from area of study

Completely same kind of study was not found from history. Study mentioned earlier, (Nordmark & Oja 2004) gave interesting point of views according to results of predicting board values from data of 3 D scanning and X-ray scanning with mathematical models, which were promising.

Another interesting study for background was (Piira, Kilpeläinen, Malinen, Wall &Verkasalo 2007). They studied measure- and distribution objective impacts for wood product accrual and sale values. In their study to the log yield and sale value mostly affected top the diameter of saw log, and impact was bigger with Norway Spruce than Scots pine. Special wood products increased sales values significantly. They also found out in the study, that for Scots pine lowering minimum length of log the yield was significantly lower. Impact of long measures of logs turned out to be minimal for yield and sales values. In 2007 they end up to conclusion, that distribution bucking influence to log yield and sale value of felling site over to value bucking needs extension studies.

According to Carl Lundahl (2007) there is obvious potential to improve log yield by evaluating logs as individuals in sorting and saw process rather than parts of big rash. He also end up to conclusion, that 3 D measurement gauge combined with online sawing simulation process procedure make it possible to increase sorting accuracy and volume of log yield, thus decreasing the demand for raw material. Those fully support the canvas of this study.

In previous studies according Herman Hakala (1992) the economic value in sawing process increased significantly by increasing the diameter of logs. Absolute difference between smallest diameter class 133-152 mm and the biggest 307-331 difference were 99,1 FIM/m3 (≈17,47 €/m3). He also found that impact of different revenues and costs to economical result of sawing process and product values with raw material costs were much bigger than other costs. Difference was so quantum that if need to increase value of sawmill it was possible only by decreasing raw material costs or increasing sawn product values.

4 MATERIAL AND METHODS

Material for this study consisted of 39 814 Scots Pine saw logs. They were harvested from UPM Kymmene`s own forests in 2014 and 2015. Material was divided to comparison material (19 315 pcs) and test material (20 499 pcs). Both materials consists of 7 different felling sites and for those felling sites has been calculated max. and min values to describe the average for volume, length and diameter of saw log and range (table 1).

TABLE 2. Average emblems for both comparison- and test materials

	Comparison material	Range Max-Min (comp.)	Test material	Range Max-Min (test)
Average volume/log (l)	180	*53*	188	*59*
Average length /log (cm)	476	*43*	487	*29*
Average volume/1 log (l)	222	*95*	228	*118*
Average volume/2 log (l)	166	*55*	172	*64*
Average volume/3 log (l)	132	*26*	137	*17*
Average top diameter/log (mm)	196	*25*	198	*25*

These felling sites are located in central Finland about circle of 100 km from Korkeakoski sawmill, so in this study can be assumed that the technical quality of wood is the same with both materials. Basic characteristics for the felling sites like forest types and calculatory diameters of logs can be found from below (table 3).

When comparing different felling sites, it is very common to use average diameter (cm) from breast height (1,3m) to compare different areas. In this study it was not possible since some of the files from harvester where deleted so following formula was used for describe the felling sites by diameter:

$$\sqrt{((\textit{Vol of log}/1000)/(\textit{Avg length of log}/100)/3{,}14)}*2000$$

When harvesting the test material, harvester was using customer based cutting matrix (Appendix 2). Material was harvested with four different harvesters and drivers. Variation with different harvesters and drivers may have influence to results, but it can be assumed that it is not significant. Drivers are experienced and bucking Scots Pine stems to logs according to quality is their daily base work.

TABLE 3. Forest types and average log volumes of felling sites

Comparison sites	*Forest type*	*Average volume of stem, (L)*	*Calculatory average diameter, (mm/log)*
1	9,6 ha MT, 2,5 ha VT	521	221
2	VT	310	199
3	15 ha MT, 8,5 VT	474	214
4	5,6 ha VT, 0,9 ha MT	593	230
5	MT	814	245
5 (sect.2)	MT	539	221
7	VT	485	204
8	8 ha MT, 8,2 CT	812	245
8 (sect.2)	8 ha MT	593	221
Test sites			
10	VT	583	231
11	8,9 ha VT	653	239
11 (sect.2)	2,5 ha OMT	619	228
13	MT	503	221
14	VT	576	230
15	18,8 ha VT, 4,5 ha CT	343	204
16	7,8 ha MT, 10,5 ha VT	413	209
16 (sect.2)	2,9 ha MT	406	206
18	2,9 ha CT	571	230

For comparing the matrix used daily bases for bucking logs to Korkeakoski sawmill can be found from Appendix 1. When looking the different matrixes it is good to note that even if matrix “guides” the harvester to do as long log pieces as possible the final quality control remains on the driver. This is the basic reason why certain lengths are bucked from stems even if they are not valued in matrix. Curve of the log, boy branch, scar or rotten part may be the reasons to buck the log differently than harvester would “think”. Additionally the division defined in matrix advices the harvester to make certain lengths by the need of the factory. Emphasis to these lengths can be seen by higher values in matrix. In addition UPM provides the division matrix for the harvester contractor, which guides the bucking of stems in forest.

Optimization of bucking and different timber assortments is one of the main parts of modern harvester and computing system. Bucking to timber assortments is guided by so called value bucking in which the main purpose is to optimize the value of single stem. Optimization computing is based on these division- and value matrixes, which are two dimensioned tables. Division matrix is based on demand of a mill where can be defined the combination of certain diameters and lengths by need of the mill for these assortments. Value matrix specifies the combination of lengths and diameters and their value in relation of different combinations and other timber assortments of tree species (Uusitalo 2003).

UPM don´t provide the value matrix to the harvester contractors. They are formulated by bucking programs of forest machine manufactures. In basic they are created so that every cell which has a value >1 gets the value from division matrix by same cell as “basic value relation”. As harvesting moves on the machine computes every length-diameter combination in basis of amounts of these combinations, are there more or less of them than there is objective. Usually the bucking program also rises the value of thinnest diameters in addition to assure the bucking of logs close to minimum diameter.

It is very common in Finland that combination of division- and value matrix is used in harvesting. The machine is aiming to division matrix but taking care that stems are bucked to the most valuable assortments determined according to accepted deviation. Using this combination and automatic bucking the driver needs to take care that lengths provided by machine are overtaken if quality of log don’t fulfill the quality claim of the mill.

In this study the harvester driver was guided to do the first log as long as possible, no matter how the harvester would be willing to buck the stem. So the driver was overtaking the bucking of first log no matter how the forest machine were willing to optimize the stem and all other log parts.

Original material was more extensive, but it needed to be moderated, so that average emblem for each group was comparable. Scots Pine logs which were harvested to be part of test material had specific code (513) in UPM logistics, so they were able to transport in own bundles to Korkeakoski. Comparison material were harvested and transported according to normal procedures to the mill. If needed in cutting, log part was allowed to move to the pulp wood part in this study. Cutting matrix was converted so that all values of wood products except A-quality bottom log were closer to pulp wood values. Typically machine manufacturers own programs and cutting matrix´s automatically rises values of wood products on lowest diameter class, so that cutting to log limit is ensured.

At the mill logs went through process normally, and data for analyzing the logs for this study were collected from log gauge measuring device and from X-ray gauge. Collected parameters were:

VM_VO_LAATU	(acceptance quality)
VM_TUKIN_PITUUS	(log length)
VM_VO_LATVAHALK	(top diameter)
VM_KT_TILAVUUS	(log volume)
VM_KARTIOKKUUS	(taper of log)
T_LOG_POSITION	(log position in stem)
T_C49_KNOT_CLUSTER_COUNT_2	(branch groups in log/pcs)
T_C50_KNOT_CLUSTER_DIST_AVG_2	(average distance of branch groups)
T_C85_OKS_PINTAPUUPITUUS	(plane wood area without branches)
T_C90	(volume of branches in log (%))
T_C126	(dead branch index, bigger number=dead branches, 0 = all living branches)
T_C152	(distance of dead branch area from bottom end, mm)

(Parameters starting VM_ are from log measuring device, and starting with T_ are from X-ray device).

All the material was gathered to xls. file, and data was analyzed in Excel- pivot table. That was reasonably good tool managing this data. It was possible to filter data in Excel-pivot table by every needed combination according to diameter, length, and parameters from log gauge device and X-ray device.

At UPM Korkeakoski sawmill every log goes through X-ray device for sorting the logs into acceptance qualities. This means that by daily base process it is possible to collect basic data from logs which are:

- branch mass volume
- branch group pieces
- branch group count
- acceptance qualities
- taper of logs
- dead branch index

The objective in this study was to find out with these emblems that what kind of qualitative changes happened in sawn logs which were harvested using the test cutting matrix. In results various different ratios was formed between these emblems and log dimensions to find out the differences with log pieces made according to different cutting matrixes.

For this study separately from UPM Korkeakoski´s X-ray gauge was performed two parameters:

3. Dry branch part in top log bottom end
4. Plane wood area without branches in second log

From these parameters log length, top diameter and log volume are general and basic information when analyzing logs. According to means of them is made general picture of material, and they have been used also as filters when calculating results. Acceptance quality has been by one self a compiled result from this data, when comparing different cutting matrixes how they divide in different qualitative classes. Tapering of logs comes out from x-ray gauge without any particular action, so that assigned to one of presented diagram. Log position is useful information through all results, and it is also used as filter when dividing the data in Excel. C49 and C90 parameters is used together making ratio between branch group pieces/log and volume of branches in log. Parameters C85, C126 and C152 are ordered from x-ray gauge specially for this study to find out possible changes in plane wood area in second log, what is amount of dead branches and distance of dead branch area from bottom end of third log.

4.1. Qualitative research method

In a qualitative research method, information is examined numerically. The examined phenomena are accurate and can be described by numbers (Vilkka H, 2015, 101). If the results needed to be confirmed or become more reliable, the qualitative and quantitative research method can also be used side by side (Kananen 2008, 10-11). The outlook of a research report is usually clear: introduction, material and methods, results and discussion.

Research should always have a goal. The purpose of qualitative research is to either explain, describe, map or predict things close to people or phenomena in nature. The purpose of this work was to explain how, for example, the shortening or increased amount of dry of top log branches was related to the extension of the bottom log. Qualitative research is intended to present causal relationships between phenomena (Vilkka H, 2005, 23).

The main objective of the explanatory study is to find the law of subordination that explains the causal relationships found, for example how much dry branches are transferred to the middle log if the bottom log is extended for 3 dm. Presentations are generally distributions, averages and standard deviations (Vilkka H 2005, 50).

In quantitative studies, it is customary for a researcher to set a research problem that is set as a hypothesis. Setting the hypothesis is characterized by explanatory and comparative qualitative studies. The hypothesis tells in advance what is expected from results. The nature of this work was a developmental task designed to create causal relationships with the extension of the bottom log and the changes in middle and top log. The purpose was also to gather more information on these changes. The company had not previously tried a corresponding logging matrix, so a clear numerical hypothesis could not be presented.

The sample is the method by which the sample is taken from the population. The sample consists of observation units. The observation unit, the statistical unit, is the one for which information is to be obtained. The sample is part of the research target group, that is, a population that can provide an overall picture of the target group. The sample represents the population in which conclusions are to be drawn (Walliman 2005, 276-277). In this work the total sampling was used, whereby all observation units belonging to the population were measured. The basic set consisted of two sets timber bucked with different matrix.

4.2. Reliable of the study

The reliable of a research means that it does not yield random results. Reliability therefore estimates the persistence of the results from one measurement to another. The study is reliable and accurate when repeated measurements produce the same result regardless of the researcher. (Vilkka 2015, 194).

Issues related to the reliability of this work were monitored during work by checking the calculation formulas manually which were entered into Excel. This could eliminate the occurrence of random error. Measurements of base units, ie trees, were unambiguous for measurements of lengths and pieces. These were difficult to measure in a variety of ways and thus provide correlations between the responses that are typical of survey research, for example. It can be assumed that in the repeated measurement the result would be the same.

4.3. Validity of the study

When looking at the validity of the study it is evaluated how the work was done to measure what was to be measured. At the planning stage of the work it was decided that the hypothesis was started to open with the selected methods. It was found that the branchless part from the bottom of middle log describes both the properties of the extended bottom log and the middle log. The dry branch area measured from the bottom of the top log was appropriate in monitoring the effects on the characteristics of the branch limits in top logs.

4.4. Overall reliability of the study

In this work, the whole population was measured, and the sample depicts the population. To prevent random errors, data analysis has been checked for each computation column in Excel. Measuring logs on the saw is accurate and these measurements do not have any significance for the results. Measuring is mechanical, so occasional mistakes would have been possible, but it would have been revealed in the charts as illogical. Methods and measurements can be considered successful because the sample is inclusive and there are few random errors.

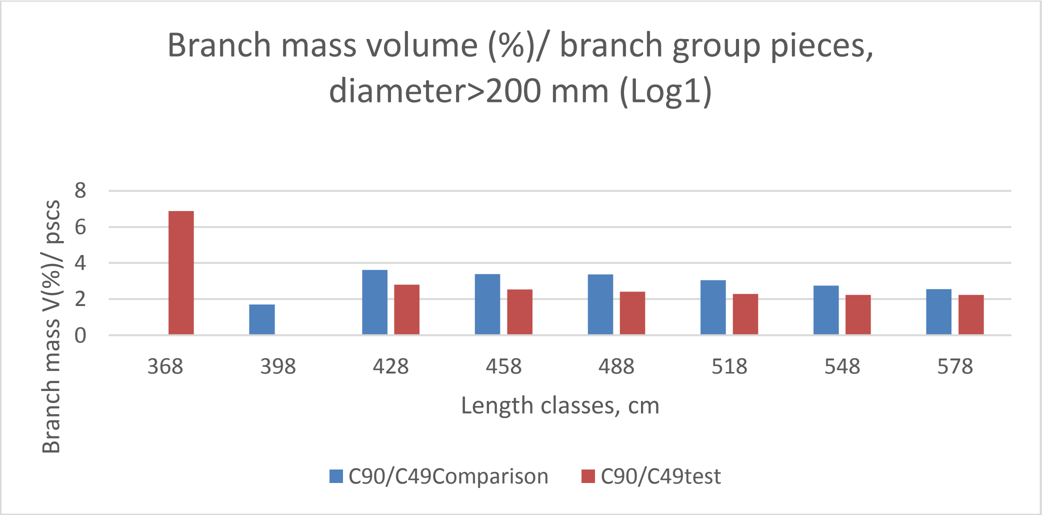
5 RESULTS

5.1. First log

All the mainline emblems for analysis of third log are in table 4 below. Even if the aim in this study was maximize the first log of stem, the parameters from X-ray gauge for examination of logs are for second and third log. Parameter of branch mass volume is eventual in some level to analyze first log. Index is branch mass volume (%) of log volume. In picture 3 is pointed ratio of branch mass volume and number of branch groups, first log and diameter over 200 mm.

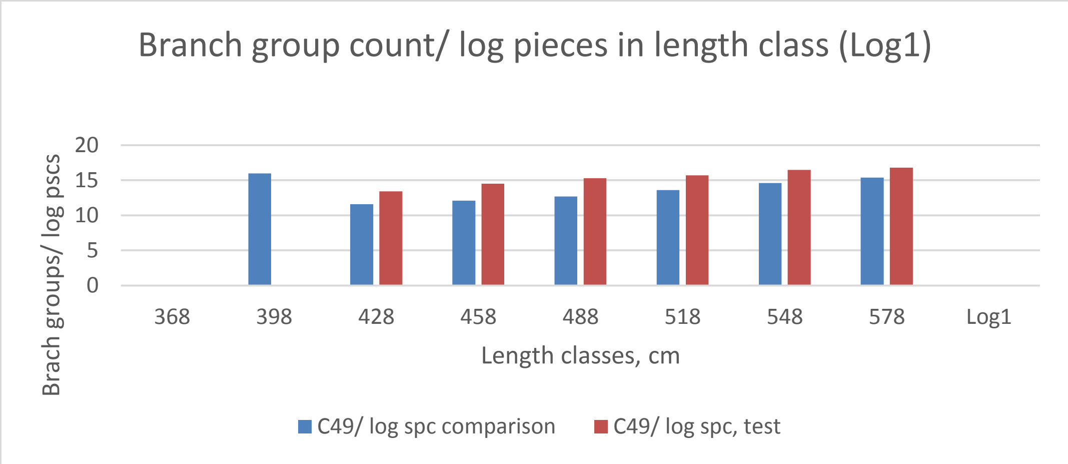
TABLE 4. Average emblem of first log.

	Comparison material	Test material
Number of logs	7120	8380
Volume (l)	222	228
Length (cm)	475	496
(Knot volume/log volume)/log pieces	19	16
Branch group count/log pieces (C-49)	12	17



PICTURE 3. branch mass volume/ branch group pieces

Value of ratio is linear being slightly smaller with test matrix, but that is due to average volume being higher in test material overall. This logic shows, when log pieces are placed to divider in picture 4. In picture is counted ratio for number of branch groups and log pieces in length class. There are more pieces in test material in position of first log, and those pieces are longer. As a result from that there seems to be slightly more branch group pieces in test material according to ratio of log pieces.



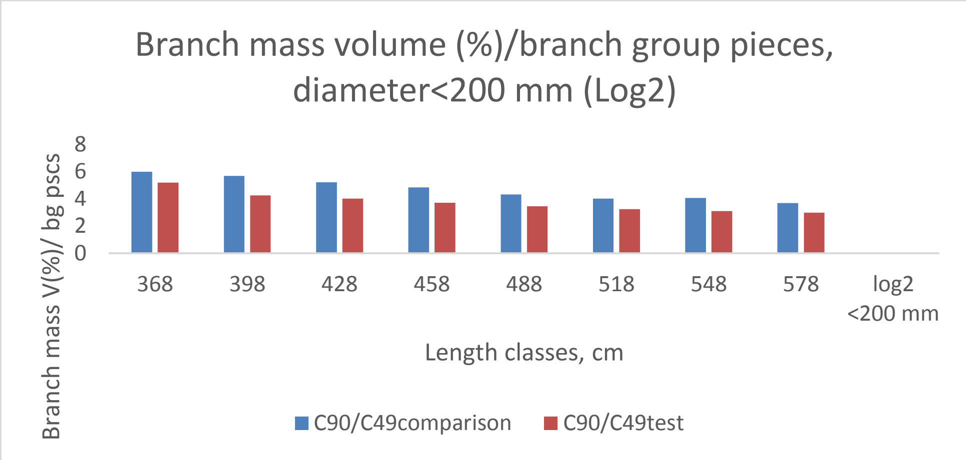
PICTURE 4. branch group count/ log pieces in length class

5.2. Second log

All the mainline emblems for analysis of third log are in table 5 below. In second lo results branch mass volume divided with number of branch group pieces is slightly less with test material than comparison material, when top diameter was <200 mm (picture 5). In this group there were 5331 pieces of logs in comparison material, with average volume 131 liter and average length 468 cm. With test material same emblem were 4631 pieces, average volume 134 liter and length 484 cm.

TABLE 5. Average emblem of second log.

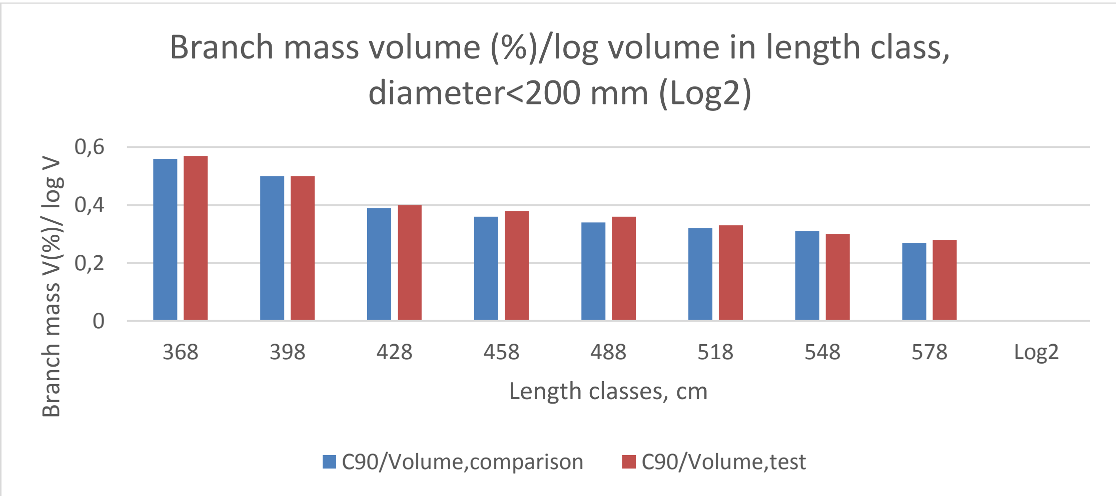
	Comparison material	Test material
Number of logs	8614	7959
Volume (l)	166	172
Length (cm)	482	484
(Knot volume/log volume)/log pieces	28	28
Branch group count/log pieces (C-49)	10	13



PICTURE 5. Branch mass volume (%)/ branch group pieces, diameter of logs <200 mm

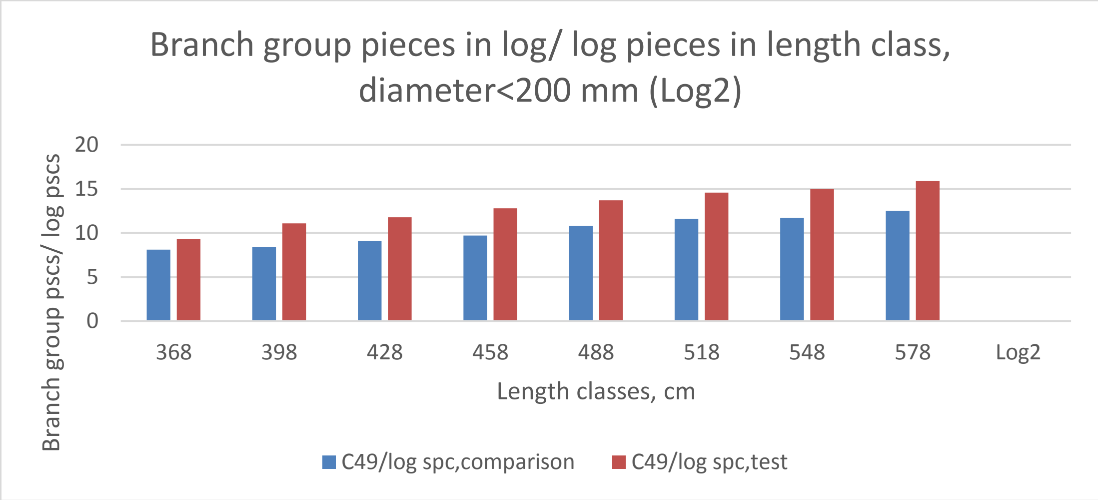
When looking the emblem we see, that there is difference in average length 16 cm, so in second log that means more branch groups. In this ratio branch group count decreases the value. Also the bigger average volume of log decreases the volume of branch mass, and that leads to smaller value in this ratio.

If taking to divider instead of branch group species the log volume, differential is irrelevant in this ratio (picture 6).



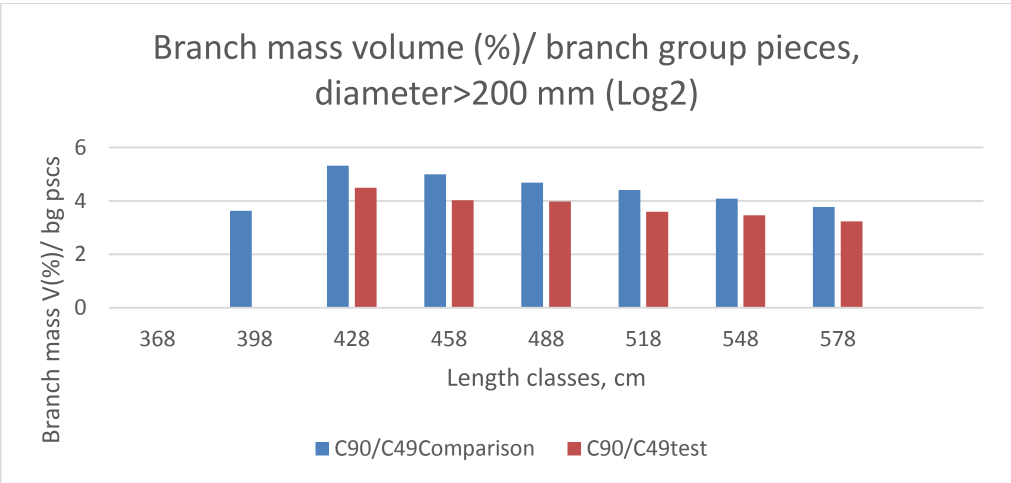
PICTURE 6. Branch mass volume (%)/ log volume in length class, diameter <200mm

If we survey the ratio between branch group pieces and log pieces, the linear result can be found (picture 7). Smaller amount in pieces and longer logs by average in test material are increasing the value of this ratio.



PICTURE 7. Branch group pieces in log/ log pieces in length class, diameter <200 mm

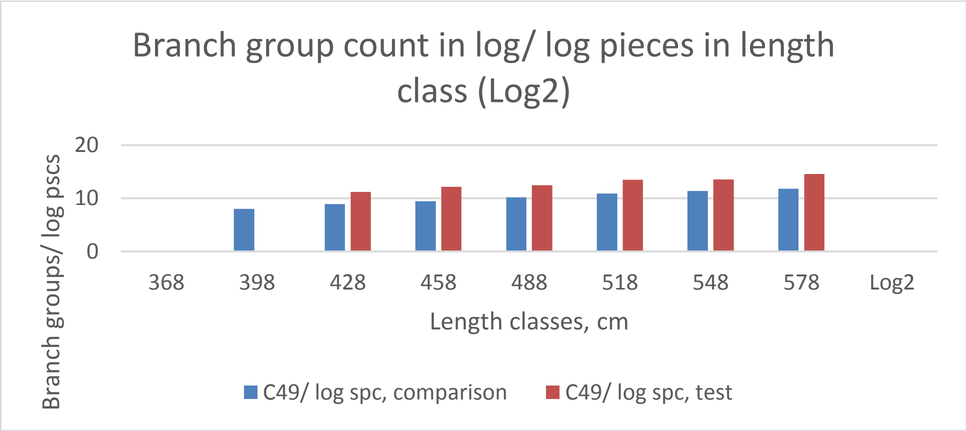
With survey of bigger logs in position 2 (top diameter >200 mm) the materials with comparison and test are almost identic by average. Amount of log pieces are 3196 in comparison material, average volume 224 liter and average length 484 cm. In test material numbers are: 3242 pieces, volume 225 liter and length 484 cm. Number of branch groups average/ log are 10 pieces in comparison material and 13 pieces in test material. Bigger divider by test material gives slightly smaller value to the ratio (picture 8).



Picture 8. Branch mass volume (%)/ branch group pieces, diameter >200 mm.

When looking logs of all diameters together in log position 2 the ratio between branch group pieces and log pieces is shown in picture 9. Number of branch groups/ log average in comparison material is 9, and in test material 13. Result is logic, because there were more log pieces made in longer lengths according to test matrix, especially in dimensions

518 cm and 578 cm. Also total amount of log pieces in this position according to test material is smaller 7959 pieces



PICTURE 9. Branch group count in log/ log pieces in length class (Log position2, all diameters)

compared to 8614 pieces in comparison material. Together this emblem lead higher value in this ratio.

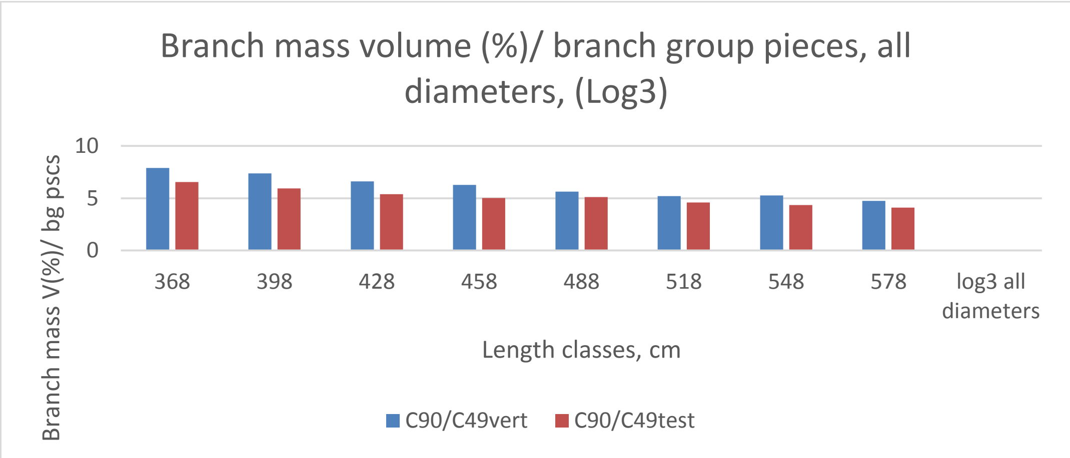
5.3. Third log

All the mainline emblems for analysis of third log are in table 6 below. Total number of logs was bigger in this log position. Average values are quite even excluding the length, which was 49 cm bigger in test material. According to that it is obvious that branch group count is 4 pieces more/ log in average.

TABLE 6. Average emblem of third log.

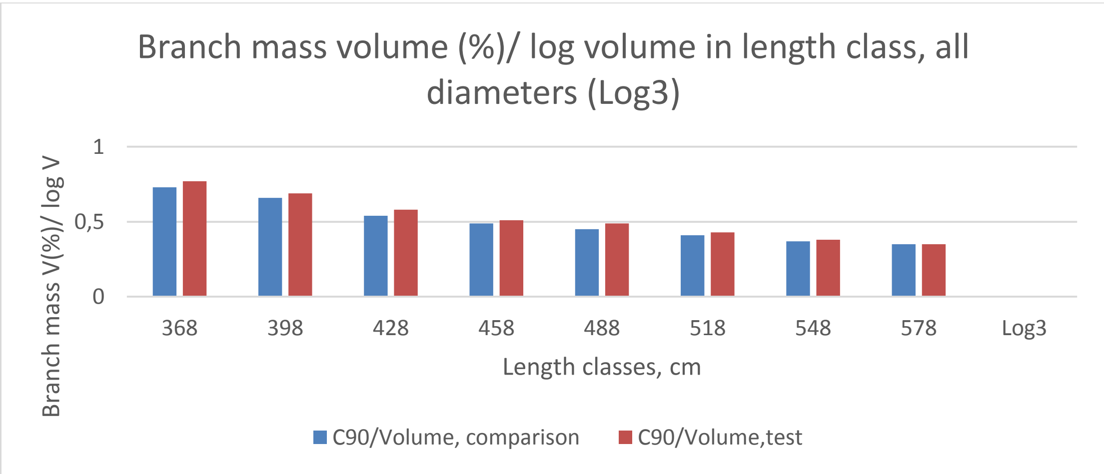
	Comparison material	Test material
Number of logs	3550	4160
Volume (l)	132	137
Length (cm)	462	475
(Knot volume/log volume)/log pieces	59	67
Branch group count/log pieces (C-49)	10	14

The ratio between branch mass volume and branch group pieces is little lower with test material (picture 10). When monitoring this result, it is good to note the emblem with test matrix- higher branch mass volume and branch group pieces.



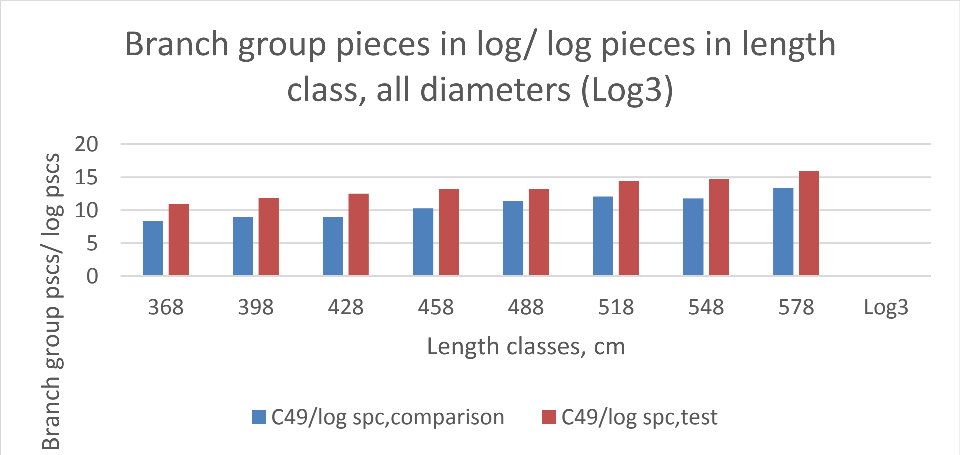
PICTURE 10. Branch mass volume (%)/ branch group pieces in all diameters of log 3

Ratio between branch mass volume and log volume turns out to slightly higher with test material. Relation is getting more even with the longest measures 548 cm and 578 cm (picture 11). That happens due to branch mass volume decreases to level of comparison material with longer dimensions, average volume is almost the same with both.



PICTURE 11. Branch mass volume/ log volume in length class, log 3

In picture 12 is shown ratio between branch group pieces and log pieces in log position 3. It shows clearly linear difference with number of branch groups, being higher in test material. Difference is about three groups more in one log.



PICTURE 12. Branch group pieces in log/ log pieces, log 3.

5.4. Acceptance qualities

As pointed out earlier, the differences in results of this study shows up by bucked lengths into certain length classes. And according to cutting matrixes (Appendix 2) can be seen, that mostly long measures are wanted. For A- Quality log emphasis is only to make the long as possible. For other saw log length 518 (made from position 1 or 2) is most wanted, lengths 548 and 578 are well valued. 488 cm log is guided to be shorted measure, where measures 458 and 428 assists bucking the stem. Fresh branch log is objectively bucked to measures 548 and 488 cm, 428 is valued for lower and 398 assists.

On the results significant acceptance qualities are 10, 20, 30 and 40, so presentation is defined in to them. As described briefly process of sorting logs in Korkeakoski sawmill is following. Person who is qualifying logs presses log into crock according to rotten, scar or any else matter of bad quality (Appendix 3). That selection is not changed any more in any phase of process. Accepted acceptance qualities are formed by log measuring gauge and x- ray device.

Position 1 (first log) is either A- or B- bottom log. A bottom log is >200 mm in top diameter, and it has certain level of branches (Appendix 4). B- bottom log is < 200 mm in top diameter, or it has too many branches even if the diameter is >200 mm. Position 2 (second log) is middle log, or if is equal with branch level it can be B- bottom log. Position 3 (third log) is top log with fresh branches. Diameter is <180 mm.

On the results the qualities are presented as follows:

10 A quality bottom log

20 Other bottom log

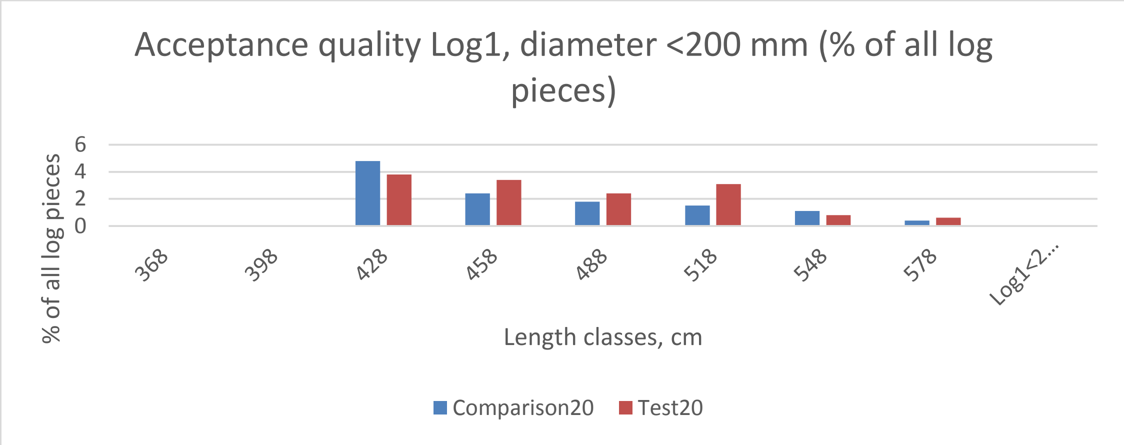
30 Middle (2) log

40 Top (3) log

Log pieces made of first log are shown in picture 13. On shorter measures 428 cm and 458 cm are rather identic according to bottom log (10) pieces made with these two different matrix. In both measure classes there are 0,4 percentage points more logs with test matrix. With other bottom log (20) amounts are double with comparison matrix compared to test matrix on sort measure. On longer measures further on clearly larger amount has been made of first log with test matrix. Most distinct difference comes with measure 518, where is 2,9 percentage point more logs of all log pieces in bottom log (10). Also from these longest measures amount of other bottom log (20) amount is slightly bigger wit test matrix.

PICTURE 13. Acceptance quality, diameter >200 mm (% of all logs)

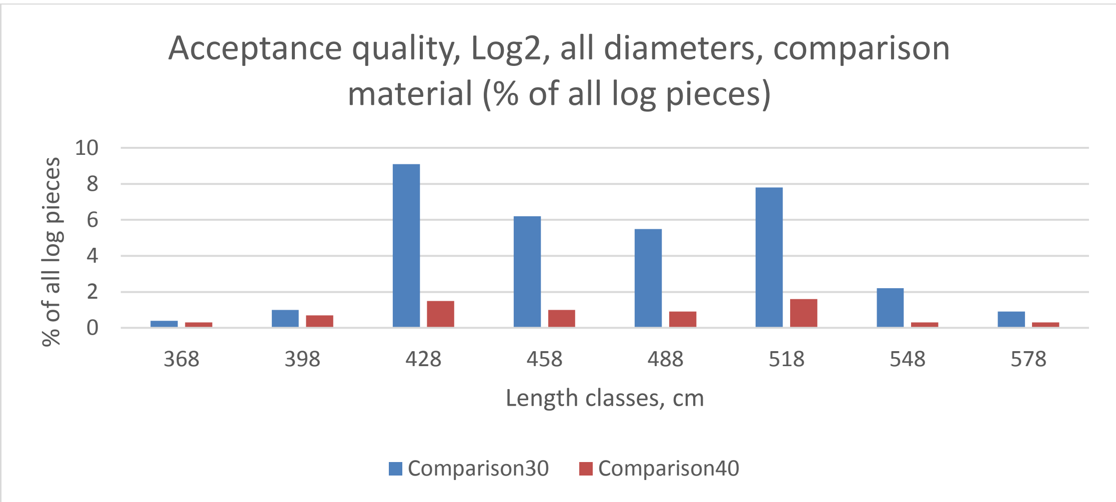
Other bottom logs (20) made of first log are represented in picture 14. On short measure 428 cm distinctly larger amount is found with comparison matrix. In the middle length classes 458, 488 and 518 cm larger amounts made according to test matrix, being roughly 1,5 percentage bigger with measure 518 cm. On longest measures 548 and 578 cm amounts are roughly the same.



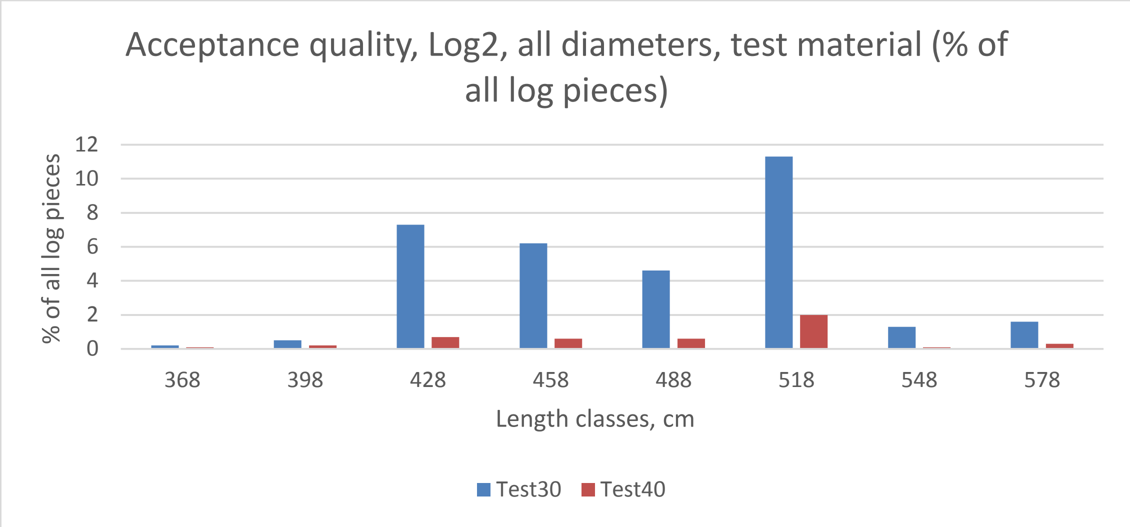
PICTURE 14. Acceptance quality, Log1, diameter <200 mm (% of all log pieces)

Pieces made of second log into comparison material are represented in picture 15. These log pieces are mainly middle logs (30) with dry branches. Small part of stems have been that small, that also some top logs (40) has been made to this log position. Pieces divide distinctly to length classes 428, 458, 488 and 518 cm. What can be marked, is that biggest amount of logs is found from short length class 428 cm. Total amount of log pieces in this position was 9134 pieces.

In picture 16 has presented logs made with test matrix into this log position. Polarization to length classes is the same as in comparison material. Very few pieces in shortest and longest classes. Still there is significant difference with test material log pieces dividing to wanted class.



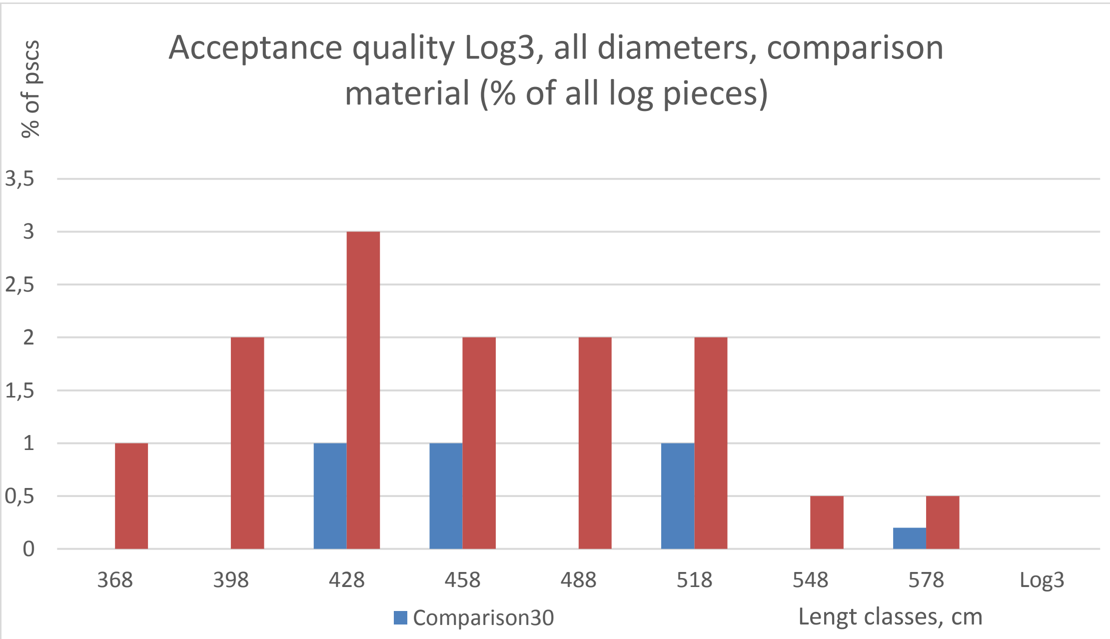
PICTURE 15. Acceptance quality, Log2, all diameters, comparison material (% of all log pieces)



PICTURE 16. Acceptance quality, Log2, all diameters, test material (% of all log pieces)

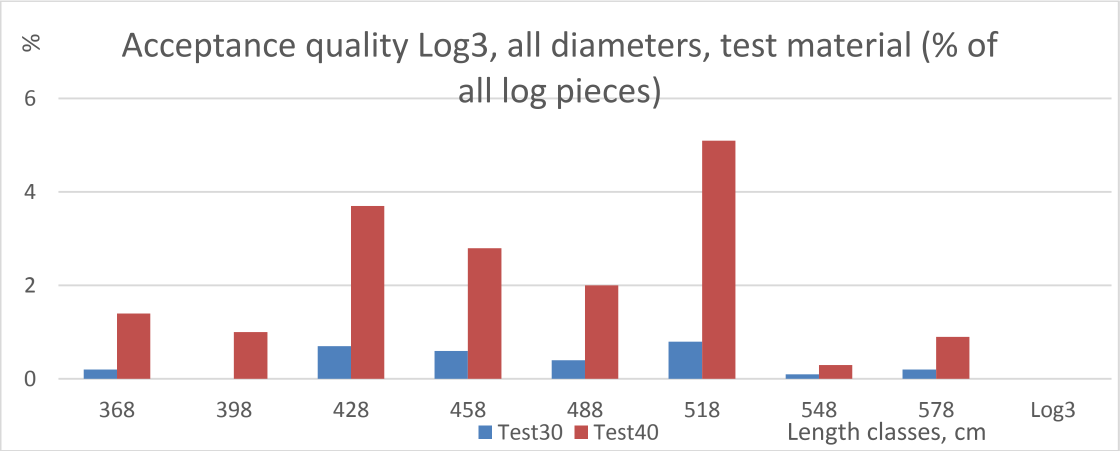
in 518 cm. With both materials there are few pieces in longest measures 548 and 578 cm. Slightly more with comparison matrix in 548 and other vise in length 578 cm. Total amount of log pieces in this position was 7959 pieces.

In log position 3 division of logs is more extensive with comparison material (Picture 17). Biggest concentration is found from length class 428 cm, where are 3 % of all log pieces. Otherwise the logs are coalesced evenly to classes from 398 to 518 cm. Total amount of logs in this position was 3550 pieces.



Picture 17. Acceptance quality, all diameters, comparison material

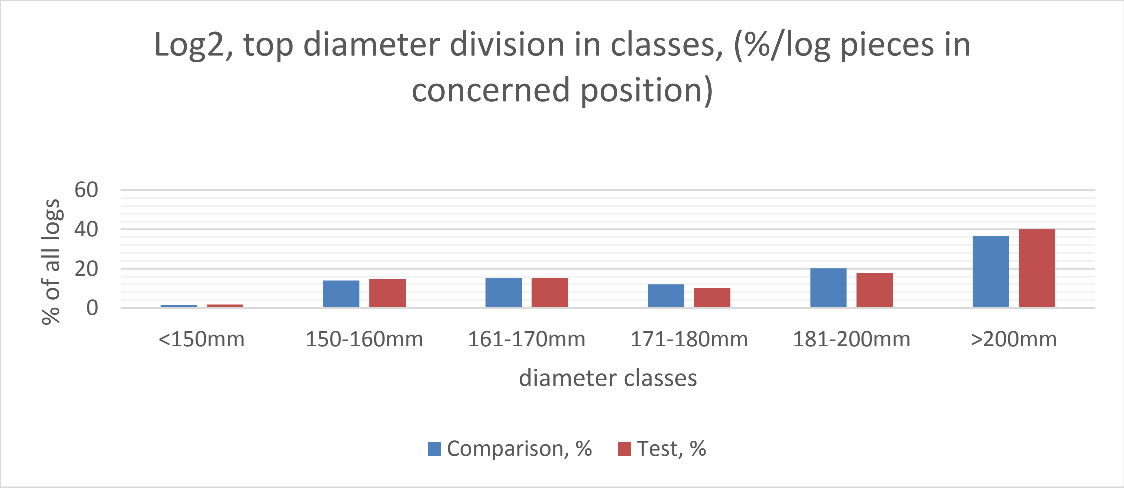
With total amount of 4160 logs in position 3, test material results are found in picture 18. There are slightly more pieces in shortest class 368 cm (0,4 percentage points). In class 398 less pieces than in comparison material, more pieces in 428 and 458 cm. Same amount in class 488 cm, but clear concentration in class 518 cm, where was 3,1 percentage points more pieces with test material.



PICTURE 18. Acceptance quality, all diameters, test material

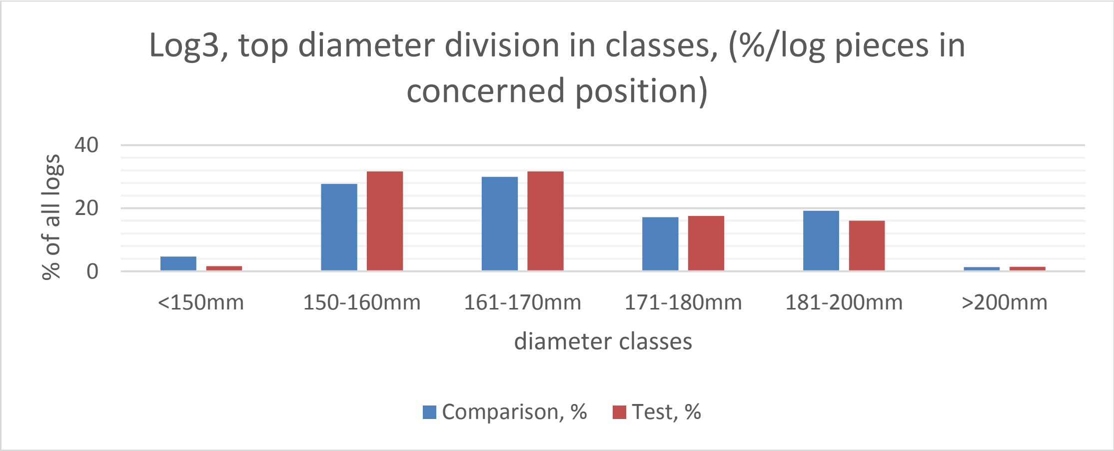
5.5. Diameter divisions of logs 2 and 3

In paragraph above was presented the division of log pieces in different log positions. In the log position 3 was appearing significant difference in log division according to their length. In this paragraph is aim to study, if there is variety in division according to top diameter of logs. In picture 19 is presented the division of second logs according to diameter to six different diameter classes. Results are reminiscent in this position. With both matrixes there are roughly the same amount of logs in diameter class < 150 mm. In biggest class > 200 mm there are 3,3 percentage points more logs in test material.



Picture 19. diameter division, % of log pieces in concerned position 2

Log position 3 results are in picture 20. In small diameter < 150 mm was significantly more pieces in comparison material, difference was 3,1 percentage points. In the classes 150-160 mm and 161-170 mm more pieces were done with test matrix. The result is concerning when



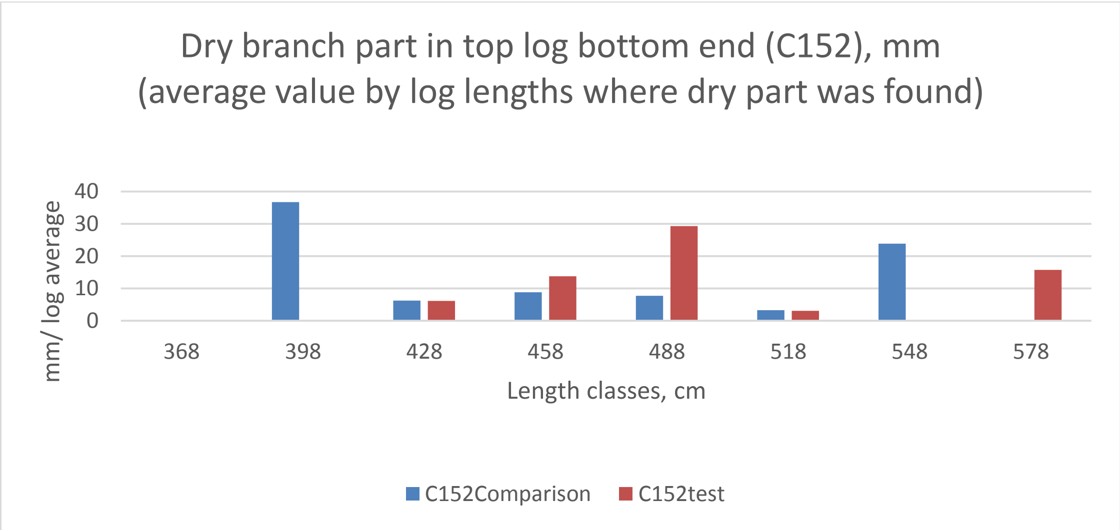
PICTURE 20. diameter division, % of log pieces in concerned position 3

knowing the objective with test matrix to make longer and thicker log pieces (Appendix 2). Same matter is being reflected with bigger class 181-200 mm, where also slightly more pieces made with comparison matrix.

5.6. Dry branch part in third log

This indicator dry branch in top log bottom end (C152) and following plane wood area without branches (C85) were ordered from Korkeakoski sawmill x-ray gauge for this study. In picture 21 is presented dry branch parts in log position 3. At first is good to mark, that this indicator shows very small amounts of dry branch part of log 2 proceeding to log part 3. Highest value is found from comparison material length class 398 cm, roughly 37 mm/ log piece. Significant peak from picture can be also found from length class 488 cm, from test material value being around 30 mm/ log in this position.

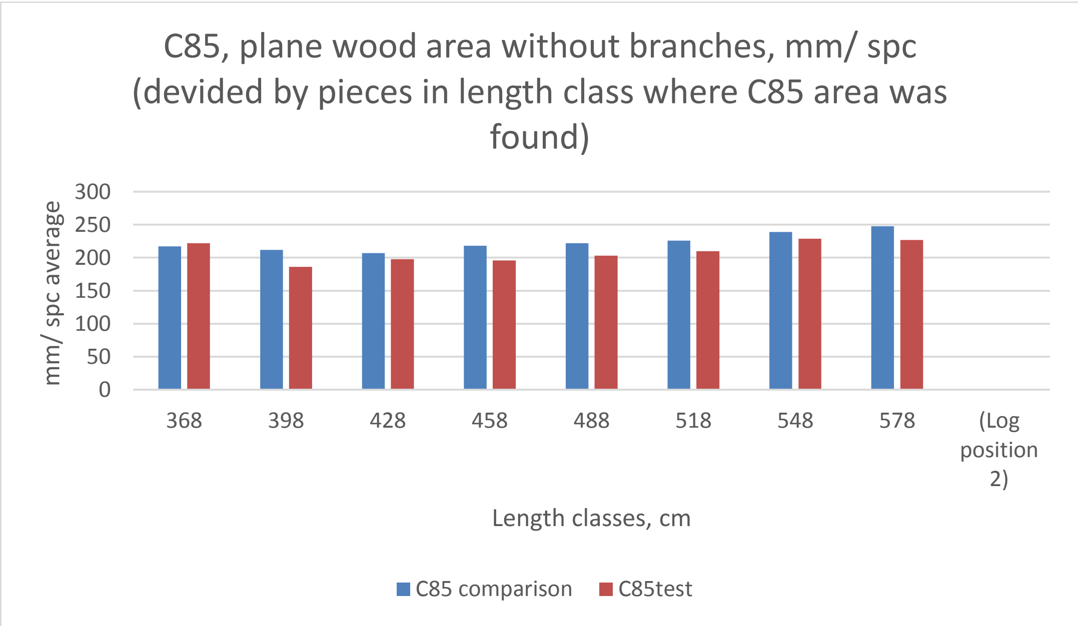
It is striking that a clearly distinct difference is created in one length class. The same observation can be found in the comparison material length classes 398 cm and 548 cm. 398 cm is an additional length that is made by hand drive, so it may be that the log section has been "running out", so that the driver has wanted to buck off the top log, as a result of the fact that about 30 mm dry branch area has moved to the bottom of top log. Also the lengths 488 cm and 548 cm are long top logs, so it explains the dry branch area slip. It is possible that bucking with a certain length of stems have not matched the external branch limits of the trunk and there is a small but still measurable difference. The material of this work deals with a large sum, and it is not possible to obtain bucking data for individual stems.



PICTURE 21. dry branch part in top log, mm/ log average

5.7. Plane wood area without branches in second log

This indicator points out, how much plane wood from first log was proceed from first log to middle (2 position) log. The results shows plane wood passing roughly 200 mm/ log average, and it shows very systematic this value for every length class (picture 22). There was no significant difference found in this study, very small contention in class 368 cm. Then in longer classes around 20 mm/ log smaller values with test material.

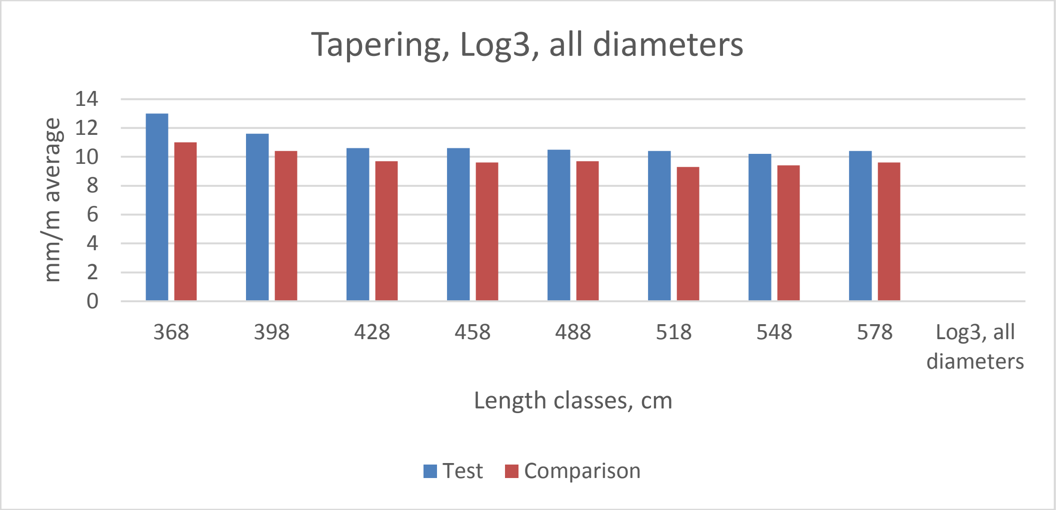


PICTURE 22. plane wood area without branches in second log, mm/ log piece

5.8. Tapering of logs

Tapering of logs is counted by data from x-ray gauge. It is a value calculated 3/4 length of log from top towards bottom end. Unit is mm/m. Results in this paragraph are presented according to this value mm/m divided by count of logs.

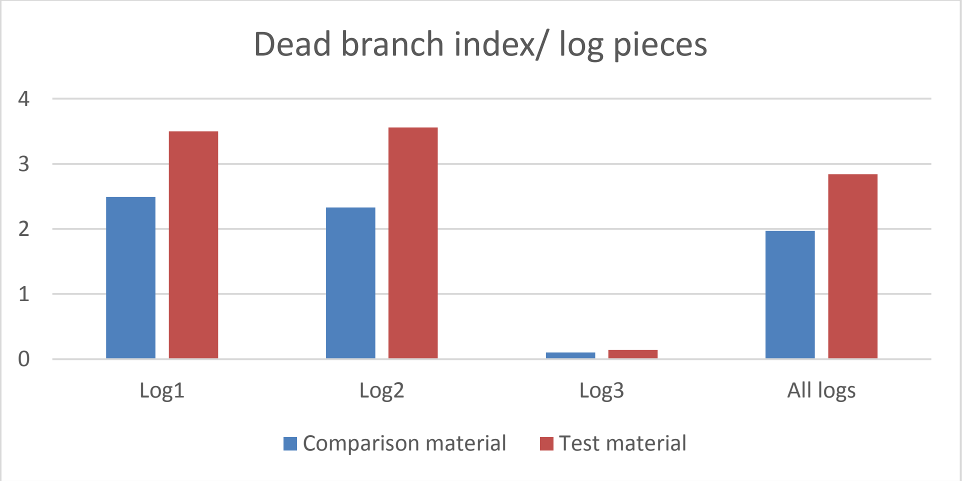
In this study was systematically appreciable difference in taper of logs. The difference between two materials were around 8 % average, being at highest in log position 3, average 10% (picture 23) . In this log position there were difference in average length, when comparison material logs were 463 cm and test material logs 475 cm.



PICTURE 23. Taper of logs, Position 3, all diameters

5.9. Dead branch index

This index means that what kind of branches can be found from a log. This is just an index (C126), no measure unit in it. The bigger is index, it means more dry branches in saw log. Value zero means, that all branches are fresh. Results here are presented with ratio of index and log pieces. Distinct observation from result is index of third log with both material. This is the log part where dead branches are not wanted, and results are good with both materials. Fractionally higher values were found from test material. (picture 24).



PICTURE 24. Dead branch index divided with log pieces

6 DISCUSSION

The purpose of this study was to find out what kind of qualitative changes take place with Scots Pine saw logs when they were bucked with a customer based cutting matrix. Among these qualitative changes it was essential to research the divisions of different lengths and average volumes of logs between these matrixes. The saw logs made with customer based matrix were slightly bigger by average volume, but significantly bigger by length in average and in most valuable dimensions. Results of increased average volumes and lengths of saw logs in this study supports the findings Herman Hakala (1992, s.23).

In this study, no significant qualitative changes between test and comparison materials were found. Technical values were described with various ratios based on branch groups and their volumes. Still, it is good to take notice that the quality of saw logs did not improve with this matrix. Conversely, they were fractionally worse by studied qualitative emblem, but not that big that they would have quantifiable impact on the sawing process and end products.

It is necessary to follow the natural branch limits of Scotts Pine when bucking the stem. Otherwise the end product will not match the requested quality. The observation that the quality did not change with the cutting matrix used in the experiment supports the theory (Hakkila et al., 1972). It is known that in the southern Finnish Scotts Pine forests, the area of the branchless area of the bottom log ends at an average of 4.1 meters with a deviation of 2-3 meters (Hakkila et al., 1972). Consequently, the cutting matrix of the experiment should not be used even in the average felling sites because there is no possibility to extend the bottom log. It would be important for the forest machine driver of to identify the sites where customer based matrix can be used.

In this study fractionally bigger values in tapering were found with logs made by test matrix. The results seems logical, when knowing the tendency of test matrix to make longer and thicker logs. In UPM Korkeakoski sawmill, and definitely in many other sawmills strongly tapering logs are “over inched”, where a little roundness is allowed in the top part of the log. In so doing it is possible to get more bigger and high valued sawn products in average. In Korkeakoski sawmill this kind of values in tapering does not cause any quantifiable meaning in sawing process.

Interesting observation was found from X-ray parameter plane wood area without branches in second log. When comparing both materials slightly better result was found with logs made by test matrix, when roughly 20 mm/ log average less plane wood area was passing to the middle log. Even if the first log was made as long as possible with test matrix there was still roughly 220 mm of plain wood area passed to the middle log. Viewing only the results by X-ray device there seems to be potential to make the first logs even longer. In that scenario one must remember the other qualitative factors of saw log like curves.
According to results of this study, no significant qualitative differences in saw logs made by different matrixes were found. That is obviously an implication that logs are bucked passably by comparison matrix matrixes used in daily bases, and forest machine drivers are making good work with them. Clearly slight change in bucking does not affect the quality of timber. Major impacts of using test matrix in this study were found in accrual of certain dimensions and measures which were more valuable to Korkeakoski sawmill. There was significant increase with valuable longer lengths, for instance 518 cm log pieces.

When considering future research further studies should be carried out on determining log qualities with x-ray were the directive parameters could be e.g. log shape and location of branches. Also with technical capacity of present time would be reasonable to develop methods to collect data from forest and provide the data to the sawmill. Now forest machines are collecting data from stems, but that is not used in sawmilling. In future we are likely to have 3D models of trees from harvested forest site before logs are at the mill, which makes qualification and sorting of logs easier (Nordmark & Oja 2004). For purchasing raw wood it would be valuable to have e.g. mathematical 3D model made of forest to be cut. Models done with 3D devices on forest machine during thinning are already technically possible . In that case the buyer would have distinct outlook of quality of trees under purchase. Presumably the quality of raw wood will not improve in future, but forest industry is willing to pay from raw wood based on quality rather than cubic meters.

In future area of wood supply it would be consistent to study wood pricing based on quality. It is obvious that in future forest industry will buy rather quality than cubic meters. It may mean price setting models like whole stem-, quality based- and dimension pricing for raw wood (Haring 2015.) By Malinen, Wall, Kilpeläinen and Verkasalo

(2011) there has been various implementations from this area since 1990. None of them have become stabled into long term use.

In the future additional studies from this area could be analyzing the economics of sawing process and values of end products by saw logs made with this matrix. By Malinen, Verkasalo, Wall, Kilpeläinen and Verkasalo (2011) use value of timber is defined by timber assortments quantitative and qualitative suitability to production. This may mean that maximization of timber assortments with highest sales values can decrease the use value of the yield.

In this study the detected observation of increased log volume has significance for UPM Korkeakoski sawmill. That is one of the basic factors for sawmill to have added value to the sawing process. According to the results of the study there are no qualitative reasons for not bucking logs to the mill using this kind of test matrix. If the economic studies from this area are conducted in future and the results are somewhat promising it would be reasonable to start forest political discussion concerning wood pricing and log dimensions.

As a final remark it can be said that the work was worth doing. According to the results, the traditional bucking of Scotts Pine stems can be changed to customer based and this can be accomplished without significant degradation of log quality. According to customer needs, suitable dimensions can be increased considerably while maintaining quality as desired at the same time. In the case of Scotts Pine, it is important to note that the outer branch limits will eventually define cutting points. In the future, it would be good to carry out an economic study to determine the impact of the customer based bucking on the value of end products. In addition, quality and size pricing should be developed in the purchase of wood, so that customer based bucking could be possible in practice.

SOURCES

Asikainen, A., Leskinen, L., Pasanen, K., Väätäinen, K., Anttila, P. & Tahvanainen, T. Metsäkonesektorin nykytila ja tulevaisuus 2009. Työraportti Metla.

Dems A., Rousseau L-M., Frayret J-M. 2013. Effects of different cut-to-length harvesting structures on the economic value of a wood procurement planning problem.

EOS European Organisation of the Sawmill Industry 2014. Facts & Figures. http://www.eos-oes.eu/en/sawmill_industry_facts_figures.php

Hakala, H., 1992. Financial result of sawing pine logs as influenced by top diameter and other associated factors. Acta Forestalia Fennica.

Hakkila, P., Laasasenaho, J. & Oittinen, K. 1972. Korjuuteknisiä oksatietoja. Folia Forestalia, 147.

Haring, M. 2015. The performance of the pricing system in the wood raw material flow – a simulation study. Joensuu 2015.

Kanannen, J. 2008. Kvali - Kvalitatiivisen tutkimuksen teoria ja käytänteet. Jyväskylän ammattikorkeakoulu.

Kauppalehti 2015. Ilman sahoja ruksit sellutehtaiden päälle. Read 21.12.2015. http://www.kauppalehti.fi/uutiset/ilman-sahoja-ruksit-sellutehtaiden-paalle/AffeUZvH

Korpilahti, E., Hyvä metsänhoito on osa metsäsektorin kilpailukykyä. Metsätieteen aikakauskirja 4/1997: 493-504.

Kärkkäinen, M. 1980. Mäntytukkirunkojen laatuluokitus. Commun. Inst. For. Fennica . Metsäntutkimuslaitoksen julkaisuja 96 (5). 143 p.

Luke 2015. Exports of forest industry products 2014. Read 11.12.2015. http://www.metla.fi/metinfo/tilasto/ulkomaankauppa/2014/12/

Lundahl, C. Optimized Processes in Sawmills. 2007. LTU Skellefteå 2007.

Malinen, J., Kilpeläinen, H., Wall, T., & Verkasalo, E. 2006. Variation in the value recovery when bucking to alternative timber assortments and log dimensions.

Malinen, J., Wall, T., Kilpeläinen, H., & Verkasalo, E. 2011. Leimikon arvonmuodostus vaihtoehtoisissa loppukäyttökohteissa.

Nuutinen, T. & Hirvelä, H. 2006. Hakkuumahdollisuudet Suomessa valtakunnan metsien 10. inventoinnin perusteella. Metsätieteen aikakauskirja 1B/2006: 223–237.

Metsä Group Annual Year Book 2014.

Metsälehti 2014. UPM:n investointi tuo työtä Kaakkois-Suomeen Read 20.12.2015. http://www.metsalehti.fi/Metsalehti/Metsauutiset/2014/3/UPMn-investointi-tuo-tyota-Kaakkois-Suomeen/

Ministry of Employment and Economy 2013. Suomalaisen saha- ja puutuoteteollisuuden toimiympäristön vertailu keskeisempiin kilpailijamaihin nähden, 2013. Final Report. https://www.tem.fi/files/37395/52X161005_Loppuraporttifinal_28082013.pdf

Mutanen, A. & Viitanen, J. 2015. Suomen sahateollisuuden kansainvälinen kustannuskilpailukyky 2000-luvulla. Metsätieteen aikakauskirja 2/2015: 69–85.

Nordmark, U., Oja., J. 2004. Prediction of Board Values in Pinus Sylvestris Sawlogs Using X-ray Scanning and Optical Three-dimensional Scanning of Stems.

Peltola A,. ed. 2014. Finnish Statistical Yearbook of Forestry 2014.

Piira, T., Kilpeläinen, H., Malinen, J., Wall, T. & Verkasalo, E. 2007. Leimikon puutavaralajikertymän ja myyntiarvon vaihtelu erilaisilla katkontaohjeilla.

Pohjoismainen sahatavara. 1998. Suomen Sahateollisuusmiesten Yhdistys. 2. p. Jyväskylä: Gummerus Kirjapaino Oy.

Rakennepuutavara: Laatua rakentamiseen. 2012. Metsä Group. Read 28.3.2012. http://www.metsawood.fi/tuotteet/sahatavarajalosteet/Pages/Rakennepuutavara.aspx?TMI=topMenuContainer1

RT21-10978-ohjekortti. 2009. Puutavara: Sahattu, höylätty ja jatkojalosteet. Rakennustietosäätiö. Read 29.9.2017. http://www.uswood.fi/PDF/RT%20kortti%202010.pdf

Stora Enso 2014. Varkauden investointi lisää havukuitupuun kysyntää. Read 21.12.2015. http://www.storaensometsa.fi/varkauden-investointi/

Tavoitteena laadukas puuraaka-aine. 1992. Metsätehon opas. Helsinki: Tuokin-print Oy.

Toivonen, A. quality controller 2016. Tutkintotyö. Sähköpostiviesti.ari.toivonen@upm.fi. Read 12.2.2016.

UPM Annual Year Book 2014.

Usenius A., Heikkilä, T., Song, J., Fröblom, J. & Usenius, T. 2010.
Joustavat ja itseoppivat tuotantojärjestelmät sahateollisuudessa. VTT julkaisuja.

Usenius, A., Heikkilä A., Usenius T., Makkonen M. & Väätäinen, O. 2014.
Digital product process and optimised sawing. Hankkeen loppuraportti VTT.

Uusitalo, J. 2003. Metsäteknologian perusteet. Helsinki. Kustannusosakeyhtiö Metsälehti.

Verkasalo, E., Hautamäki, S. & Kilpeläinen, H. Mänty- ja kuusisahatavaran laatujakaumat ja sahatukin laatu Suomessa ja Luoteis-Venäjällä. 2012. Metsätieteen aikakusikirja.

Vilkka, H. 2015. Tutki ja kehitä. 4., uudistettu painos. Jyväskylä: PS-kustannus

Vilkka, H. 2005.Tutki ja kehitä. 1.–2. painos. Helsinki: Tammi.

Walliman, N. 2005.Your Research Project. 2. painos. Lontoo: Sage Publications.

Ylitalo E., ed. 2013. Finnish Statistical Yearbook of Forestry 2013.

APPENDIXES

Appendix 1. Normal matrix (Division matrix)

Normal matrix, A-quality bottom log

D (mm)	428	458	488	518	548	578	%/kpl
200	0	0	0	0	0	100	100
220	0	0	0	0	0	100	100
240	0	0	0	0	0	100	100
260	0	0	0	0	0	100	100
290	0	0	0	0	0	100	100
330	0	0	0	0	0	100	100

Normal matrix, other than A-quality log

D (mm)	428	458	488	518	548	578	%/kpl
150	10	20	25	25	20	0	100
160	10	20	25	25	20	0	100
180	10	20	25	25	20	0	100
190	20	20	20	20	20	0	100
200	40	5	20	20	15	0	100
220	30	5	20	20	25	0	100
240	30	5	20	20	25	0	100
260	15	5	15	20	20	25	100
280	10	10	15	20	20	25	100
300	10	10	15	20	20	25	100
350	10	10	15	20	20	25	100
400	10	10	15	20	20	25	100

Normal matrix, healthy branch log

D (mm)	370	398	428	458	488	518	548	578	%/kpl
150	K	0	10	20	25	45	K	K	100
160	K	0	10	20	25	45	K	K	100
180		0	10	20	25	45	K	K	100
190			10	20	25	45	K	K	100
200			10	20	25	45	K	K	100

Appendix 2. Test matrix (Division matrix)

Test matrix, A-quality bottom log

D (mm)	428	458	488	518	548	578	%/kpl
200	0	0	0	0	0	100	100
220	0	0	0	0	0	100	100
240	0	0	0	0	0	100	100
260	0	0	0	0	0	100	100
290	0	0	0	0	0	100	100
330	0	0	0	0	0	100	100

Test matrix, other than A-quality log

D (mm)	428	458	488	518	548	578	%/kpl
150	10	15	20	40	15	0	100
160	10	15	20	40	15	0	100
180	10	15	20	40	15	0	100
190	15	15	15	40	15	0	100
200	20	15	15	40	15	0	100
220	15	15	15	40	15	0	100
240	15	15	15	40	15	0	100
260	8	8	11	40	15	18	100
280	8	8	11	40	15	18	100
300	8	8	11	40	15	18	100
350	8	8	11	40	15	18	100
400	8	8	11	40	15	18	100

Test matrix, healthy branch top log

D (mm)	370	398	428	458	488	518	548	578	%/kpl
150	K	0	10	18	22	48	1	1	100
160	K	0	10	18	22	50	0	0	100
180		0	10	18	22	50	0	0	100
190			10	18	22	50	0	0	100
200			10	18	22	50	0	0	100

Appendix 3. UPM Korkeakoski sawmill acceptance qualities

10 A quality bottom log

20 Other bottom log

30 Middle (2) log

40 Top (3) log

41 Under sized measure

42 Over sized measure

43 Fault measure

44 Curve + crooked

45 Bottom curve

46 Rotten

47 Fresh branch

48 Dry/rotten/boy branch

49 Scar

50 Basic quality

60 Iron wood

61 Insect failure

62 Color issues

63 Careless issues

Appendix 4. Quality classes of Pine Logs UPM Forest

A- quality bottom log ; Allowed max. 20 mm fresh and dry branches. Min diameter 200 mm

B- quality bottom log ; Allowed max. 60 mm fresh-, 40 mm dry- ja 30 mm rotten branches and 1 pcs.. non rotten 40 mm boy branch.

Middle log ; Allowed max. 60 mm fresh-, 40 mm dry- ja 30 mm rotten branches and 1 pcs. non rotten 40 mm boy branch.

Top log ; Allowed max. 60 mm fresh-, 40 mm dry- ja 30 mm rotten branches and 1 pcs. non rotten 40 mm boy branch. Max. diameter 180 mm.

In fresh branched top log dry branches are allowed only in bottom of log, in distance of first 1/3 part of log.