Helsinki University of Technology Department of Forest Products Technology
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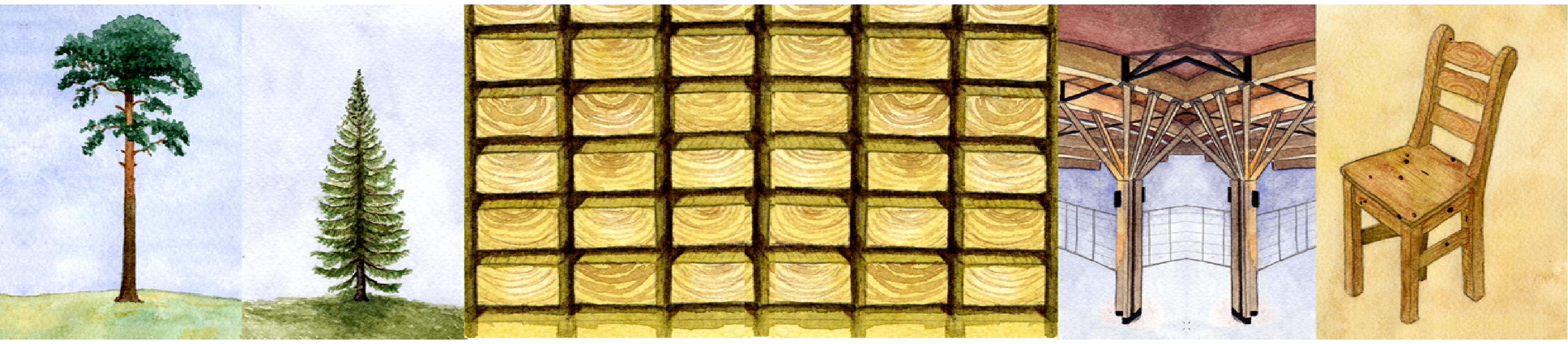
Espoo 2005 Report 96

# ANALYSING SAWNWOOD SUPPLY DISTRIBUTION IN FINNISH SAWMILLING INDUSTRY WITH DATABASE APPROACH

**Jussi Virtanen**



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# ANALYSING SAWNWOOD SUPPLY DISTRIBUTION IN FINNISH SAWMILLING INDUSTRY WITH DATABASE APPROACH

Jussi Virtanen

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*Herran pelko on viisauden alku, ja*
*Pyhimmän tunteminen on ymmärrystä.*
*- Salomo -*
*Snl. 9:10*

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Abstract

The thesis analyses sawnwood supply in the Finnish sawmilling industry using the database approach. The analyses help to understand the supply and demand of sawnwood between customers and sawmills. In the analyses two databases were used to examine the supply of sawnwood. In addition, the following three criteria were used: 1) quantity, 2) price and 3) quality. The study focused on a sample of 63,774 sales of over 19 million $m^3$ sawnwood from 1995 to 2000. Quality in the thesis is defined in terms of dimensions, quality classes, end moisture contents and user segments. The coniferous species in the sample were Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*). Additionally, time series data about the consumption of coniferous sawnwood from the years between 1961 and 2002 was used in the study. The most essential new result of the thesis was that the features of sawnwood as a commodity product were clear in the sample from 1995 to 2000. Nevertheless, the marketing and the operations of the Finnish sawmilling industry at the time emphasised the features related to special and customer products.

In 2002, the global consumption of coniferous sawnwood (CSW) was 283 million $m^3$. The same year in Finland, the consumption of sawnwood increased to 1.02 $m^3$ per capita, the highest in the world. Finland experienced a structural change in the sawnwood consumption between the periods of 1961–1996 and 1997–2002.

From 1995 to 2000, sawnwood supply and sales from Finnish sawmills were largely limited to only a few volume dimensions. For pine, 20% of the number of dimensions encompassed 91% of volume and 90% of value. For spruce, 20% of the number of dimensions covered 82% of volume and 83% of value. The Pareto principle assumption applied to the distribution of sawnwood dimensions from the quantity ($m^3$) and value (€) perspectives. There was a sawnwood market trend towards smaller batch sizes. It was observed that the end moisture content class MC 18% has a dominant position – over 90% – in the end moisture content distribution. The results supported the view that sawnwood supply consists mainly of a limited number standard products. Dimensions had big differences specific to country and species of timber. The basis price system worked by dimension, quality class and species with a defined basis of pine 50 x 150 mm U/S or similar. This system was used in the pricing of sawnwood in the Finnish sawmilling industry in 2000.

In the analyses, the supply of sawnwood was divided according to end moisture content classes, countries, dimensions and segments. In the supply analyses, standard dimensions and qualities were linked with the standard moisture content classes as MC 18%. The results showed that the supply was greatest for standardised sawnwood. The supply and demand for special qualities increased particularly for pine. There was a correlation between sawnwood export countries, moisture content classes and end-user segments. The results showed that sawnwood user segmentation was still unfinished.

The thesis seeks to present such methods that give relevant information to sawmills and other segments of the forest cluster. These useful methods include logistic regressions and other statistical tools. Applying these tools can give new insight into business management as well as the dynamics of the demand for sawnwood and other wood products.

Key words: sawnwood, supply, demand, consumption, analysis, pine, spruce, price, logistic regression, linear regression, length, sawmill, end moisture content, quality class, user segment, sale size, dimension, basis price, Pareto, sawmilling industry, wood product industry, sawn timber, wood.

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SAHATAVARAN TARJONNAN TIETOKANTALÄHTÖINEN ANALYYSI SUOMEN SAHATEOLLISUUDESSA

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Tiivistelmä

Väitöskirja analysoi havusahatavaran tarjontaa ja kysyntää Suomen sahateollisuudessa tietokantalähtöisesti. Väitöskirjassa esitetään analyysejä, joiden avulla voidaan kuvata sahatavaraa tuotteena sekä ymmärtää tarjontaa ja kysyntää sahojen ja niiden asiakkaiden välillä. Sahatavaran tarjontaa selvitettiin kahden tietokannan pohjalta määrän, hinnan ja laadun avulla. Aineisto kattoi dimensiot, laatuluokat, loppukosteudet ja käyttösegmentit. Tutkimuksen pääaineisto oli 63774 sahatavarakauppaa, jotka käsittävät yli 19 milj. $m^3$ sahatavaraa vuosilta 1995–2000. Puulajit olivat mänty (*Pinus sylvestris*) ja kuusi (*Picea abies*). Lisäksi tutkimuksessa käytettiin havusahatavaran kulutuksen aikasarja-aineistoa vuosilta 1961–2002. Työn keskeisin uusi tulos on sahatavaran standardituotteenomaisten piirteiden näkyminen pääaineistossa vuosina 1995–2000 siitä huolimatta, että samaan aikaan sahateollisuuden markkinoinnissa ja toiminnassa korostettiin asiakas- ja erikoistuoteominaisuuksia.

Havusahatavaran globaali kulutus oli 283 milj. $m^3$ vuonna 2002. Suomessa havusahatavaran kulutus nousi vuonna 2002 korkeammalle kuin missään muualla maailmassa, 1,02 $m^3$:iin henkeä kohti. Tutkimuksessa havaittiin sahatavaran kulutuksen rakennemuutos Suomessa aikajaksojen 1961–1996 ja 1997–2002 välillä.

Havusahatavaran tarjonta ja myynnit suomalaisilta sahoilta käsittivät suuren määrän dimensioita. Tarjonta kuitenkin rajoittui muutamiin suurien volyymien dimensioihin Pareto-periaatteen mukaisesti sekä määrän ($m^3$) että arvon (€) mukaan. Männyllä 20 % dimensioiden määrästä kattoi 91 % volyymistä ja 90 % arvosta. Kuusella 20 % dimensioiden määrästä kattoi 82 % volyymistä ja 83 % arvosta. Yli 90 % havusahatavaran tarjonnasta oli kosteusluokkaa 18 %. Sahatavarakauppojen koko pieneni merkittävästi tarkastelujakson aikana. Sahatavarakauppojen dimensioiden välillä oli suuria maa- ja puulajikohtaisia eroja. Esimerkiksi Suomesta vietyjen suurten mäntydimensioiden merkitys väheni UK:n markkinoilla tarkastelujakson aikana. Tutkimuksessa havaittiin, että basis-hintajärjestelmä oli edelleen käytössä havusahatavaran hinnoittelussa vuonna 2000. Basis-hintajärjestelmän mukaan sahatavaran hinnat riippuivat dimensiosta, laatuluokasta ja puulajista niin, että hinta määrättiin mänty 50 x 150 mm U/S:n tai vastaavan perusteella.

Sahatavaran tarjonta jakaantui malleissa loppukosteusluokkien, maiden, dimensioiden ja segmenttien mukaan. Esimerkiksi tarjontamalleissa havaittiin, että vakiodimensiot ja -laadut liittyvät vakioloppukosteusluokkaan 18 %. Tulokset tukivat kuvaa, että tarjonta kohdistui suureksi osaksi vakiosahatavaraan. Samanaikaisesti erikoislaatujen ja alempien loppukosteuksien merkitys kasvoi erityisesti männyllä. Tutkimuksessa havaittiin yhteys vientimaiden, kosteusluokkien ja loppukäyttösegmenttien välillä. Tulokset osoittivat sahojen käyttäjäsegmenttistrategian olevan vielä kesken vuosina 1995–2000. Lisäksi havaittiin sahojen toiminnan perustuvan vakiotuoteajatteluun.

Tutkimus esittelee keinoja, joiden avulla voidaan käytännössä tuottaa hyödyllistä tietoa sahoilla ja muille metsäklusterin segmenteille. Tutkimus tavoittelee analysointitapaa, jota voidaan soveltaa laajasti kaupassa ja teollisuudessa. Tutkimuksessa sovelletaan logistista regressiota sekä eräitä muita tilastollisia menetelmiä. Menetelmien käyttö antaa uuden näkökulman sekä liiketoiminnan ohjaamiseen että sahatavaran ja muiden metsäteollisuustuotteiden kysynnän seurantaan.

Asiasanat: sahatavara, tarjonta, kysyntä, kulutus, analyysi, mänty, kuusi, hinta, logistinen regressio, lineaarinen regressio, pituus, saha, loppukosteus, laatuluokka, käyttäjäsegmentti, kauppakoko, dimensio, basis hinta, Pareto, sahateollisuus, puutuoteteollisuus, puu.

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I dedicate this work to my dear Mari, the mother of our children and my precious support, with whom I have had a privilege to share everything since we got married. It is true that a prudent wife is from the Lord (Proverbs 19:14).

My main source of strength and guidance for this dissertation has been the Lord Jesus Christ - a man and the Son of God. He lived on earth, he taught the truth, he died painfully as a punishment for our sins and he conquered death rising from the dead. He did all this because he loves you and me. He wants to give us eternal life with God instead of a permanent separation from God which we would have deserved because of our sins. How do we learn to know Jesus? Jesus said: “Behold, I stand at the door and knock; if anyone hears my voice and opens the door, I will come in to him, ...” (Rev. 3:20). This promise is in the Bible, the word of God, and God does not lie. I asked Jesus to come into my life when I was eight years old and He came. He wants to live with you just as he lives with me. Just pray this simple prayer, which is similar to the one I prayed when I was eight: “Dear Jesus, forgive all my sins. Jesus, come into my life. Thank you, Jesus, that you came.”

In Espoo 04 September 2005,

Jussi Virtanen

# Abbreviations

In Table 1 there are explanations for abbreviations and acronyms used in the thesis and process of analysing the data as well as writing the thesis. Note that some abbreviations and acronyms do not appear in the thesis. In that case they are given in the WPDB.

**Table 1. Abbreviations and acronyms.**

| Abbreviations and acronyms | Explanation | Abbreviations and acronyms | Explanation | Abbreviations and acronyms | Explanation |
|---|---|---|---|---|---|
| **%** | Per cent | **MC NO INF** | Moisture content no information | **Q-SFFQ** | SF furniture quality |
| **A** | A (U/S) is the highest export grade, divided into sub-grades A1, A2, A3, A4. | **MC8** | Moisture content 8% | **Q-SFLQ** | SF log quality grade |
| **AB** | AB (SF) is a combination of A and B grades. | **MC10** | Moisture content 10% | **Q-SFMB** | SF möbel (furniture) grade |
| **ABC** | ABC (SF) is a combination of A, B and C grades. | **MC12** | Moisture content 12% | **Q-SFSG** | SF strength graded SR-11 grade |
| **AT** | Austria, country code | **MC14** | Moisture content 14% | **Q-SFSP** | SF splitted quality grade |
| **AU** | Australia, country code | **MC16** | Moisture content 16% | **Q-SFUSV** | SF U/S-V mix grade |
| **B** | B (V) is the middlemost export grade | **MC18** | Moisture content 18% | **QTY** | Quantity |
| **BE** | Belgium, country code | **MC20** | Moisture content 20% | **Q-US** | U/S grade |
| **C** | C (VI) is the lower falling export grade | **MDF** | Medium density fiberboard | **Q-US13** | U/S 1–3 grade |
| **C-** | Destination country | **mm** | Millimetre | **Q-USCCA** | U/S CCA treated |
| **CAN** | Canada, country code | **$Mm^3$** | Million cubic metre | **Q-USF** | U/S heart free |
| **CAS** | Correspondence analysis | **MY** | Malaysia, country code | **Q-USSP** | U/S splitted grade |
| **CCA** | pressure-treated or impregnated wood with Copper, Chrome, Arsenic or one of these | **Möbel** | Furniture quality | **Q-USSQ** | U/S stair quality |
| **CHI** | Chile, country code | **N** | Sample size | **Q-V** | V grade |
| **CN** | China, country code | **NA** | Not available | **Q-VA** | V Algeria grade |
| **CSW** | Coniferous sawnwood, coniferous sawn timber | **Nag.** | Nagelkerke | **Q-VF** | V heart free |
| **CY** | Cyprus, country code | **NCSW** | Non coniferous sawnwood, non coniferous sawn timber | **Q-VSP** | V splitted grade |
| **C&S** | Cox & Snell | **NL** | The Netherlands, country code | **Q-VIB** | VI blue grade |
| **D** | D is the lowest CSW quality mainly for domestic markets | **No** | Number | **Q-VIC** | VI C grade |
| **DE** | Germany, country code | **NO** | Norway, country code | **Q-VID** | VI domestic quality grade |
| **df** | Degrees of freedom | **obs.** | Observations | **Q-VIE** | VI export quality grade |
| **DIST** | Distribution | **OECD** | Organisation for Economic Co-operation and Development | **Q-VIEJ** | VI export quality J grade |
| **DIY** | Do it yourself | **PC** | Per capita | **Q-VIJ** | VI Japan grade |
| **DK** | Denmark, country code | **PLAN** | Planing | **Q-VIM** | VI M grade |
| **DZ** | Algeria, country code | **PL/VL** | Surface board, export quality | **Q-VIW** | VI wane grade |
| **EG** | Egypt, country code | **PRI** | Price | **Q-VM** | V möbel grade |
| **ES** | Spain, country code | ***p*-value** | Probability value | **R2** | R-squared |
| **EWP** | Engineered wood product | **QA** | Quality Average | **RA** | Row Average |
| **F** | F-value (in distribution comparison) | **Q-** | Quality class, grade | **S-** | Segment |
| **FAO** | Food and Agriculture Organization of The United Nations | **Q-FRA** | Frame FJ grade | **SA** | Saudi Arabia, country code |
| **FAOSTAT** | FAO, FAOSTAT Forestry - statistics on imports, exports for wood products | **Q-GLUE** | Glued frame FJ grade | **SE** | Sweden, country code |
| **FI** | Finland, country code | **Q-HVS1** | HVS grade, for boards | **SF** | Sawfalling grade, see AB or ABC |
| **FIM** | Finnish markka (currency) | **Q-HVS2** | HVS + knotless grade | **Q-SIDE** | Side board grade |
| **FJ** | Fingerjointed | **Q-KNO** | Knotty J grade | **Q-STGR** | Strength graded grade |
| **FOB** | Free on Board | **Q-KNOT** | Knottypine grade | **SME** | Small and medium enterprises |
| **FR** | France, country code | **Q-LAMA** | Lamina A grade | **STGR** | Strength graded |
| **FUR** | Furniture | **Q-LAMB** | Lamina B grade | **T-** | Thickness |
| **GB** | England, country code | **QLT** | Quality | **TH** | Thailand, country code |
| **GNP** | Gross national product | **Q-OTH1** | Other grade | **THS** | Thickness |
| **gof** | goodness−of−fit | **Q-OTH2** | Other J grade | **TN** | Tunisia, country code |
| **GR** | Greece, country code | **Q-PL** | PL grade, for boards | **TW** | Taiwan, country code |
| **HaL** | Hosmer and Lemeshow | **Q-PLKL** | PL/KL grade, for boards | **t Stat** | Statistic value *t* |
| **HK** | Hong Kong, country code | **Q-PLKL J** | PL/KL jointed grade, for boards | **U/S** | As A, unsorted grade |
| **HU** | Hungary, country code | **Q-PLKNL** | PL knotless grade, for boards | **UK** | United Kingdom |
| **$H_0$** | Null hypothesis | **Q-PLVL1** | PL/VL grade, for boards | **US** | The USA, country code |
| **IE** | Ireland, country code | **Q-PLVL2** | PL/VL + better grade, for boards | **USE** | User segment |
| **IL** | Israel, country code | **Q-PLVLB** | PL/VL b grade, for boards | **V** | As B, V grade |
| **IT** | Italy, country code | **Q-PLVLJ** | PL/VL jointed grade, for boards | **W-** | Width |
| **J** | Jointed, quality parameter | **Q-PLVLPLA** | PL/VL plane grade, for boards | **WTH** | Width |
| **JOI** | Joinery | **Q-SF15** | SF 1–5 grade | **VI** | As C, VI grade |
| **JP** | Japan, country code | **Q-SF15B** | SF 1–5 + better VI grade | **VN** | Vietnam, country code |
| **LINREG** | Linear regression | **Q-SF15F** | SF 1–5 heart free grade | **WPDB** | Wood product database |
| **$m^3$** | Cubic metre | **Q-SF16** | SF 1–6 export quality grade | **[a,b]** | $\{ x \mid a \le x \le b \}$ |
| **MC** | Moisture content, % | **Q-SF56** | SF 5–6 export quality grade | **[a,b[** | $\{ x \mid a \le x < b \}$ |

# Definitions

In Table 2 there are definitions for terms used in the thesis. It should be noticed that these definitions apply only to the thesis context but may be valid elsewhere, too.

**Table 2. Definitions for terms.**

| Term | Definition |
|---|---|
| **A priori** | Supposition involving deductive reasoning from a general principle to a necessary effect, not proved or supported by tested fact. |
| **Apparent consumption** | Proxy measure for consumption of a product or material, in the thesis sawnwood, defined as production plus imports minus exports of the product or material (United Nations 1997). User segments of sawnwood are not known. |
| **Batch size** | An amount ($m^3$) of sales and deliveries of sawnwood from Finnish sawmills; a delivery volume or delivered size ($m^3$). |
| **Board** | CSW when thickness under 38 mm and width over 75 mm. Exception: centre board. |
| **Centre board** | CSW from centre yield, see Figure 8. |
| **CIS** | The Commonwealth of Independent States (CIS) (in Russian: Содружество Независимых Государств (СНГ) - Sodruzhestvo Nezavisimykh Gosudarstv) is a confederation or alliance consisting of 12 former Soviet Republics: Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan (Nationmaster 2005). |
| **Classification** | The act of distributing things into a priori known classes or categories of the same type. |
| **Commodity** | A transportable article of trade or commerce that can be bartered or sold. |
| **Coniferous** | Cone-bearing trees with needles. In the thesis only Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*). |
| **Consumption** | Apparent consumption, which see. |
| **CSW** | Coniferous sawnwood or sawn timber, lumber; in the thesis only Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) |
| **Data mining** | The process of analysing sales data to identify patterns or relationships. In the thesis data mining is applied to analysing sales data of sawnwood sales from Finnish sawmills. |
| **Demand** | The desire to possess a commodity (e.g. sawnwood) combined with the ability to purchase it. Also the amount of a commodity (e.g. sawnwood) that customers are ready to buy for a given price. User segments of sawnwood are known. |
| **Dimension** | A measure of spatial extent of sawnwood, especially width, height, thickness or length. |
| **Efficiency** | The ratio of the output to the input of a machine, a sawmill, sawmilling industry or forest-sawmill-customer chain. |
| **EWP** | Engineered Wood Product, a glued wood product for mainly structural purposes with improved technical properties as high strength, light weight, dimensional stability, uniform and predictable quality, and efficient use of wood. |
| **Fingerjointing** | Jointing short pieces of sawnwood with an adhesive by cutting fingers of wood and jointing adjacent fingers together with pressure. |
| **GDP** | Gross Domestic Product, the total market value of all final goods and services produced in a country in a given year, equal to total consumer, investment and government spending, plus the value of exports, minus the value of imports (Investorwords 2005). |
| **GNP** | Gross National Product, the total market value of goods and services produced by all citizens and capital during a given period in a country or area. GNP is GDP plus the income accruing to domestic residents from productive activities abroad, minus the income earned in domestic markets accruing to foreigners abroad (Investorwords 2005). |
| **Green** | CSW with no drying in kiln, MC normally around 30% or more. |
| **Group** | Any number of entities, members, cases or sales considered as a unit where the entities are not known or defined. |
| **Grouping** | The act of putting things together in groups without a common, a priori known and defined attribute. |
| **Intermediate consumption** | The cost of raw materials and other inputs which are used up in the production process (National Statistics 2005). |
| **Kurtosis** | A measure of peakedness and symmetry of point probability on probability density functions. |
| **Logistic regression** | A variant of standard multiple regression used when the dependent variable is a dichotomy, such as a specific quality class is/is not linked with sales of sawnwood. |
| **Mean** | The mean is the average data point value within a data set. |
| **Method** | A way of doing something systematically, often implies an orderly logical arrangement. |
| **Model** | An abstraction of reality referring to a defined mathematical or other logic formula designed to determine model objects. Also a schematic description of a system or phenomenon that accounts for its properties and may reveal its characteristics. |
| **Moisture content (MC)** | Weight of water in wood or sawnwood divided by weight of solids in wood or sawnwood. Generally expressed as an estimation of percentage (%) of the oven dry weight of sawnwood. |
| **Multiple regression** | An equation or analysis where two or more independent (predictor) variables affect the dependent variable. |
| **Qualitative data** | Measurements that cannot be measured on a natural numerical scale; they can only be classified into one of a group of categories (McClave et al. 2005). See more in Figure 41. |
| **Quantitative data** | Measurements that are recorded on a naturally occurring numerical scale (McClave et al. 2005). See more in Figure 41. |
| **the Pareto principle assumption** | In any population that contributes to a common effect, a relative few of the contributors−the vital few−account for the bulk of the effect. See more in 3.6.3. From behavioural theory perspective, it must be said that the Pareto principle assumption is more seen as a folk theorem. |
| **Pine** | *Pinus sylvestris*, Nordic pine, redwood, Scots pine. |
| **Plank** | CSW to be in construction use and dimensions larger than thickness of 38 mm. |
| **Price** | The amount of money at which sawnwood or other thing is valued, bought or sold but not offered for sale. |
| **Profitability** | A measure of business success of a sawmill of the sawmilling industry through comparing profit or result made with the amount sold. In the thesis: result before extraordinary items/turnover, %, unless not defined in the context in a different way. |
| ***p*-value** | The probability value (*p*-value) of a statistical hypothesis test is the probability of getting a value of the test statistic as extreme as or more extreme than that observed by chance alone, if the null hypothesis $H_o$, is true. |
| **R-squared, R2** | A mathematical term describing how much variation of the dependent variable is being explained by the independent variables in a regression equation. |
| **Refining** | Refining sawnwood, i.e. value adding further processing of sawnwood to value added products; further processing. |
| **Sawn timber** | Sawnwood, which see. |
| **Sawnwood** | Coniferous sawnwood (sawn timber) when the general term for piece of wood sawn from four sides. In the thesis sawnwood as a concept covers only Scots pine and Norway spruce unless there is an exception in the context. |
| **Side board** | CSW from side yield, see Figure 8. |
| **Skewness** | The metric that indicates the degree of asymmetry. |
| **Slating batten or strip** | CSW when thickness and width under 75 mm. |
| **Spar** | Pieces of small square sawnwood with four sawn sides with a thickness and width 75 mm or more. |
| **Spruce** | *Picea abies*, Nordic spruce, whitewood, Norway spruce. |
| **Standard deviation** | the square root of the sum of the squared deviations from the mean, divided by the sample size minus one. |
| **Stud** | CSW when thickness over 38 mm and width over 75 mm. |
| **Supply** | The total amount of a good (e.g. sawnwood) or service available for purchase; along with demand, one of the two key determinants of price. User segments of sawnwood are not known. |
| **Tendency, trend** | a general direction in which something (e.g. The Finnish sawmilling industry or CSW) tends to move. |
| **Value added, gross** | is the difference between output and intermediate consumption for sawmilling industry; the difference between the value of goods and services produced and the cost of raw materials and other inputs which are used up in production (National Statistics 2005). |

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# 1 INTRODUCTION

## 1.1 Area of the thesis

The thesis builds on two premises: (1) sawnwood supply, demand and consumption evolve over time, and (2) there are logical patterns that can be discerned from sawnwood supply, demand and consumption based on database information. On the basis of these premises, it is justified to research how and why sawnwood supply, demand and consumption evolve and what the logical sawnwood supply, demand and consumption patterns are like.

The thesis report analyses sawnwood supply, demand and consumption from three perspectives. It approaches sawnwood (1) supply and demand mostly from database perspective (sawnwood sales information from sawmills' internal databases, e.g. see Section 3.4.1) but in some cases sawnwood consumption also from (2) time series and (3) per capita analysis perspectives.

The thesis does not approach the sawnwood demand by trying to prove that it comes from construction, joinery and other sources of demand. A number of studies have been published which have revealed these sources of sawnwood demand logically, e.g. Timwood (1998) and Roadmap 2010 (2003). The sawmilling industry understands this demand and supply dependency of construction activities. However, there is little, if any, research information on the characteristics of sawnwood supply from the perspective of internal databases of sawmills. These sawmill databases are based on information systems used by sawmills, although the data in these databases were not designed to be analysed scientifically. Furthermore, there are a number of sawnwood supply and demand research topics that have not been covered so far.

A foundation for thesis propositions and data analysis is set by expectations for practical business uses. This area of the thesis belongs to a topic often called as business intelligence, BI. The purpose of the study is to find out how sawmills and sawmilling industry could benefit from the large databases they have. Obviously they do not utilise these databases in a large scale so far.

There are many practical uses for the study. Sawnwood pricing logic is often seen from either an econometric or macroeconomics perspective (e.g. Latta and Adams 2000). Studies on the logic of sawnwood practical price formation are scarce. The Pareto principle assumption, which often asserts that 20% of the causes usually account for 80% of the effects, has not been widely tested in the sawmilling industry. Although the Pareto principle assumption is a folk theorem, it can produce useful information for sawmilling companies. For more of the Pareto principle assumption, see the definitions on page 4 or Section 3.6.3. In addition, little information exists on how the numbers of dimensions have evolved and what the number of sawnwood dimensions is on the market.

## 1.2 The purpose of the thesis

The thesis focuses on changes and relationships in the Finnish sawmilling industry. The purpose of the thesis is to analyse sawnwood supply distribution with database approach in such a way that it can benefit a sawmill or a company of several sawmills. Therefore the thesis sample has been selected by the criterion that a similar sample (sales and event database) can be found in the own systems of sawmills or in public sources (e.g. FAOSTAT data 2004).

Moreover, the purpose of the thesis is to describe and analyse the interface and dynamics between a sawmill and its customers in terms of sawnwood sales. The thesis seeks to answer to the following questions:

1. What phenomena and indicators can be found to explain coniferous sawnwood as a product? The question includes approaches of quantity, price, quality and user segments.
2. How the strategic changes can be seen in the sawnwood sales in the Finnish sawmilling industry from 1995 to 2000?

## 1.3 Thesis design

The analysis of the sawnwood supply distribution refers to the sawnwood supply and demand related phenomena in the thesis. The analyses are reduced to conceptual analyses. Many examples of supply and demand phenomena are sought in the analyses. These analyses can be repeated by taking a sales sample from sawmills' own databases to verify the research results.

The thesis does not intend to create an analysis that would cover all situations of sawnwood supply and demand. In addition, the thesis does not aim to explain and quantify demand sources like construction, furniture, or package segments. Likewise, there is no need for a deeper focus on factors related to economics such as changes in the GDP. There are two reasons for these limitations (see more in Section 1.5 Thesis limitations):

1. Demand analysis for sawnwood and other forest products have already been created (e.g. Timwood 1998 and Roadmap 2010, 2003).
2. The two databases that were available for the thesis (see Section 3.4) create an opportunity for a new, more accurate view to analysing sawnwood supply and demand features.

The statistical method was chosen as the main methodology for the thesis. The statistical methods were selected by two criteria:

1. Validity of a method for the research object.
2. Reliability of a method for the sample and analysis.

The thesis sample is mostly based on private sales databases of the Finnish sawmilling industry companies described in Section 3.4.1. From the reliability perspective, it must be stated that reliability is also based on the sales database reliability of the Finnish sawmilling companies. An important scientific criterion, research repeatability, is fulfilled in the way that the research process and results have been documented. No signs of unreliability were found in the private sales databases.

The thesis is, with some exceptions, confined to the Finnish sawmilling industry. Also the Nordic sawmilling industry is briefly described. On the one hand, the thesis might be regarded as a case study in the sense that its generalisations only apply to the Finnish sawmilling industry. On the other hand, the thesis differs greatly from a case study by two criteria:

1. The thesis can be repeated with a similar sample from sawmills anywhere in the world.
2. The thesis does not study the behaviour of a human population or organisations or a process in history.

The thesis design is explicated using the hypotheses in Figure 1. They include the research idea, which is to analyse features of supply and demand, and to see how this is transformed into sales and deliveries. These hypotheses are:

1. The sawn timber operational environment – products, consumption, supply and demand – can be examined with the model shown in Figure 1.
2. The research method – database and data mining – can be used to describe sawnwood as a product and present connections between product properties.
3. The data from 1995 to 2000 can be used to (a) show the situation in the Finnish sawmilling industry, and (b) present ideas of various development needs.

The research focuses on the connection between the Finnish coniferous sawmilling industry and its customers. The research also touches context of the global sawmilling industry with connections to the Finnish sawmilling industry. Some research topics are listed in Figure 1.

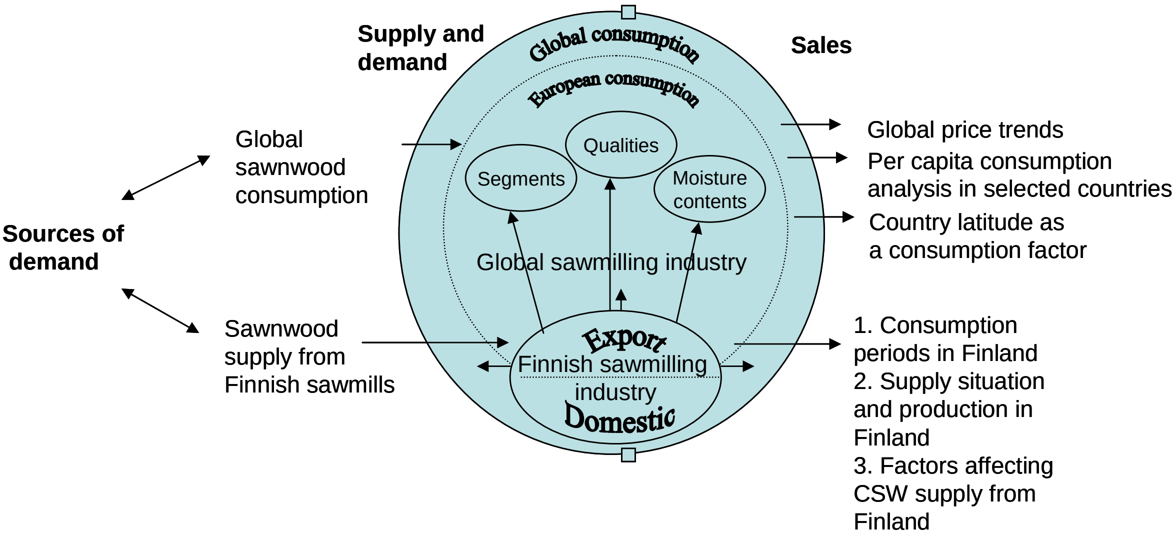


**Figure 1. Thesis hypotheses about the coniferous sawnwood supply, demand, consumption and sales.**

The emphasis of the thesis is in the area of sales and deliveries and it is also is closely linked with the supply and sources of demand. The thesis research is done more on a database analysis instead of time series or pure econometric area (like e.g. Latta and Adams 2000 or Flinkman 2004), yet some minor parts of the thesis are linked with time series. In the thesis (see Figure 1) the sources of demand are divided into two approaches:

1. Global sawnwood consumption.
2. Sawnwood supply from Finnish sawmills.

The sawnwood consumption is approached by focusing on coniferous sawnwood global volumes and the analysis of price trends per capita. The sawnwood consumption analysis includes the countries that are important to the Finnish sawmilling industry. The sawnwood supply is approached by focusing on the relationships between the Finnish and global sawmilling industry.

In Figure 1, the Finnish sawmilling industry is divided into two sectors: (1) Export (i.e. sales to other countries) and (2) Domestic sales (i.e. sales to Finland). Traditionally, the Finnish sawmills have exported the best sawnwood qualities and sold the other qualities in the domestic markets.

The relationships between the Finnish sawmilling industry and its customers (see Figure 1) are analysed by the following categories: product and user segments, qualities and end moisture contents. Furthermore, these analyses cover the price and batch size approaches. Consequently, the thesis presents an analysis of CSW consumption periods in Finland, the supply situation and production as well as factors affecting CSW supply.

In practice, the thesis hypotheses (Figure 1) are used in three sections:

1. Sawnwood consumption environment (Chapter 4).
2. CSW supply and production (Chapter 5).
3. Examples of analysing factors affecting coniferous sawnwood supply (Section 5.8).

The use of sawnwood consumption environment results is described in Figure 2. The following symbols are used to separate coniferous sawnwood from other wood products:

● coniferous sawnwood
○ other wood products

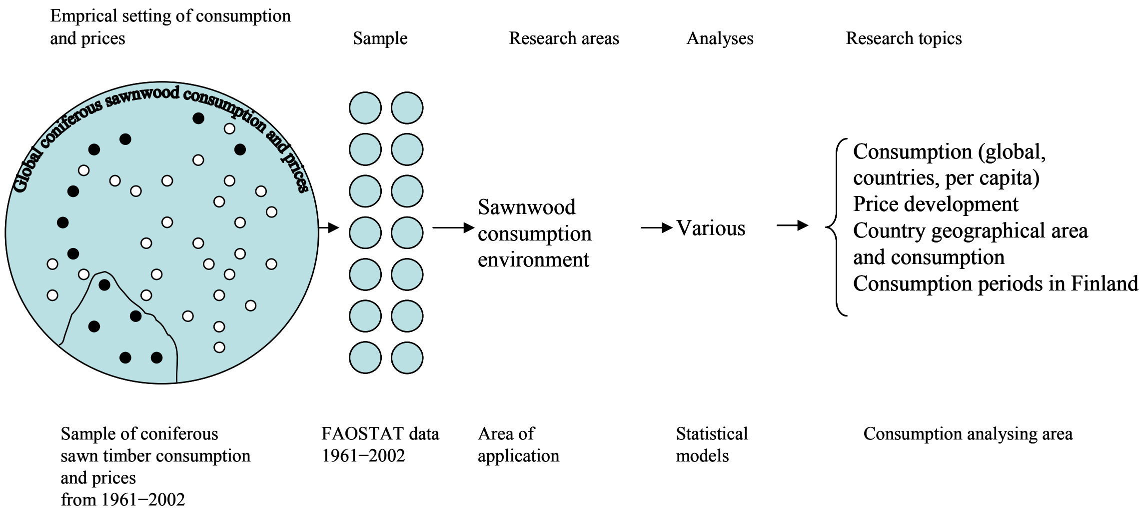


**Figure 2. Implementation of the hypotheses in the area of sawnwood consumption environment.**

Regarding sawnwood consumption environment, the use of results of the thesis is based on FAOSTAT data (2004), which covers country and global area based data of sawnwood consumption and prices as well as population from 1961 to 2002.

The use of results of the thesis in the area of supply and production situation of CSW in Finland, and factors affecting CSW supply, are described in Figure 3. The main research idea is to analyse a sample of wood product database (see Section 3.4.1) in two research areas with various statistical and database methods.

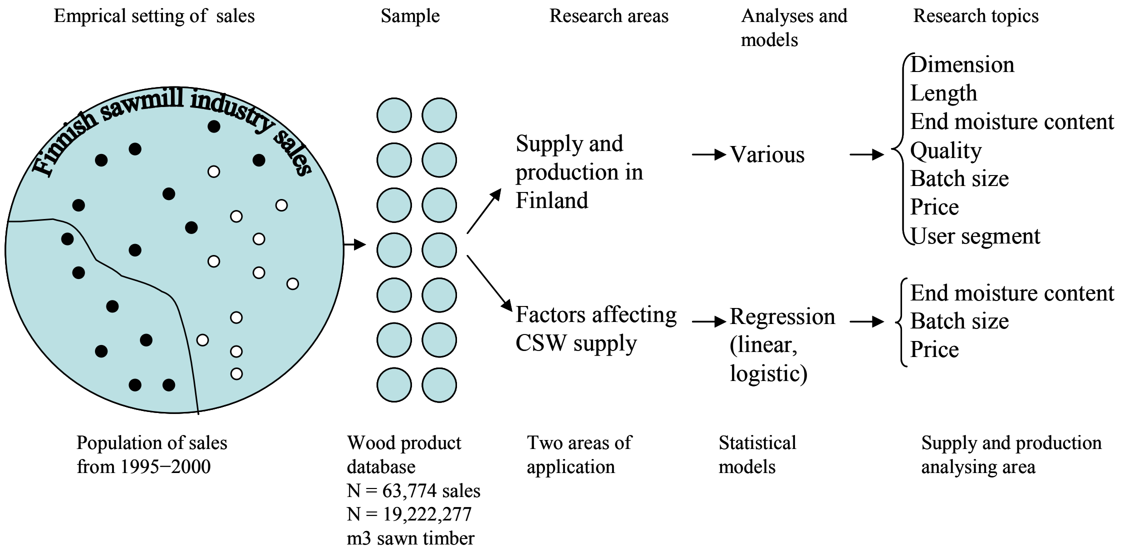


**Figure 3. Implementation of the hypotheses in the area of supply and production.**

When the CSW quality and dimension distributions are focused on, the thesis describes the picture of raw material quality from the forests, too, although this is not the main focus. The thesis indirectly gives information of how industrial users, here Finnish sawmills, have utilised the quality of raw material. Sawnwood quality describes also raw material quality, as the quality of sawnwood is closely linked with the logs. Sawnwood is always somewhat inhomogeneous and depends on the raw material quality, as sawnwood is produced by sawing and not, for instance, by chipping. In this conversion chain (see e.g. Figure 32), the wood properties are transferred directly to from logs to sawnwood. Moreover, the database analyses (Figure 1 and Figure 3) are based on sales and deliveries database information given by the Finnish sawmills to be analysed (see Section 3.4.1).

## 1.4 Thesis outline

The thesis deals with two different branches: 1) coniferous sawnwood as a product, 2) coniferous sawnwood supply and its analysis from the perspective of sawnwood sales between the Finnish sawmills and their customers. This section introduces these two branches.

Chapter 2 describes a contextual frame of the study with an emphasis on sawnwood and sawmilling industry applications. Chapter 3 describes thesis concepts and methodology. It introduces the analysing approaches that have been used in this study as well as the Wood product database, WPDB. Chapter 4 presents the sawnwood consumption environment based on FAOSTAT data (2004). Chapter 5 presents the results based on the data from the Wood product database, WPDB. Finally, Chapter 6 consists of discussion and conclusions. References and appendices at the end of thesis give background information and tables.

## 1.5 Thesis limitations

There is a need to restrict the area of the thesis for several reasons. The scope of the thesis is limited to phenomena related to sawnwood supply and demand. The analyses are reduced to conceptual analyses and based on two databases: (1) FAOSTAT data (2004) the (2) Wood product database, WPDB. Many phenomena are presented as results of the analyses that are based on the two databases.

Concerning the concepts of the thesis, there are some limitations. The concept of sawnwood supply is limited to coniferous sawnwood sales between Finnish sawmills and their customers. The concept of sawnwood demand used is the ability and desire to purchase coniferous sawnwood from sawmills that sell sawn goods to those who have the ability and desire to purchase coniferous sawnwood. The concept of sales includes both coniferous sawnwood sales and deliveries. The thesis sample data come from the sales database from coniferous sawnwood sales from Finnish sawmills between 1995 and 2000. The supply analyses are based on this sales database.

There are several limitations in the outline of the thesis with some exceptions mentioned in the context. The limitations are:

1. Coniferous sawnwood supply and demand are approached as interaction between sawmills and their customers. Demand sources such as construction systems, traditions and activities, industrial end-users (e.g. furniture, joinery, package and garden industries) and some other aspects are approached in a limited scale (see Figure 4).
2. The thesis presents several analyses with a product approach (e.g. end moisture content or quality) for some supply situations, but it does not present a universal analysis.
3. The thesis approaches sawnwood consumption from a country or region perspective during the period from 1961 to 2002. The thesis focuses especially on sawnwood supply and demand between the Finnish sawmilling companies and their customers during the period from 1995 to 2000.
4. There is no test for sawmill data reliability but the data can be assumed to be correct.
5. The thesis approaches sawnwood features mainly through database analysis.
6. The Finnish sawnwood sales from 1995 to 2000, the main sample in the thesis, are limited to the Finnish sawmill quality classes that may be better than some CSW quality classes elsewhere in Europe. Therefore the sawnwood supply and demand picture is more accurate when limited to the sawnwood sales in the Finnish sawmills. Moreover, sawnwood supply and demand in Finland can be described with the sample as CSW import to Finland is small.
7. The log origin and qualities need be taken into account with the Finnish sawnwood sales from 1995 to 2000, when quality, length and other aspects are evaluated. The CSW sample from 1995 to 2000 describes raw material originating mainly from the Finnish forests. However, the sample may emphasise CSW quality from mature forests due to the Finnish forest tax reform during the period. It is possible that the imported log as raw material in the Finnish sawmilling industry is a temporary phenomenon. Nevertheless, the timber import from Russia to Finland may have an effect on CSW quality distribution.

8. The concept of sawnwood refers here only to the coniferous sawnwood and these two species: the Scots pine (*Pinus sylvestris*) and the Norway spruce (*Picea abies*).
9. The distribution character of sawnwood as a product needs to be taken into account when the sample is approached and the results evaluated. Therefore, most results have to be viewed and evaluated with methods appropriate for distributions.
10. Data mining is the main analysing concept for databases in the thesis (see more e.g. in Section 3.1.2).

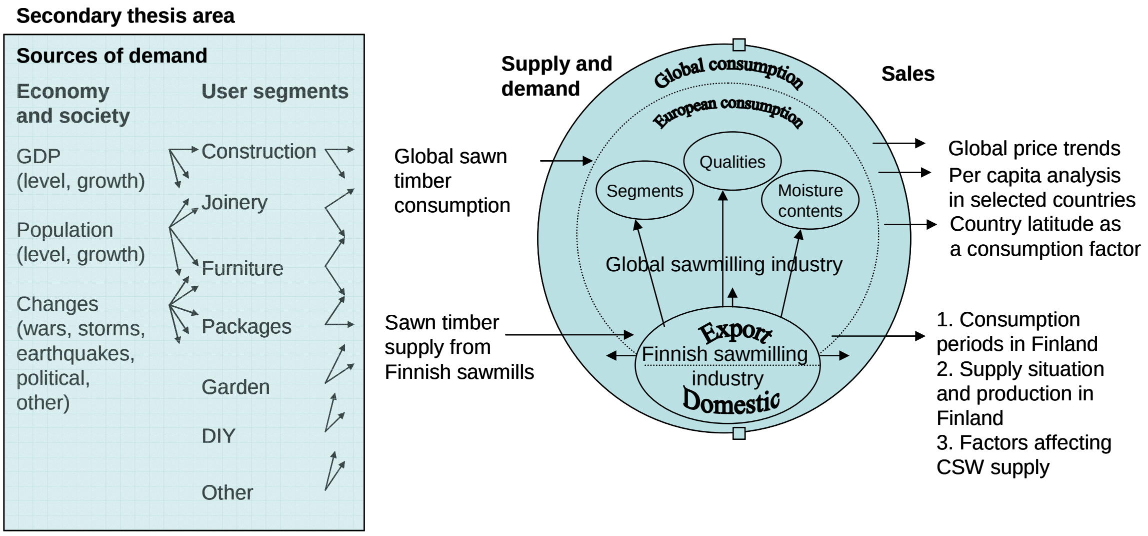


**Figure 4. Limitations of the thesis. The secondary research areas are shown on the left.**

There are two reasons for limitations shown in Figure 4:

1. There are demand models analysis for coniferous sawnwood and other forest product industry products (e.g. Roadmap 2010, 2003 and Timwood 1998). These demand models and analysis are usually designed to forecast or estimate demand of a product or products in a market environment. In addition, some demand models may use the methodology of time-series analysis, which is restrictedly used in the thesis.
2. Thesis data, a large database from sawmills' sales, give an opportunity for a new, more accurate perspective to analyse sawnwood supply and its patterns between sawmills and their customers. These supply and demand features have not been published or have been published seldom in the relevant literature or the scientific papers.

# 2 CONTEXTUAL FRAME TO ANALYSE SAWNWOOD SUPPLY DISTRIBUTION

## *2.1 Coniferous sawnwood as a product*

### 2.1.1 Product concept

#### 2.1.1.1 Commodity product character

The product definition of Kotler (1990) can be applied so that coniferous sawnwood as a product is a produced commodity, which can be defined as an article of (1) a measured amount, (2) defined quality and (3) interchangeability on the market. According to Parkin (1999), articles can be end or intermediate products, goods and services. End products are consumption articles. Intermediate products are goods and services used as inputs in the products that firms eventually sell to end-users. Sawnwood is often used as an input in the construction process to produce e.g. houses, furniture and bridges. Thus sawnwood can be seen as an intermediate product.

Kotler (1988) also defines an idea behind the product, a concept, so that the product concept includes the idea that consumers will favour those products that offer the most quality, performance, and features. According to Kotler (2000), a product is any offering that can satisfy a need or want; in this definition, offerings include goods, services, experiences, events, persons, places, properties, organisations, information and ideas. Compared to the product definition of Kotler (1990), coniferous sawnwood fulfils the requirements (1) and (3), but the requirement (2), defined quality, must be adjusted with sawnwood.

#### 2.1.1.2 Elasticities

The sensitivity of sawnwood supply and demand to respond to changes is estimated by demand elasticities. The sawnwood price elasticity of demand is a units-free measure of the responsiveness of the quantity demanded of sawnwood to a change in its price when all other influences on buyers’ plans remain the same (Parkin 1999). Sawnwood supply and demand elasticity in this context means a connection with quantity – e.g. quality class, end moisture content, end-user segment – price or number of sales, and a change in the estimated variable. Elasticity is the ratio of the sawnwood percentage change in the quantity demanded to the percentage change in the price, quality (e.g. end moisture content) or other product variable (Parkin 1999). Variable changes are expressed as relative values for mutual comparisons of elasticities. Elasticities – e.g. quality or price elasticity of demand – can vary from –infinity to +infinity. If the elasticity value is less than one, demand is inelastic, and if elasticity is more than one, elasticity is seen as elastic. The amount of demand elasticity is affected by the necessity of the sawnwood to buyer and the replacability of the sawnwood (Parkin 1999, Vaara 1998). In addition, the concept of the demanded bundle may reveal the connection between consumer behaviour and demand. The demanded bundle expresses how much of each good the consumer desires at a given level of prices and budget (Varian 1992).

### 2.1.2 Quality

#### 2.1.2.1 Definitions

Sawnwood quality is a subjective concept, not absolute. It is often based on visual examples and, to some extent, exact definitions. Often all sawnwood quality measurements are vis-à-vis comparisons, estimates or conditional definitions. For instance, this is the case in manual sawnwood dry sorting where the sorting operator compares quality in his or her mind to the quality image and makes a grading decision in a few seconds based on this comparison.

The dependence of quality on the background and the needs of decision maker is characteristic of sawnwood quality. Quality has two sides, quality as a value, which is the aim of economic operations, and quality as production based concept (Lillrank 1990). For sawnwood, quality as a production concept has usually been considered more important in sawmill production.

In North European sawmill operations, quality usually means a value as such. As an example of this, quality systems have become a common standard in sawmills during the last ten years. In quality grading, the line quality is a production parameter, which is approached through quality instructions, images by experience as well as comparing visual quality with other surfaces.

The customers of a sawmill see quality also on two levels. They assess the quality of a sawmill (1) from the image based on the operations of a sawmill, e.g. the quality system of a sawmill or willingness to hear the needs of a customer, and (2) from the feedback of their own operations, e.g. sawnwood reject rate. The first level of these – the image based on the operations of a sawmill – can be seen in the traditional sawnwood invoice, where there used to be a statement "Shipper's usual quality". This referred to quality differences between shippers as well as sawmills (Luther 1986b).

The concept of quality can be defined in many ways. Quality can be defined as a product's or an operation's ability to meet a customer's needs or expectations (Danielsson 1981, Kettunen 1981, Sandholm 1988, Soin 1992). A concept of Japanese origin, Total Quality Control (TQC), has a similar basis with the expression that quality means customer satisfaction (Lillrank 1990). Quality can also be defined as a product's or a service's suitability for the use (Danielsson 1981, Sandholm 1988). In Swedish quality terminology, standard quality covers all product-related properties that help a product to meet the need that has been expressed completely or partially (Sandholm 1988, SS 020104 1987). Garvin (1988) does not try to define quality with a sentence but analyses the quality concept in the five approaches of principle that have been presented in Table 3.

**Table 3. Five quality definitions. The references are adapted through Garvin (1988) or from Kotler (2000). Modified by author.**

| Definition | Explanation |
|---|---|
| **I. Transcendent** | •...condition of excellence which means good quality separation from bad quality … quality is achieving a higher level instead of being satisfied with careless or dishonest work (Tuchman 1980) |
| **II. Product-based** | • Quality differences mean differences of amount in a desired thing or feature (Abbott 1955, pp. 126–127)<br>• Quality refers to amount of unpriced features that are included in every priced feature (Leffler 1982, p. 956) |
| **III. User-based** | • Quality consists of capacity to meet the needs (Edwards 1968, p. 37)<br>• In final market place analysis product quality depends on how well it fits to ideal of customer's preferences (Kuehn et al. 1962, p. 101)<br>• Quality is suitability to use (Juran 1974, p. 2–2)<br>• Quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs (Kotler 2000, p. 57) |
| **IV. Manufacturing-based** | • Quality is adaptation to requirements (Crosby 1979, p. 15)<br>• Quality is the degree that a certain product is adjusted to plan or cost estimate (Gilmore 1974, p. 16) |
| **V. Value-based** | • Quality is a level of excellence with an acceptable price and distribution control with an acceptable cost (Broh 1982, p. 3)<br>• Quality means the best for certain customer conditions. These are a) actual use, b) the selling price of a product (Feigenbaum 1961, p. 1) |

Quality often includes an idea of continuous quality improvement. If development stops, this means at least a threat of declining quality compared with competitors. According to Soin (1992), Kano (1984) approaches this perspective by suggesting a two-dimensional quality concept, which states that quality approaches are 1) Compulsory quality level, must be quality, 2) Attractive quality. The compulsory quality level is the level of a product or a service that a customer expects, but the attractive quality level exceeds present needs and expectations.

An example of attractive quality can perhaps be the ability of a sawmill to deliver special dimensions and customer-based grades to a customer with sufficient information of product and production process. On the other hand, one must take into account that an attractive quality of sawnwood changes gradually into a compulsory quality. For this reason, the concept of sawnwood quality must always be linked to time and place as well as the needs of the seller and the buyer. These needs that can be different.

The definition of sawnwood quality concept does not differ from other quality concepts significantly. Swedish Skogsordlista (1994) defines sawnwood quality as suitability for defined further processing or use. Perstorper (1994) states that quality concept is more often used with wood products to express a level of a specific property than suitability to a defined end use. Sipi

(1991) divides sawnwood quality in production and use based on material flow as (1) raw material quality, (2) sawnwood quality and (3) end product quality. Sipi (1991) groups sawnwood quality based on end use as visual quality and constructive quality, i.e. strength-graded quality. Visual quality is based on sawnwood surface qualities. Strength-graded quality is based on wood properties linked with strength.

On sawnwood market, the obscurity of product character leads both sellers and buyers to more accurate but still not unambiguous product definitions. One example of this is to group sawnwood as commodity, special and customer products, which is an idea by Juslin and Hansen (2002). As an operation mode, this emphasises product definitions between sawmills and their customers.

The Association of Finnish Sawmillmen (2002) emphasises product definitions, too. The Association of Finnish Sawmillmen (2002) states (p. 24) that it is an imperative to attach the grading rules of a sawmill and their exceptions to a contract of sale, if a sawmill wants to settle quality disagreements according to its own grading rules. Often after the quality decision, a customer of a sawmill orders a CSW test sample and sees how the CSW price and quality fit to the use of the customer. After this, the customer typically makes specifications and more accurate requirements in the next sales negotiation. Some of the customer relationships that have begun with an experiment like this lead to standardised specifications, where a customer wants a certain quality from a sawmill even for many years, because the quality grading of the sawmill suits the needs of the customer.

Coniferous sawnwood as a product has changed in the direction suggested by Juslin and Hansen (2002), where sawmills produce not only commodity products but also special and customer products. These special and customer products are typically special qualities, for which quality names have not been defined in common grading rules. The Association of Finnish Sawmillmen (2002) emphasises that these qualities must be listed in the own grading rules of sawmill and they must be defined carefully in contracts of sale. For instance, if sawfalling quality (SF) is used, it must be stated which qualities belong to this quality. Other quality grades that need to be defined carefully according to The Association of Finnish Sawmillmen (2002) are qualities with wane such as schaalboards or export quality with wane (often with abbreviation VS/VL), and halvrena or a half clear side board, which have different quality contents in different sawmills. For strength graded timber sales, The Association of Finnish Sawmillmen (2002) recommends the use of standards such as SFS-EN 338 (2003) and SFS 5878 (2000), which is also called with the name INSTA 142.

Complexity of sawnwood as a product is emphasised by the different grading rules in different markets and species. For instance, in the United States coniferous sawnwood is most commonly graded according to the American Softwood Lumber Standard PS 20–70 (1970), established by the U.S. Department of Commerce. The standard PS 20–70 (1970) uses in some its sections fairly similar principles to Nordic timber (1994) by emphasising knot sizes and dimensions and by dividing sawnwood for general construction purposes into stress-graded, non-stress-graded, and appearance sawnwood. In descending order of quality, the grades in PS 20–70 (1970) are No. 1 (Construction), No. 2 (Standard), No. 3 (Utility), No. 4 (Economy) and No. 5 (Economy).

#### 2.1.2.2 Product properties

As summarised by Virtanen (1995), sawnwood quality requirements are reflected by (1) raw material quality and properties, (2) technical quality requirements (e.g. dimensional accuracy and other properties by Juvonen 1974 or Vuorilehto 2001), and (3) customer specified definitions of properties (e.g. furniture segment fresh knot qualities).

Sawnwood quality is directly connected to the properties of raw material, i.e. quality of logs for sawmills. For instance, eccentric growth and compression wood formation play major roles in the development of stem straightness and thus sawnwood straightness and deformation defects (Warensjö 2003). On the other hand, log quality distributions depend on wood species genes and ecological factors (e.g. climate, soil, location, external strains). Therefore sawmills are often recommended to adjust their operations and qualities according to harvesting area. For instance, Jäppinen (2000) recommends that mills should verify and develop log scanner classification models for their own log supply and sorting criteria.

When there were logs of various qualities delivered from forest to sawmills, the aim for sawnwood marketing was set to selling the whole CSW product combination with the best possible average price and total result. The main questions for sawnwood marketing have traditionally been (1) control of CSW product mix derived from log quality distribution, (2) the effect of CSW sales specifications to the average price of all production, (3) optimal CSW production allocation to markets. Sawnwood trade has characteristically matched product enquiries and available lots to sales specification by seller and buyer negotiations, where both CSW quality distribution availability and demand on the market have been taken into account. As long as CSW products were mainly standard quality classes, sales specifications could be matched between different customers and market qualities. When the number of special and customer quality classes increased, sales specifications, balance between markets and customers as well as the effect of average prices became much more difficult for sawmills. Moreover, the change of purchase inquiries from general list-based to specific quality class and product inclusive inquiries has made the demand situation more complex for sawmills.

Sawnwood quality requirements are traditionally expressed at sawmills by using quality instructions that divide sawnwood into as homogenous quality classes as possible. At least until recent harmonisation, both sawmills and sawnwood users have expressed sawnwood quality requirements as country-specific or company-specific. This may lead to misunderstanding of wished quality between a sawmill and a user, which causes retardation to woodworking industry development (Casselbrant 1992, Nordisk träteknik 1993).

According to Sipi (1991), sawnwood grading can be classified into visual and strength grading. Coniferous sawnwood grades are based principally on either structural uses (strength) or uses for which the board appearance, as a whole, is important (Bowyer 2003). In visual grading, sawnwood grading classes are defined on the basis of those visual properties that suit visual uses well. In strength grading, sawnwood is given strength values either by machine or visual method. Visual strength grading is based on inspection of defects that affect strength and stiffness. Machine strength grading can be executed by various operating methods.

Both material and demand factors affect sawnwood quality. Material properties depend on species. According to Gibson and Ashby (1988), species properties depend on wood anatomy and stem structure. The location, number, size and type of knots (see Figure 5) have traditionally been the most decisive properties of sawnwood qualities as well as of grading of a piece of Finnish sawnwood (Nordic timber 1994). Knot quality has been seen as the most important quality requirement for sawnwood as seen in Figure 5. Nevertheless, knots are often categorised by their form, location, size or composition. This makes knot quality a multi-level issue (Nordic timber 1994, see Figure 5). Properties like age and moisture have a significant effect on wood properties, too.

Grace (1993) says that the stem position of a sawn log (top, middle, butt) has a significant effect on sawnwood quality. Butt log gives better quality sawnwood than middle or top log. Moreover, Grace has recognised that tapering and gnarled form correlate with sawnwood quality. According to Grace (1993), logs with tapering more than 25 mm/m give higher quality sawnwood than other. This is probably not because of tapering but the reason is butt logs giving more often better quality. Therefore it can only be said that tapering indicates quality.

Thörnqvist (1993) assumes that some modern forestry models will probably produce sawnwood that has a low density and a small heartwood share. For sawnwood supply, this means two quality aspects: 1) sawnwood with more knots, lower density and lower strength, 2) larger juvenile wood share. The latter causes more easily shakes and deformation in drying.

Logging stage and log sorting decisions have an effect on sawnwood quality. For instance, optimised log length cutting optimisation can increase sawnwood production value for pine by

5% compared with traditional length cutting executed by forest worker (Usenius et al. 1987). Forsén et al. (1993) state that sawnwood quality can be improved in a sawmill by drying actions targeted to decrease sawnwood splitting in drying. This is possible by developed sawnwood drying simulation models for specified dimensions. Decisions made for sawnwood size (thickness, width, length) and technical quality properties (surface quality, size control and moisture content) have an effect on sawnwood quality (Juvonen 1974, Sipi 1991).

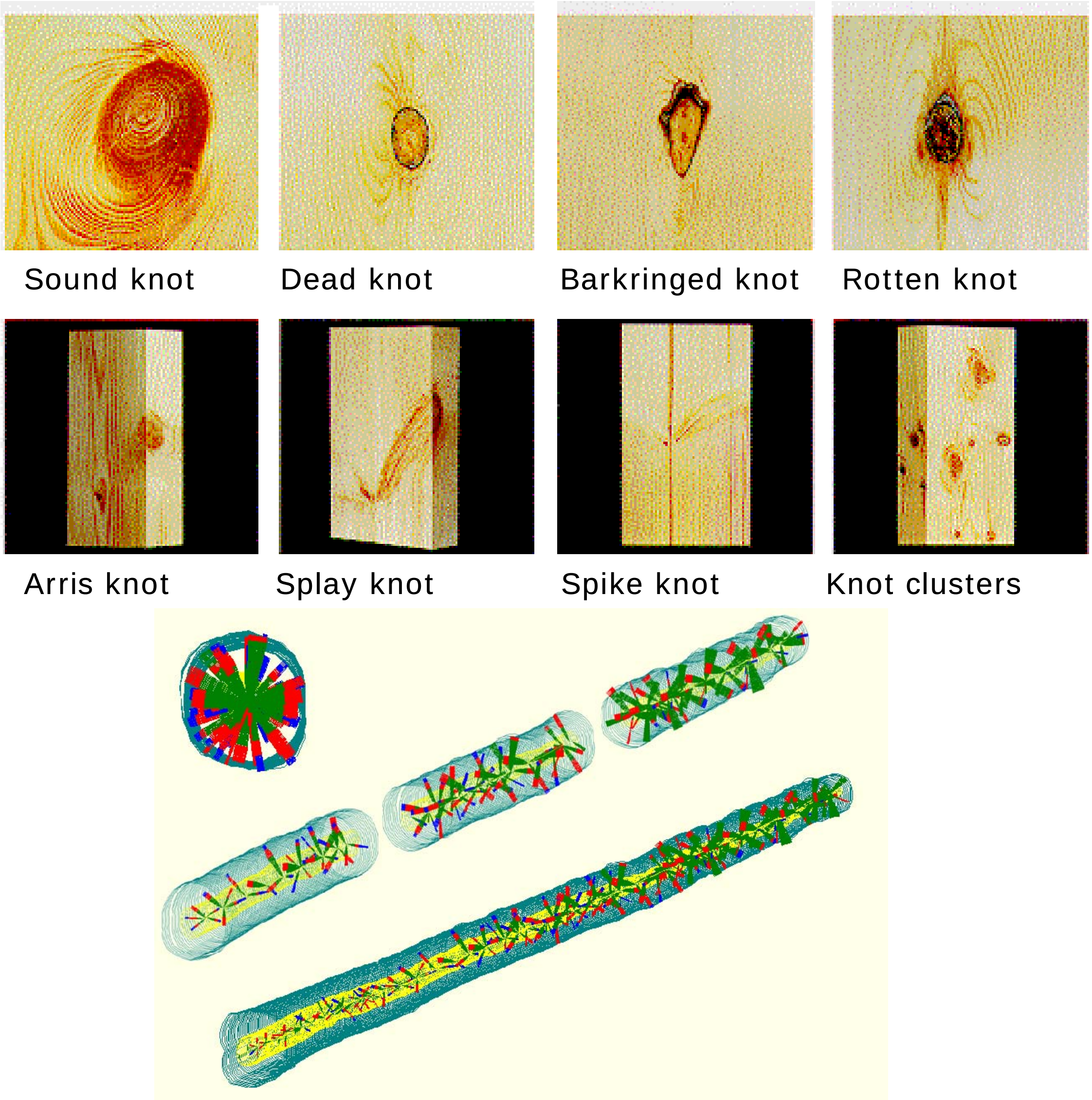


**Figure 5. Knots (above) by Nordic timber (1994) and knot formation (below) by Usenius (2005).**

Rydell (1992) states that sawnwood quality requirements are expected to change within a period of 10 years. Present sawnwood supply and demand profile differs from what it was 10 years ago but the trends were recognizable that time. Some trends within the demand profile have been the following:

- Batch sizes have become smaller. This is probably partly because of increased requirements for turnover time.
- Smaller dimensions have replaced larger dimensions in joinery and construction segments. This is probably partly because component manufacturing through joints and gluing has given new opportunities to both sawmills and their customers.
- New customer qualities (including quality class, dimension, and length) have come to be a part of the demand profile of some markets. This is probably partly because new markets and their new customer demand and new processes like machine vision systems in grading.
- Consciousness of environment has increased. This has greatly affected forestry and sawmilling. Some of the present themes are forest certification and information reliability in forest-customer chain.

Rydell (1992) assumes that sawnwood demand of joinery and furniture segments is based more on preferences and visual taste than operational requirements (e.g. machine efficiency). For instance, window quality requirements differ from country to country based on accepted national quality level. In some countries, a knotless surface is required, but in others, small knots are allowed. In some countries, solid blanks for joinery are preferred, whilst in other countries people insist on laminated structures with finger joints. On the other hand, in the solid wood furniture market, fashion and visual tendencies play a significant role. In history, there have been furniture trends for pine surfaces with large, fresh knots as well as for knotless appearance.

### 2.1.2.3 Classes and grading

Savolainen (1971) says that the commercial quality of sawnwood is influenced by raw material quality, production method, finished sawnwood care (storage conditions etc.) and grading. Puuteollisuus (1964) presents a similar list but adds service, which means rapidity of delivery, terms of payment, specifications and other adaptations to requirements of a customer.

According to Green book (1960), the quality class is determined by two traditional principles: (1) defects in quality (structure, manufacture, shakes and deformities), (2) defects in condition (moisture, blue, other discolouration). Nordic timber (1994) expresses more accurately that sawnwood quality is determined according to sawnwood properties, and location, amount, size and contents of defects. Juvonen (1974) presents the concept of technical quality and says that technical quality includes sawnwood properties that can be achieved in the sawing and kiln drying process. According to Juvonen (1974), technical quality is measured based on sawnwood size and shape accuracy, surface quality and moisture content.

Sawnwood quality classes (e.g. U/S or SF) are often used both in sawmills and distribution channels with identical names but different contents of the names (Virtanen 1995). Nordic timber (1994) uses the main quality class names A, B, C and D, of which A broadly corresponds to Green book (1960) U/S quality class, B corresponds V quality, and C (partly D) VI quality class (Figure 6). The sawmills use more often quality class names U/S, V, VI as well as other names. Accordingly, the quality class names of U/S, V, VI and other names are used in the thesis instead of names A, B, C, D and other.

**Figure 6. Three sawnwood quality classes U/S-A (above pine, below spruce), V-B (middle p, s), VI-C (below p, s) according to Nordic timber (1994).**

Määttä (1986) presents that full edge quality classes with no wane are U/S quality class (covering quality classes of I, II, III and IV) and quality classes of V and VI. According to Määttä (1986) quality classes with wane are export quality (VS/VL) for studs, and board qualities PL/VL (export quality), PL/KL (domestic quality), knot free boards and half clear quality (halvrena). According to Nordic timber (1994), quality class A is the highest quality class that covers falling share of production qualities A1, A2, A3 and A4. D is the lowest quality class that has a minimum with a verbal definition but no detailed table values. Sawnwood can also be graded with every quality class separately or combining qualities to quality AB or ABC. Nordic timber (1994) uses the terms customer or special qualities for some quality combinations like fresh knot sawnwood (e.g. knotty pine) and stammware – sawnwood.

The names and contents used in grading instructions differ significantly between instructions. Green book (1960) uses the term Export qualities and Nordic timber (1994) main, customer and special qualities. Puuteollisuus (1964) describes quality class differences between countries and in history by comparing quality class names of Finland, Sweden and the Soviet Union. According to Puuteollisuus (1964), Finnish and Swedish sawmills graded their sawnwood to quality classes of U/S (four classes - prima, sekunda, tertia and kvartta), V and VI. The grading system in the Soviet Union was to grade sawnwood into two quality classes, U/S and the fourth quality (kvartta). According to Puuteollisuus (1964), the quality class V in Finnish and Swedish sawmills corresponded to the fourth quality class (kvartta) in the Soviet Union at that time.

The Finnish sawmills have their own quality classes whose names and contents differ between sawmills. The own grading rules of sawmills can classify quality classes by dividing them into e.g. qualities with no wane and qualities with wane. The fresh knot customer quality classes can be named e.g. “Knotty pine” or “Möbel fifth, i.e. Furniture quality fifth”. The contents of these customer quality classes can differ between sawmills (Virtanen 1995).

According to Savolainen (1971), quality can be better described by sawnwood mark than by quality class. These sawnwood marks indicated quality and origin of both sawnwood and raw material, and were called pine and spruce quality marks, too (Table 4). Puuteollisuus (1964) uses the name the shipping mark instead of the sawnwood mark. According to sawnwood marks, sawmills were divided to six pine price groups and four spruce price groups (Table 4). According to Savolainen (1971), sawnwood mark had little to do with pricing because sawnwood basis price better describes sawnwood price quality. However, Määttä (1986) connects quality marks (shipping marks) and prices. According to Puuteollisuus (1964), in the sawnwood trade between the Finnish sawmills and their customers, knowing the shipping marks (or price groups) and their quality content stability was much more important than knowing the sawmill that has produced the sawnwood. According to Määttä (1986), in the sawnwood trade between the Swedish sawmills and their customers they more often referred to the locations and shipping ports of sawmills. Määttä (1986) also comments that there was quality and price variation in price groups, and therefore price grouping was one of the most difficult tasks to explain and describe in sawnwood trade.

**Table 4. Quality marks and price groups of pine and spruce according to Savolainen (1971) and Määttä (1986). Modified by author.**

| Pine quality marks and price groups | Spruce quality marks and price groups |
|---|---|
| 1. Leading shippers of North and East Finland, representing joinery quality. The highest price.<br>2. Leading marks (shippers) of West Finland and similar large marks of North Finland that represent joinery quality. The second highest price.<br>3. Leading marks of South Finland. Severe grading.<br>4. Leading marks of South Finland. The raw material mainly comes from Central, East and South Finland. Not as severe grading as in the three previous groups.<br>5th and 6th group – other pine shippers including small sawmills that do not follow severe grading. | 1. Leading shippers of West and East Finland (spruce marks). Severe grading.<br>2. Shippers of South Finland practising severe grading (spruce marks). Good but slightly less expensive than the previous group.<br>3. Leading shippers of South Finland.<br>4. Group of other spruce shippers. Small spruce marks. Prices below the previous groups. |

Pakkanen et al. (1999) have researched pine and spruce quality class distribution in 1997 in Finland (Table 5). According to Pakkanen et al. (1999), the main quality class for pine was V and for spruce SF. The largest part of pine and spruce SF qualities were such that SF quality does not include VI qualities. It is also interesting that the knotty pine quality had only a small importance. Only 4% of pine was graded according to fresh knot quality class grading criteria.

**Table 5. CSW quality class distribution 1997 adapted from Pakkanen et al. (1999). Modified by author.**

| **Quality class** | **Pine** | **Spruce** |
|---|---|---|
| **U/S** | 20% | 19% |
| **V** | 30% | 23% |
| **VI** | 21% | 6% |
| **SF (U/S+V)** | 12% | 35% |
| **SF (+VI)** | NA | 2% |
| **VL, export quality** (In Finnish “vientilaatu”) | 5% | 11% |
| **KL, domestic quality** (In Finnish “kotimaan laatu”) | 4% | 2% |
| **HVS, quality for planing with wane** (In Finnish “höylävajaasärmä”) | 4% | 2% |
| **Knotty pine** | 4% | Not available |
| **m$^3$** | 4,900,000 | 5,700,000 |

From the thesis perspective, it is interesting to ask how quality class supply – quality class distributions – developed during the period from 1995 to 2000.

### 2.1.2.4 Quality classes, dimensions and export countries

Juslin and Karppinen (1983) showed that, in the 1970s, the quality classes of the Finnish sawmilling industry and wood species depended on the country of buyer and the demand in that country. Thus, in sawnwood supply and demand there can be found countries that use certain species-quality class connections more than other countries. According to Juslin and Karppinen (1983), in the 1970s, UK markets bought on average 45% of Finnish CSW pine U/S quality, 4% of pine V quality and 40% of pine and spruce VI quality. Furthermore, Denmark was recognised as a country that bought significant amounts of pine U/S quality. Juslin and Karppinen (1983) also presented the Netherlands, France and West Germany as countries with significant purchases of spruce CSW from the Finnish sawmilling industry.

Furthermore, Juslin and Karppinen (1983) researched the importance of dimension classes in Finnish sawnwood exports in the 1970s, broadly by dividing dimensions into boards, planks, studs and wane edged sawnwood. According to the results, planks and studs were significantly exported from Finland to UK, France, the Netherlands and West Germany in large amounts. Markets for wane edged sawnwood were in West Germany, Denmark and the Netherlands. According to Juslin and Karppinen (1983), the buyers’ behaviour was the most stable when measured by quality and dimensions in the following countries (in descending order): Denmark, Belgium, UK and France. In West Germany and Ireland, the buyers’ behaviour was the least stable. Furthermore, Juslin and Karppinen (1983) found the five most popular CSW products purchased by countries and exported from Finland in the 1970s (Table 6).

**Table 6. The five most popular Finnish export CSW products by country in the 1970s. Data from Juslin and Karppinen (1983).**

| UK | Denmark | France | West Germany | the Netherlands |
|---|---|---|---|---|
| Pine U/S 63 x 150 | Pine U/S 50 x 125 | Spruce U/S 63 x 150 | Pine/Spruce schaal 22 | Spruce U/S 22 x 100 |
| Pine U/S 50 x 150 | Pine U/S 25 x 100 | Pine/Spruce SF 63 x 150 | Spruce U/S 44 x 100 | Pine/Spruce SF 22 x 100 |
| Pine U/S 50 x 100 | Pine U/S 19 x 100 | Spruce U/S 75 x 150 | Spruce U/S 50 x 100 | Pine/Spruce schaal 19 |
| Pine V 50 x 150 | Pine/Spruce schaal 25 | Spruce U/S 63 x 175 | Spruce U/S 55–57–100–150 | Pine/Spruce halvrena |
| Pine V 50 x 100 | Pine/Spruce schaal 19 | Pine/Spruce SF 63 x 175 | Spruce V 22 x 100 | Spruce V 22 x 100 |

Assumptions by author: a) Schaal = export side board (QPLVL1) with small wane, b) halvrena = half clear side board with wane on both edges. Both a) and b) can be used for tongue and groove products.

From thesis perspective it is interesting to see if similar dependencies of species and quality classes can be found for the countries in Table 6, and, if dependencies can be found, what is the strength of the dependencies.

### 2.1.2.5 Distribution

In a contract of sawnwood sale, sawnwood has a categorical quality typical for nature products, a quality class, for which the quality contents must be defined separately according to sawmill, sale or customer. In a contract of sawnwood sale, the defined quality is always a distribution of defined quality. Therefore historically, in contracts of sawnwood sales, there have been typical specifications such as “sawmill’s usual” or “shipper’s usual quality” (Määttä 1986). However, it has always been a challenging task to define sawnwood quality in an unambiguous way because CSW is based on nature material. Therefore, CSW product definitions typically contain percentage values of a feature or a share of the feature in proportion to an entity, e.g. 5% or 10% of CSW amount may contain a specified defect.

The question of coniferous sawnwood as a product is linked with restrictions of sawnwood business, sawmilling history and nature material. These restrictions together define sawnwood product assortment and product demand dynamics (Figure 7).

Coniferous sawnwood as a product is always a distribution of several properties, which have forms and limits. These properties can be classified into those that can be measured accurately or fairly accurately and into those measured by distributions. Accurate properties typically include tasks done in the sawmills, such as packaging and labelling. Fairly accurate properties include product sizes (width, thickness, length) that a sawmill can produce according to customer requirements with a limited distribution. Those properties measured by distributions include most sawnwood properties such as moisture content, strength and the visual properties of a product. Distribution-based properties can be defined only by a distribution and limits. A typical distribution is sawnwood moisture content distribution, e.g. 12 ± 2%.

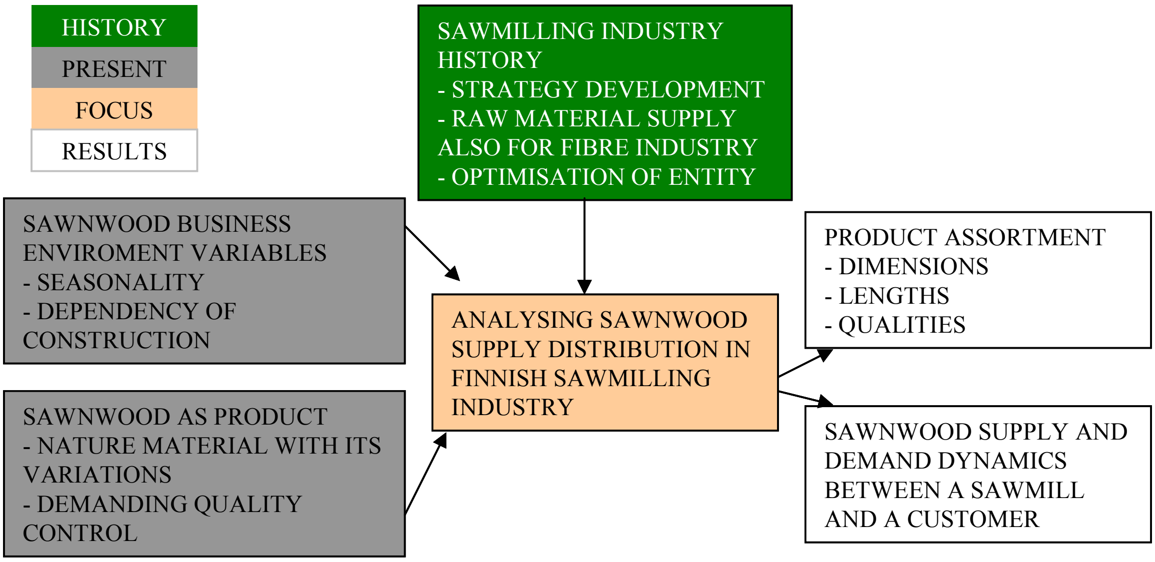


**Figure 7. Sawnwood as a product and factors affecting the supply distribution.**

According to The Association of Finnish Sawmillmen (2002) (Nordic timber, Sawnwood contract handbook) used by Finnish sawmills, the seller is committed to deliver a grading which is described as “supplier’s usual quality”. In practice, this ensures stable quality between a sawmill and a customer. In addition, this means exceptions for sawmills and suppliers as well as rights to negotiate the grading between sawmills and customers. According to the principles in The Association of Finnish Sawmillmen (2002), sawnwood is not approached as an exactly defined product but through a certain product frame in which there are allowed sawmill grading exceptions, which must be exactly defined in the contract. Nordic timber (1994) and EN 1611–1 (1999) thus form a frame for the quality and grading of a product. In this frame of sawnwood quality and grading, the production method of sawnwood is often a product component (Figure 8). Furthermore, there have been several instructions and standards designed to help in unambiguous understanding of sawnwood trade and its relevant terminology, such as e.g. Casselbrant et al. (2000), SFS-EN 1611–1/A1 (2002), SFS-EN 1611–1 (2000), SFS-EN 1912 (1998) and other instructions and standards listed in Appendix 6.

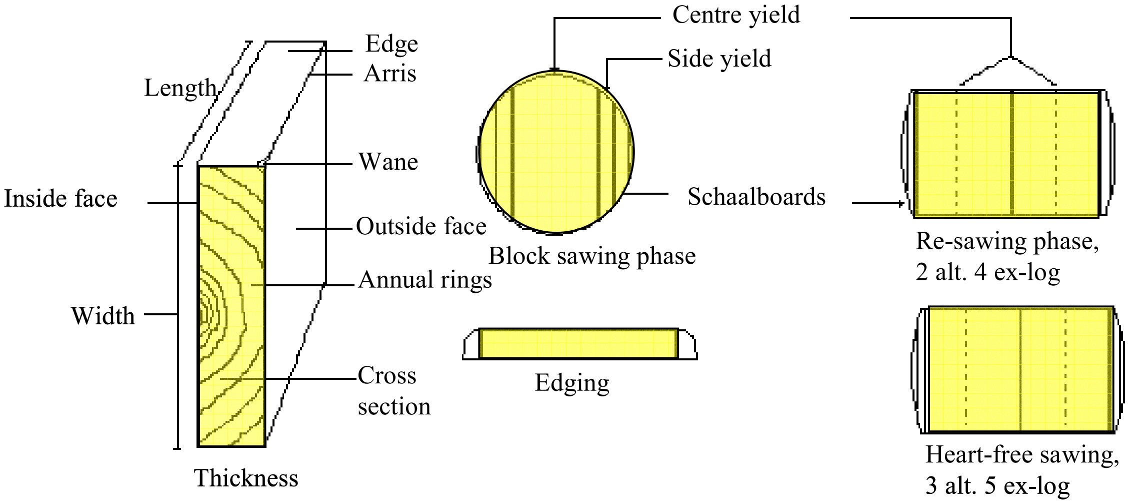


**Figure 8. A centre yield piece of sawnwood (Left), Log breakdown according to Nordic practice (Right). Terminology from Woodfocus (2003). Modified by author.**

### 2.1.2.6 Measuring

During recent years there has been a tremendous development of new measurement technology for sawnwood and similar products. This enables for the first time in history the making of absolute quality measurements within a relatively short period of time. Machine vision technology and non-destructive testing such as size control systems are examples of this.

Nevertheless, measuring sawnwood quality is a subject that is historically mostly based on categorical data instead of numerical data. Quality classes are themselves an example of categorical data. However, quality classes are often based on knot, fissure and other defect classes. They all are classified by categorical data with relative measurement compared to other quality features, e.g. knot types and sizes of these features.

Thus sawnwood quality determination is executed according to two principles:

1. Absolute measurement. This is based on a feature, e.g. size control of sawnwood, e.g. in Vuorilehto (2001). This measurement covers the following, e.g. knots, fissures, wane, resin pocket, deformation. See Nordic timber (1994).
2. Relative measurement. This is based on a comparison to a given value, e.g. amount of CSW pieces in a sample, e.g. 95%, must contain MC with 12 ± 2%. See Johansson et al. (1993).

Sawnwood quality for most coniferous sawnwood is graded by visual inspection (Bowyer et al. 2003). Visual inspection can be done by automatic visual grading systems or manual grading. Dimension timber to be used in engineered structures can also be graded by machine and therefore called machine stress-rated timber (MSR). The main use of MSR timber is in floor trusses, trussed rafters, and gluelam beams. The MSR machine usually measures the stiffness of timber by flexing in the flatwise direction and measuring the force required to do so. In 1999, more than 3.54 million $m^3$ of coniferous sawnwood was machine-rated in the United States, an increase of 90% since 1983 (Bowyer et al. 2003).

#### 2.1.2.7 Customer satisfaction

Customers ask above all that coniferous sawnwood (CSW) has straightness and strength, because coniferous sawnwood is mainly used in construction (Bowyer et al. 2003). Johansson et al. (1995) say that the performance of sawnwood used by the building industry can be expressed in different ways depending on the end use of a particular product. The mechanical performance of timber beams used in floor structures is often governed by their stiffness, while most timber used in roof structures is governed by its strength. It is assumed that the straightness will become the most important factor of sawnwood (Johansson et al. 1995).

Customers are mostly satisfied with coniferous sawnwood availability and ease of use. The largest gap between importance and satisfaction can be found in straightness, which customers demand the most but receive little (Figure 9). The second important issue is strength, which includes knots and slope of grain that are the main characteristics that reduce strength (Bowyer et al. 2003).

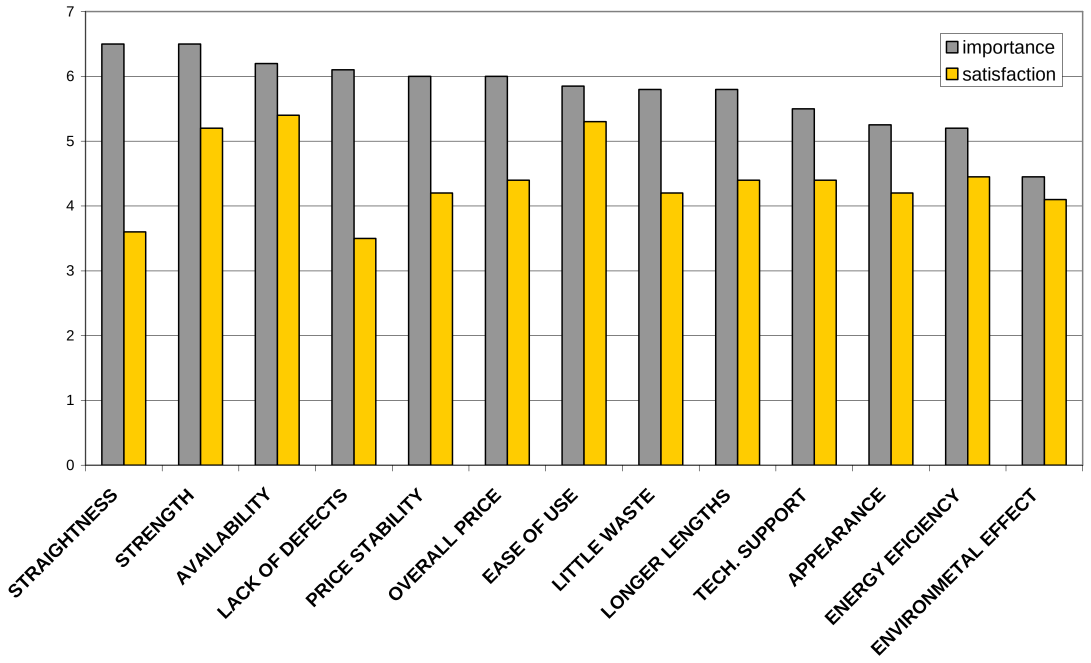


**Figure 9. The satisfaction-importance gap in the construction segment of CSW. The maximum score is 7 (y axis). Fleishman et al. (1999), Rytkönen (2003). Modified by author.**

It is probable that Fleishman et al. (1999) have got their results from a sample that emphasises structural use of sawnwood. Virtanen (1995) has presented slightly different results that largely emphasise quality aspects in kiln drying (fissures) and knot quality as well as some structural properties (Figure 10). Distribution and end-user segments had a different importance of sawnwood quality requirements in Virtanen (1995).

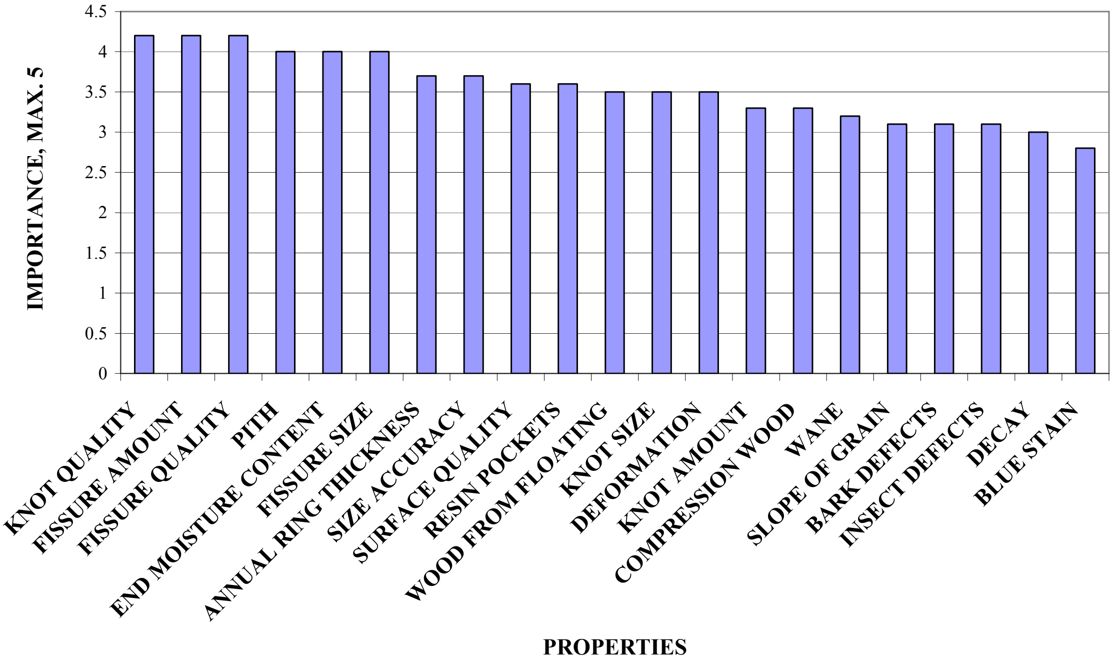


**Figure 10. Importance of sawnwood quality requirements for sawnwood users from Virtanen (1995). Maximum value for importance measure (y axis) is 5.**

The strategy of the Finnish sawmilling industry to respond to the needs of user segments are briefly defined by Woodfocus (2003): (1) precise dimensions, (2) kiln drying and grading based on highest technical standards, (3) different wood species, dimensions and grades handled separately.

## 2.1.3 User segments

### 2.1.3.1 Segmentation approaches and estimates

As stated earlier, coniferous sawnwood is used principally as building construction material. According to Bowyer et al. (2003), this includes use as structural members, for decorative or finishing purposes such as panelling, siding, decking, exterior trim material as well as windows and doors. However, there are other user segmentation approaches, too (see Table 7). Timwood (1998) uses distribution segments parallel with end-users, which may confuse segmentation, because distribution segments include end-user segments.

**Table 7. Examples of user segmentation approaches.**

| **User segmentation according to Profitable Sawmill (1993) a)** | **Segmentation according to Timwood (1998)** |
|---|---|
| Joinery – windows and doors<br>Furniture and edge glued panels<br>Gluelam (laminated beams)<br>Prefabricated houses and timber frame<br>General construction<br>Mouldings<br>DIY<br>Package and pallets | Distribution segments<br>- Box stores b)<br>- Contractor yards c)<br>Industrial end-users a)<br>- Prefab (i.e. prefabricated houses)<br>- Windows and doors<br>- Furniture |

a) All product segments.
b) Big warehouse like buildings used in mass retailing home improvement products including building materials to primarily to private customer including DIY.
c) Traditional timber yards mainly retailing building materials to primarily the professional end-user, builder or contractor.

The single largest use of coniferous sawnwood in the United States is as dimension lumber used in light-frame buildings, when some 85% of all housing units are built light-frame. Less than 5% of the housing construction in Europe is timber frame but in North America around 90% (Roadmap 2010, 2004). Similarly in Finland in 2002 as in the United States, the use of wood in frame construction was 85% for one-family houses, 57% for semi-detached houses and row houses but only 1% for apartment houses (Teriö et al. 2005). Nevertheless, the share of wood in frame construction for semi-detached houses and row houses in Finland has declined 12% in 5 years (69% in 1998).

The construction of new single-family homes in the United States utilised more than one-third of the total CSW production in 1999 (Howard 2001 through Bowyer et al. 2003). In 2001, there were 1.5 million homes constructed in the USA for a population of 280 million whereas in Europe there were 1.7 million homes constructed for a population of 380 million (Rämö et al. 2003, Euroconstruct 2000).

Coniferous sawnwood user segments can be seen in Table 8. It should be noticed that estimates contain suppositions.

**Table 8. Sawnwood user segments and estimates. Modified by author.**

| **Sawnwood demand segments** | **FI** | **Ref** | **UK** | **Ref** | **US** | **Ref** | **DE** | **Ref** |
|---|---|---|---|---|---|---|---|---|
| **Joinery-windows, doors, frames, stairs** | 8% | a, h | 8% | a, e | 5% | a, c | 3% | a, d, e |
| **Furniture, edge glue boards** | 4% | a, h | 6% | a, e | 3% | a, c | 4% | a, d, e |
| **Construction-new single family housing** | 34% | a, g, h | 17% | a, e | 38% | b, c | 24% | a, d, e, i |
| **Construction-industry, offices, farms** | 8% | a, g, h | 7% | a, e | 8% | a | 10% | a, d, e, i |
| **Construction-repair and renovation** | 11% | a, g, h | 11% | a, e | 10% | a | 11% | a, d, e, i |
| **Construction-infrastructure, bridges, other** | 5% | a, g, h | 4% | a, e | 4% | a | 3% | a, d, e, i |
| **DIY** | 5% | a, h | 17% | a, e | 12% | a | 16% | a, d, e |
| **Packaging** | 8% | a, h | 12% | a, e | 5% | a | 9% | a, d, e, i |
| **Fences, garden** | 11% | a, h | 12% | a, e | 8% | a | 10% | a |
| **Other** | 6% | a, h | 6% | a, e | 7% | a | 10% | a |
| **Total, %** | 100% |  | 100% |  | 100% |  | 100% |  |
| **Demand, million m$^3$, year 2002** | 5.3 | f | 9.8 | f | 95.9 | f | 16.2 | f |

Ref: a – estimation by author, b – Bowyer (2003) p. 329, c – Timwood (1998), d – Saksan sahateollisuus (1992), e – Profitable Sawmill (1993), f – FAOSTAT data (2004), g – Luther (1986a), h – VTT (2004a), i – Rasimus (1996).

Based on Table 8, the following user segments have traditionally been significant to sawmilling industry:

1. Joinery. In Table 8, this includes visible joinery, windows, and doors. Usually, this segment has a need for visual quality but in some cases for strength, too.
2. Furniture. This includes edge glue boards in Table 8. This segment requires visual quality. However, the concept of the visual quality of furniture varies much from furniture with fine knotless texture to knotty texture with large but sound knots.
3. Construction. In Table 8, this includes load bearing constructions, exterior cladding, interior panels, slating battens, strips, flooring boards and other construction segments. The segment sets requirements for straightness and strength. However, it does not always require visual properties, because components often are sealed into the walls and other uses, etc.
4. DIY. The number of Do It Yourself people, usually skilled customers, has increased due to the increase of labour costs and spare time. This user segment covers a wide range of wood products. Typically CSW requirements may contain some private customer specifications like “product transportation with a passenger car”.
5. Packaging. In Table 8, this includes Euro- and Finn pallets, disposable pallets and packaging. Uses large volumes but usually low quality sawnwood.
6. Fences and garden. This includes a growing CSW use in both gardens and fences alongside roads.
7. Other. This includes some minor segments such as boat building, handicrafts, decorations and material for saunas. These user segments demand high quality sawnwood. Nevertheless, segment volume is relatively small but segment user value (€/m$^3$) for sawnwood high.

These seven (7) user segments can be characterised by visual, structural, technical and volume importance as in Table 9. Visual importance covers all visual aspects related to sawnwood quality (e.g. appearance, knots, stain), structural importance all structural aspects (e.g. Modulus of elasticity (MOE), strength), technical importance all technical aspects (e.g. accuracy of size and dimension, quality after kiln drying, technical specifications according to standards and norms) and volume importance all aspects related to sales volumes (m$^3$). Sipi

(1991) approaches the themes of visual and structural importance for sawnwood whereas Juvonen (1974) approaches themes included in the field of technical importance.

**Table 9. Coniferous sawnwood main segments with visual, structural, technical and volume importance factors. The scale indicates their importance to Finnish sawmills as follows: + = some importance, ++ = much importance, +++ = very much importance. Note that the scale is only applicable here, not to all products of the segments. Values are estimates by the author.**

| Segment | Visual importance | Structural | Technical | Volume importance |
|---|---|---|---|---|
| **Joinery** | +++ | ++ | +++ | ++ |
| **Furniture** | +++ | + | +++ | + |
| **Construction** | + | +++ | +++ | +++ |
| **DIY** | +++ | ++ | +++ | +++ |
| **Garden, fences** | ++ | ++ | ++ | ++ |
| **Packaging** | + | ++ | + | ++ |
| **Other** | +++ | ++ | ++ | + |

It is likely that both visual and structural characteristics of sawnwood will have new meaning and importance as well as a new approach in the future. During the last 10 years, x-ray and other applications have been developed and applied in the sawmilling industry to detect the inner characteristics of the logs and stems (e.g. Pinto 2004, Oja et al. 2001). The development covers both computer tomography and nuclear magnetic resonance (e.g. Pinto 2004, Oja 1997, Morales et al. 2002). However, nuclear magnetic resonance has not yet been applied in the sawmilling industry.

With Table 8 and Table 9, the results of Finnish sawnwood user segments and demand dynamics can be analysed through sector information. There are almost 100 window producers and brands in the Finnish Joinery segment. Prefabricated housing has window manufacturing, too, and many local joinery companies also produce windows and doors. The window market in Finland in 1999 was almost 900,000 doors, of which interior and sauna doors form the largest group. In Finland, there were some 10 considerable door manufacturers and some small special door manufacturers. Gross value of production of the Finnish joinery industry was estimated to be between 888 M€ (RT 2004) and 1.4 billion € in 2002 (Key to Finnish Forest Industries 2000, Yearbook 2004), of which windows covered 175 M€, doors 150 M€, kitchen cabinets 180 M€ and roof trusses 42 M€ (RT 2004). Furniture segment included some 1 200 furniture manufacturers in 1999. Segment consists of SMEs, of which over two-thirds employed less than 5 persons. Gross value of production of the Finnish furniture industry was estimated as somewhat less than 1.2 billion € in 2002 (Key to Finnish Forest Industries 2000, Yearbook 2004).

Furthermore, construction segment is the largest user segment for sawnwood and other wood products in Finland. Growth prospects for domestic demand of sawnwood depend on the construction industry (Finnish Forest Research Institute 2002). More than 80% of Finnish population would prefer to live in single houses, but this dream comes true for some 50% of the population (Mikkola and Riihimäki 2002). The market for prefabricated house units for single houses was some 65% in 2003. In 2003, there were some 12,500 small-house starts, of which 8200 were house kits, including 4700 wood element constructions, 800 industrial log constructions, 1700 pre-cut constructions and some 1000 other (blocks, hardened lightweight concrete) (RT 2004). The choice of house type affects what kind of material is used in new buildings, e.g. in the choice of frame and facade materials (see Figure 11). There were some 20 wood element companies and subcontractors. Industrial log houses were produced by 200 companies, of which the smallest produced only some frames annually. Some wood housing industry companies operated in sawmilling and joinery sectors, too (Key to Finnish Forest Industries 2000).

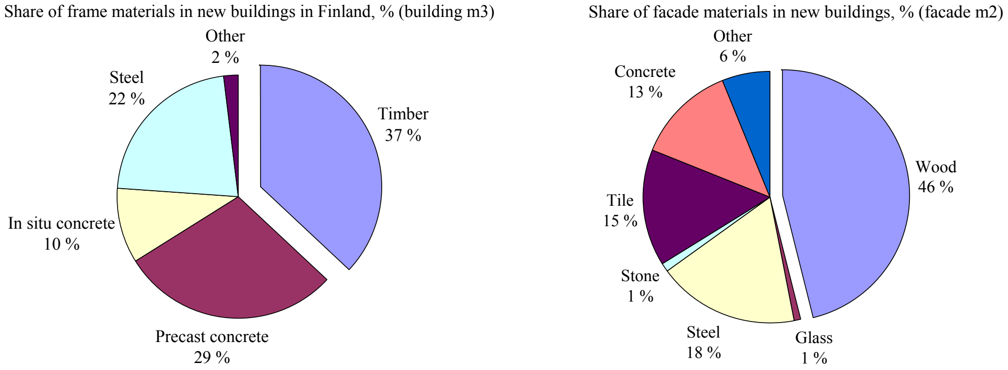


**Figure 11. Shares (%) of frame materials (left) and facades (right) in new buildings in Finland in 2003 (Statistics Finland 2004). Modified by author.**

### 2.1.3.2 User segments and quality classes

Sawnwood quality class allocation to user segments leads to quality distribution which lies in most cases two or more quality classes, because sawnwood as a varying nature material seldom meets the needs of only one user segment (Table 10).

**Table 10. CSW quality class user segments adapted from Nordic timber (1994). Modified by author.**

| User segment/quality class | A | | | | B | C | D |
|---|---|---|---|---|---|---|---|
| | A1 | A2 | A3 | A4 | | | |
| **Joinery** (high visual requirements) | ■ | ■ | ■ | ■ | | | |
| **Window sashes, frames, door frames** (to be painted) | | | ■ | ■ | ■ | | |
| **Furniture, glue boards** | | | | ■ | ■ | ▌ | |
| **Frame structures, roof trusses** | | | | ■ | ■ | ■ | |
| **Cladding** (exterior) | | | | | ■ | | |
| **Interior, furnishings** | | | ■ | ■ | ■ | | |
| **Battens** | ■ | ■ | | | | | |
| **Batten boarding** | | | | | ■ | ■ | |
| **Floors** | | | ■ | ■ | ■ | | |
| **Underside floors** | | | | | ■ | ■ | ■ |
| **Raw grooved and tongued boards** | | | | | | ■ | |
| **Fences, shelters** | | | | | ■ | ■ | |
| **Concrete moulds** | | | | | | ■ | ■ |
| **Pallets** | | | | | | ■ | |
| **Disposable pallets** | | | | | | ■ | ■ |
| **Package** | | | | | | ■ | ■ |
| **Boat construction** | ■ | ■ | ■ | | | | |
| **Decorations, crafts** | ■ | ■ | | | | | |
| **Sauna boarding** | ■ | ■ | | | | | |

Pakkanen et al. (1999) combined the Finnish sawmilling industry user segments to the segments of joinery, furniture, gluelam beams, planing, construction and packaging according to Profitable sawmill (1994). The largest spruce end-user segments were planing and construction, according to Pakkanen et al. (1999). These two end-user segments covered almost 80% of spruce sales from Finnish sawmills. The pine end-user segments covered joinery, furniture, planing and construction, which were almost equal in volume. The largest pine U/S quality user for the Finnish sawmilling industry was window industry. Furniture segment was the only user for pine CSW with fresh knots. According to Pakkanen et al. (1999), the side board quality classes of VL, HVS and KL were used for planing, construction and packaging. It is difficult to see that there would be fast radical changes in the CSW user segments. For instance, in Finland, development of portions of frame and facade materials for new buildings is somewhat slow (Figure 12).

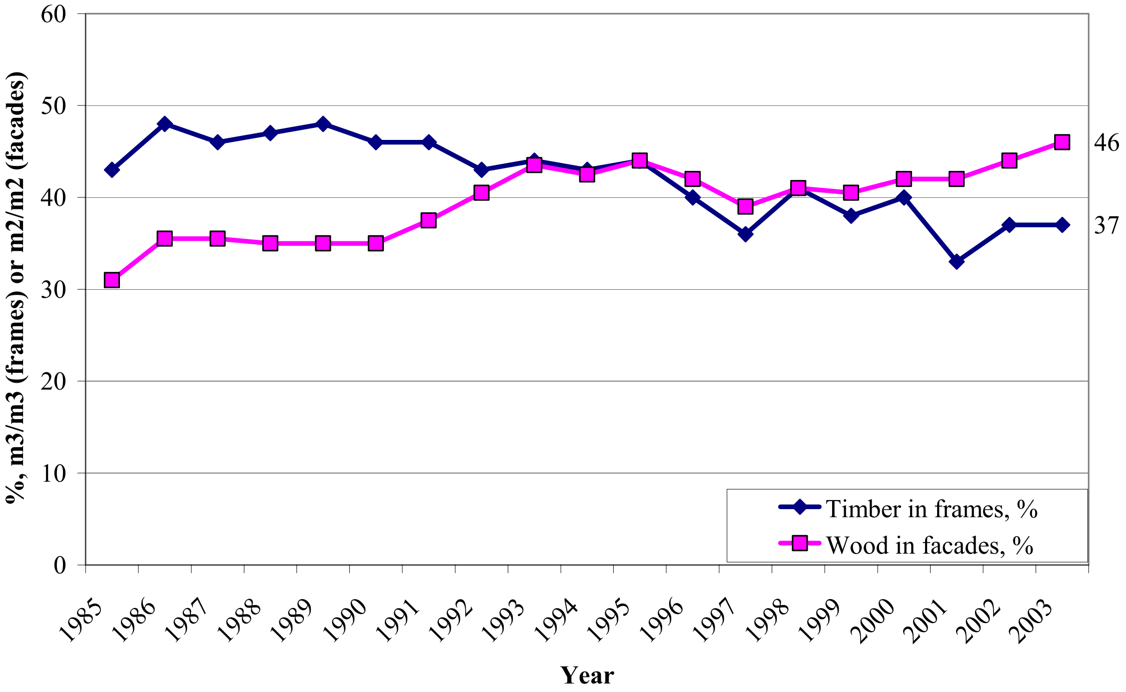


**Figure 12. Development of portions of wooden frame and facade materials used for new buildings in Finland (Statistics Finland 2004). Modified by author.**

Sipi et al. (1995) presented a system, product based sawnwood grading rules, which aims at combining user segments and sawnwood quality. The system approached sawnwood quality from segment quality requirements and sawnwood products by dividing a piece of sawnwood to four surfaces and by keeping the piece of sawnwood as a fifth surface (Virtanen 1995). User segment (e.g. Table 10) quality requirements were linked with surfaces of a piece of sawnwood, the surface was given a product based quality, and by combining the surfaces, customer quality classes were formed. The system has been affected by an opportunity to link new qualities to sawnwood in machine vision based CSW grading systems and to use different grading principles.

Pakkanen et al. (1999) presented a species-specific estimation of volumes for user segments in 1997, and the user segment share of CSW production in Finland (Table 11). According to the estimation presented in Pakkanen et al. (1999), planing was clearly the largest user segment for both pine and spruce in the Finnish sawmilling industry. Nevertheless, it is interesting to observe the following of the Finnish CSW user segments in Table 11:

- The most of user segments seemed to use mostly or only either pine or spruce.
- Pine segments included furniture, impregnation and edge glued boards. Of these, impregnation segment was using only pine.
- Spruce segments included roof trusses, gluelam beams, parquet and stairs. Of these, roof trusses, gluelam beams and parquet were using only spruce.
- The window segment was more than twice as large as door segment, and the door segment 2.6 times larger than the stairs segment.
- The planing segment was using 1.23 $Mm^3$ more spruce than pine.
- The construction segment was using 488,000 $m^3$ more spruce than pine.
- The segment “log houses” was using pine and spruce almost equally.
- The following segments were relatively small: log houses, parquet.
- The segment “other use” had a large volume, 488,000 $m^3$.
- The joinery segment used 61,000 $m^3$ more spruce than pine.

**Table 11. CSW estimations (m$^3$) by user segments in 1997 and the user segment shares (%) of CSW production in Finland. In 1997, the production of pine was 4,900,000 m$^3$ and 5,700,000 m$^3$ for spruce in Finland. Adapted from Pakkanen et al. (1999).**

| **Log houses** | **Spruce** | **Pine** | **Other use** | **Spruce** | **Pine** |
|---|---|---|---|---|---|
| Use | 28,000 | 32,000 | Use | 97,000 | 391,000 |
| % | 0.5 | 0.7 | % | 1.7 | 8.0 |
| **Furniture** | **Spruce** | **Pine** | **Door** | **Spruce** | **Pine** |
| Use | 14,000 | 854,000 | Use | 295,000 | 216,000 |
| % | 0.2 | 17.4 | % | 5.1 | 4.4 |
| **Planing** | **Spruce** | **Pine** | **Package** | **Spruce** | **Pine** |
| Use | 2,562,000 | 1,332,000 | Use | 45,000 | 274,000 |
| % | 44.5 | 27.2 | % | 0.8 | 5.6 |
| **Window** | **Spruce** | **Pine** | **Parquet** | **Spruce** | **Pine** |
| Use | 364,000 | 685,000 | Use | 9,000 | 0 |
| % | 6.3 | 14.0 | % | 0.2 | 0.0 |
| **Roof truss** | **Spruce** | **Pine** | **Stairs** | **Spruce** | **Pine** |
| Use | 563,000 | 0 | Use | 182,000 | 15,000 |
| % | 9.8 | 0.0 | % | 3.2 | 0.3 |
| **Impregnation** | **Spruce** | **Pine** | **Joinery** | **Spruce** | **Pine** |
| Use | 0 | 151,000 | Use | 96,000 | 35,000 |
| % | 0.0 | 3.1 | % | 1.7 | 0.7 |
| **Edge glued board** | **Spruce** | **Pine** | **Building component** | **Spruce** | **Pine** |
| Use | 14,000 | 75,000 | Use | 148,000 | 63,000 |
| % | 0.2 | 1.5 | % | 2.6 | 1.3 |
| **Gluelam beam** | **Spruce** | **Pine** | **Construction** | **Spruce** | **Pine** |
| Use | 128,000 | 0 | Use | 1,213,000 | 771,000 |
| % | 2.2 | 0.0 | % | 21.1 | 15.8 |

Frame structures (Table 10 and Figure 13), which can be seen as a part of construction segment (Table 11), are one of the most important user segments for sawnwood. However, there are large differences between frame materials when the competition is approached through the number of building permissions in Finland (Figure 13). According to the number of building permissions in Finland by frame, steel has gained market share whereas wood and concrete have lost their position (Figure 13).

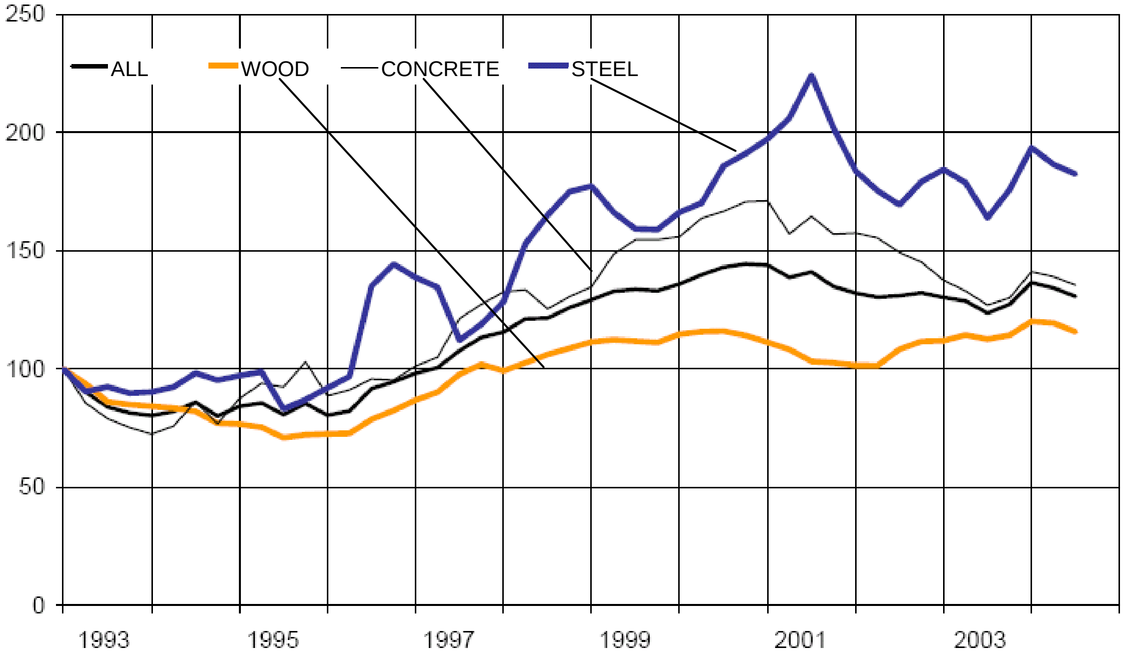


**Figure 13. Number of building permissions in Finland by frame material. Index 1992 = 100. Sources: Pajakkala (2004) and Statistics Finland (2004). Modified by author.**

There are differences in development of construction output in West Europe between countries (see Figure 14). Regarding Germany, Flinkman (2004) shows in his study of construction in North Germany the development potential in the wood supply chain. Based on Flinkman (2004), the sawnwood for construction can be divided onto two levels:

1. Products of construction: frame construction (including panelling and cladding), window, door, floor, parquet floor, staircase, other uses.
2. End-users of construction: one-family dwellings, two-family dwellings, multi-family dwellings, office non-domestic construction, industrial non-domestic construction, agricultural non-domestic construction.

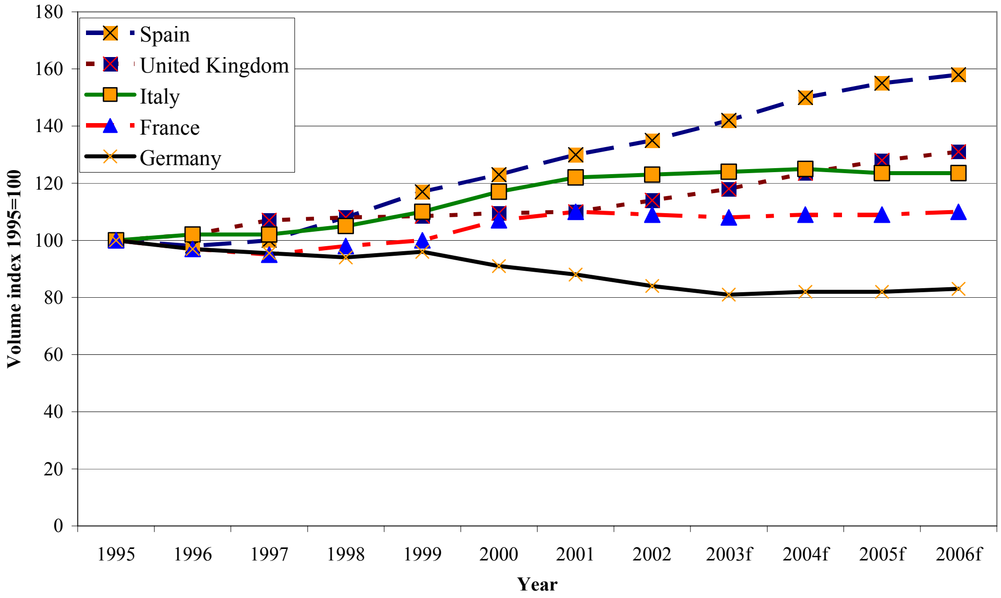


**Figure 14. Construction output in West Europe. Volume-index 1995 = 100. Data sources: Euroconstruct (2004) and Pajakkala (2004). f = forecast (e.g. 2003f). Modified by author.**

There are differences in timber frame market shares in new houses in European countries. For instance, in UK there is a vast difference between Scotland and other parts of UK (see Figure 15). In contrast, there is a relatively small difference between Wales, England and Northern Ireland when compared by timber frame market shares (%) in new houses. However, the trend has been slightly upwards to use more timber frames in new houses in UK (Figure 15).

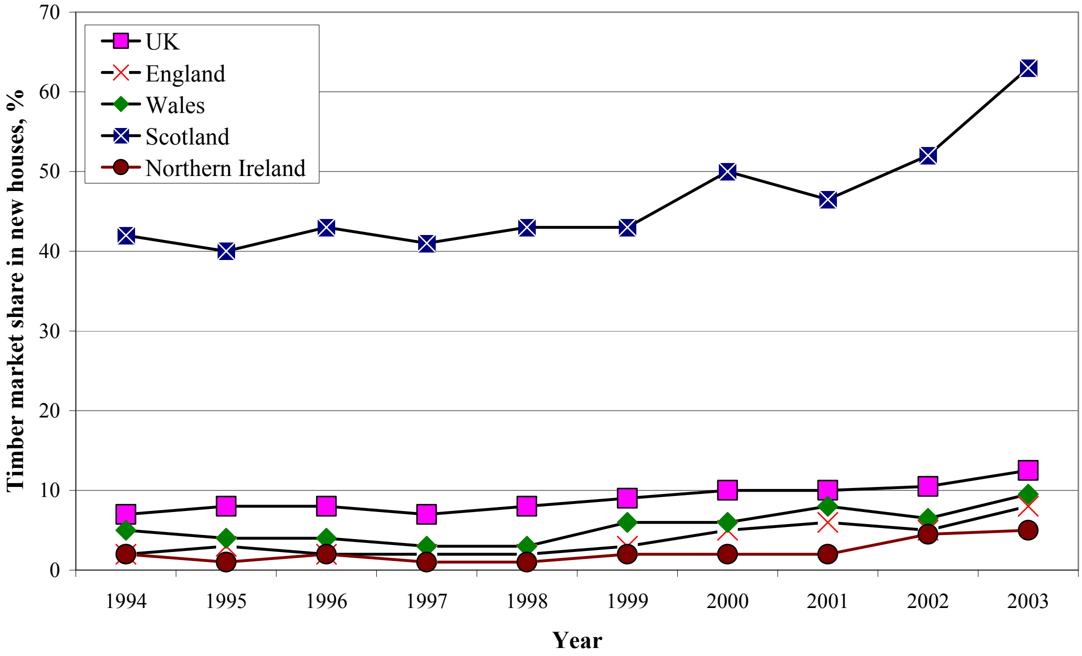


**Figure 15. Timber frame market share in new houses in UK. Data source: Pajakkala (2004). Modified by author.**

## 2.1.4 Dimensions and lengths

Siikaluoma (1995) has shown in one sawmill that the sawnwood dimension (cross-section) is the other important product attribute besides the quality class. The CSW dimension is decided in connection with marketing and sales but realised in sawing. Thus dimension cannot be compared with wood quality, which is more a falling product attribute with limited means to influence it. Product dimension limits are defined by (1) top diameter of a log, (2) application and (3) number of sawnwood pieces from the log. According to Siikaluoma (1995), the top diameter of a log is the most significant limit for CSW dimensions.

In sawnwood grading rules (Green book 1960), there are no standard dimensions or lengths for CSW. According to Nordic timber (1994), the CSW standard dimensions are by thicknesses 16, 19, 22, 25, 32, 38, 44, 50, 63 and 75 mm, and by widths 75, 100, 115, 125, 150, 175, 200 and 225 mm. CSW standard lengths are from 1800 to 5400 mm in 300 mm modules. Other dimensions in Nordic timber (1994) belong to special dimensions that are graded according to the nearest large size. Dimensions over 75 x 225 mm are graded in Nordic timber (1994) according to the size 75 x 225 mm.

Pakkanen et al. (1999) have estimated CSW dimension distribution in Finland. The research sample was based on sawmills' production, which was formed to distribution and extrapolated to the situation in Finland in 1997. The research sample covered a little less than 1500 records that were collected from the following sawmills in Finland: 1) Stora Enso Timber Ltd., Honkalahti sawmill, 2) UPM-Kymmene Ltd., United sawmills - Kajaani sawmill, Korkeakoski sawmill and Seikku sawmill, 3) VAPO timber Ltd., Kevätniemi sawmill.

According to Pakkanen et al. (1999), CSW sawing is focused only on a few dimensions (Table 12). The largest volumes for dimensions are for both pine and spruce thin boards with 100 mm width. The largest volumes for pine are 19 x 100, 50 x 100, 50 x 150 and 50 x 125 mm whereas for spruce 22 x 100 and 44 x 100 mm.

**Table 12. A sample of the most common CSW dimensions (m$^3$/m$^3$, %) in Finland in 1997. Data from Pakkanen et al. (1999).**

| | Pine | | | | Spruce | | | |
|---|---|---|---|---|---|---|---|---|
| **No** | **Dimension, mm** | **Volume, m$^3$** | **Share** | **Cumulative** | **Dimension, mm** | **Volume, m$^3$** | **Share** | **Cumulative** |
| **1** | **19 x 100** | 820,037 | 16.7% | 16.7% | **22 x 100** | 1,636,600 | 28.7% | 28.7% |
| **2** | **50 x 100** | 430,206 | 8.8% | 25.5% | **44 x 100** | 364,598 | 6.4% | 35.1% |
| **3** | **50 x 150** | 417,023 | 8.5% | 34.0% | **22 x 125** | 243,240 | 4.3% | 39.4% |
| **4** | **50 x 125** | 371,011 | 7.6% | 41.6% | **50 x 150** | 223,522 | 3.9% | 43.3% |
| **5** | **75 x 150** | 228,538 | 4.7% | 46.3% | **63 x 150** | 205,763 | 3.6% | 46.9% |
| **6** | **38 x 150** | 214,618 | 4.4% | 50.6% | **22 x 150** | 168,440 | 3.0% | 49.9% |
| **7** | **25 x 100** | 204,757 | 4.2% | 54.8% | **44 x 125** | 166,996 | 2.9% | 52.8% |
| **8** | **63 x 150** | 173,979 | 3.6% | 58.4% | **50 x 125** | 159,952 | 2.8% | 55.6% |
| **9** | **25 x 150** | 149,436 | 3.0% | 61.4% | **50 x 100** | 151,604 | 2.7% | 58.3% |
| **10** | **50 x 225** | 148,046 | 3.0% | 64.4% | **63 x 160** | 147,212 | 2.6% | 60.8% |
| **11** | **75 x 225** | 144,704 | 3.0% | 67.4% | **22 x 175** | 146,480 | 2.6% | 63.4% |
| **12** | **19 x 125** | 142,243 | 2.9% | 70.3% | **63 x 200** | 135,564 | 2.4% | 65.8% |
| **13** | **75 x 200** | 131,819 | 2.7% | 73.0% | **50 x 115** | 123,370 | 2.2% | 68.0% |
| **14** | **63 x 200** | 130,585 | 2.7% | 75.7% | **38 x 150** | 114,720 | 2.0% | 70.0% |
| **15** | **50 x 200** | 122,945 | 2.5% | 78.2% | **44 x 150** | 98,904 | 1.7% | 71.7% |
| **16** | **50 x 175** | 118,478 | 2.4% | 80.6% | **75 x 150** | 94,120 | 1.7% | 73.4% |
| **17** | **19 x 150** | 88,916 | 1.8% | 82.4% | **75 x 225** | 93,366 | 1.6% | 75.0% |
| **18** | **38 x 100** | 88,130 | 1.8% | 84.2% | **38 x 225** | 91,884 | 1.6% | 76.6% |
| **19** | **50 x 115** | 80,593 | 1.6% | 85.8% | **32 x 150** | 90,168 | 1.6% | 78.2% |
| **20** | **44 x 100** | 72,979 | 1.5% | 87.3% | **50 x 175** | 75,556 | 1.3% | 79.5% |
| **Production, m$^3$** | | 4,900,000 | | | **Production, m$^3$** | 5,700,000 | | |

Pakkanen et al. (1999) do not indicate whether the Pareto principle assumption can be seen in the production distributions of sawmills. However, there are similar comparisons in figures in which there have been drawn limits of 20% and correspondingly 80% of dimensions. According to the results, 80% of CSW volume comes with 16 pine dimensions out of 40 and

21 spruce dimensions out of 64 (Table 32 and Pakkanen et al. 1999). The result indicates that for pine, 40% of dimensions covered 80% of volume, and for spruce, 33% of dimensions covered 80% of volume. Hence the Pareto principle assumption does not apply here, but it is possible that some special dimensions have been excluded.

There are no comparative results of volume and value based dimension distribution in the literature for pine and spruce. In literature, there are neither similar results of the number of sawnwood dimensions produced in Finland, dimension distribution development between 1995 and 2000 nor results of different sawnwood dimension exports between 1995 and 2000. Profitable Sawmill (1993) names sawnwood dimensions that are used in some user segments in some countries Europe but does not tell of the use of sawnwood dimensions in those countries. There are no references in literature to the decrease of large dimension from Finland to the UK markets. Nevertheless, Profitable Sawmill (1993) and Timwood (1998) provide indirect and diffuse information about the development of the UK segment and the decrease in importance of large CSW dimensions in the UK window and door segment.

There is little literature information of length distributions for pine and spruce CSW. Usenius (1980) presents length distribution for two log classes. Furthermore, there is literature about log lengths for both coniferous and deciduous trees (e.g. Sonntag 1995 and Lindblad et al. 2004). Nevertheless, information of this remains deficient and further research is needed.

## 2.1.5 End moisture content

### 2.1.5.1 Concept of end moisture content

End moisture content distributions of sawnwood sales have not been published so far in scientific papers or literature. Nevertheless, there has been much research on wood behaviour in drying as well as wood and moisture movements (e.g. in Puuteollisuus 1964, Krisher and Kast 1978, Kröll 1978, Esping 1988, 1992, 1996). These themes have been approached e.g. in the standard SFS 5878 (2000).

In Green book (1960), the terms end moisture content or end moisture per cent are not used; instead, the terminology refers to false drying grade and shipping dry. According to Green book (1960), sawnwood is shipping dry if it can last sea transport undamaged in the bay of a ship to the destination harbour and a careful storage there. Green book (1960) mentions neither sawnwood end moisture content nor moisture tolerances. Moisture measurement is not linked with any standard. According to Nordic timber (1994), there must be at least 97% sawnwood pieces in a sale with not more than 24% moisture content, if there is no mention in sales contract of other solution (e.g. special kiln dry). Other terms of drying (e.g. linked with special kiln dry) must always be agreed in an agreement as a whole. Nordic timber (1994) mentions that moisture content measurement of sawnwood piece and lot can be applied methods shown in e.g. drying standard INSTA 141 (SFS 5878, 2000). There are no tolerances for moisture content measurements in Nordic timber (1994).

### 2.1.5.2 Moisture content distributions

It is known that little research results have been published on sawnwood end moisture content distributions in countries, user segments or according to product properties. Virtanen (2001) has presented his research results about Finnish sawnwood end moisture contents. Other results about end moisture content describe the distribution shape or approach the theme through kiln drying or drying theory.

Siimes and Kuusela (1983) showed the results of moisture content distributions in test kiln drying. In their results, end moisture contents of 18% or 20% included moisture contents that are distributed on both sides of the average. Siimes and Kuusela (1983) suggested that only 37 to 68% of sawnwood distribution was dried to the right end moisture content class, and in lower quality classes, the distributions were broader than in better qualities. Tronstad et al.

(2001) showed that when end moisture content class increases (e.g. from 10% to 18%), the standard deviation of end moisture content class increases, too. The Sawn Timber (1982) presents that in 1982 sawmills in Sweden and Finland were kilning over 90% of the total CSW production. The majority in 1982 was carried out to an average 18%, plus 4% minus 2%. In Sweden, the amount of coniferous sawnwood kilned was some 90% in 1995, some 88% in 1990, some 82% in 1984, some 77% in 1979, and some 62% in 1973 (Englund 1981, Warensjö and Jäppinen 1997).

## 2.1.6 Price

### 2.1.6.1 Shipping marks and price

According to Sipi (2002), the price of sawnwood is influenced by shipping mark and its valuation, sawnwood size (thickness and width), quality and species. Sipi (2002) indicates that the price of centre yield (see Figure 8), especially that of pine, tends to increase as the thickness and width increase. In side yield, the size does not make much of a difference. When priced according to quality, the B quality pine is 20–30% cheaper than A quality, and C quality is 30-50% cheaper than A quality. In spruce, the price differences between qualities are smaller. Spruce sawnwood is usually slightly cheaper than pine sawnwood (Figure 22) but the price difference between species can be small.

According to Määttä (1986), in the 1980s every Finnish sawmill was selling its own usual quality that was also called shipper's usual. The sawnwood price was tied to the quality image of the sawmill or the sawnwood supplier and price group. According to Savolainen (1971), sawnwood price was either basis price or average price per $m^3$. Basis price was used in pricing when pricing tied with dimension sizes. The way of thinking of basis price is similar to the grading of a sawnwood piece because in grading, the number and size of allowed defects in a sawnwood piece is determined by the thickness and width of sawnwood (Green book 1960 and Nordic timber 1994). Basis price means a price that has been calculated to a specific size and quality. Furthermore, the sizes (thickness, width) of sawnwood pieces in the pricing table around a specific sawnwood piece have effect on a specific sawnwood piece. In the Finnish sawmills, the basis price was formed for sawnwood pieces by a basis dimension of starting width 150 or 175 mm. Still, the starting width of basis price may differ between sawmills. There were price raises for pieces that had more width and price discounts for pieces with less width. Furthermore, there were a board extra added to basis price for U/S boards according to Savolainen (1971), which means that a change from e.g. 50 mm thicknesses to thinner dimensions causes the sawnwood price to rise. However, quality VI and boards were not priced according to basis price but sold with their own prices. According to Savolainen (1971), in 1971 basis price was useful to describe general pricing patterns in sawnwood trade. According to Luther (1986a), in the 1980s the sawnwood domestic pricing in Finland followed the prevailing price level in export markets.

The price raise by increase of width and decrease of thickness has been justified by the insufficiency of raw material, different quality requirements of various sawnwood uses, differences in CSW production lead times, higher sawnwood processing costs and different wood paying capacities of sawnwood users (Savolainen 1971). For instance, when changing from 2 ex-log sawing to 4 ex-log sawing, the sawnwood price (€/$m^3$) will rise but, simultaneously, the user segment will become more challenging and the distribution of use will change, too.

From thesis perspective it is interesting to see whether a similar basis pricing system can still be found over 30 years after Savolainen (1971) described it as a part of supply and demand analysing.

#### 2.1.6.2 Price, supply and demand

According to Luther (1986b), the sawnwood price is not only based on production costs, but the demand and supply on the market determine the price level. This emphasises repeated observations of market situation, demand and competitors, which can be seen in repeated market analysis of CSW (e.g. Timwood 1998 or Roadmap 2010, 2004).

In price dependency analysis, the choices of sellers and buyers are often assumed to be rational, as it is often assumed in price dependency analysis of other products, too. In practice, this means that in case of strong demand, the price of commodity goes up, and in case of weak demand, the price of commodity comes down. The general relationship between sawnwood supply and price can be seen as when the price of sawnwood rises the quantity supplied will also rise. Equilibrium in sawnwood market occurs when the price balances the plans of buyers and sellers. (Sloman 1991, Vaara 1998, Parkin 1999).

A competitive sawmill is one that takes the market price of output as being given and outside of its control. In a competitive sawnwood market each sawmill takes the price as being independent of its own actions, although it is the actions of all sawmills taken together that determine the market price. On the other hand, a competitive sawmill is free to set whatever price it wants and produce whatever quantity it is able to produce. The sawmill can get as many customers as it wants by pricing sawnwood at market price or under the market price. Simultaneously if a competitive sawmill wants to sell any sawnwood or other output at all, it must sell it at the market price. This can be expressed by saying that a competitive sawmill faces an infinitely elastic demand curve (Varian 1992).

Sawnwood can be seen as a necessity to the customers close to the sawmilling industry. These customers have sawnwood as their chief raw material, because it cannot entirely be replaced with other raw materials, and the share of sawnwood price of their total product costs is often significant. These customers are e.g. planing mills and manufacturers of edge glued boards and gluelam beams. On the other hand, sawnwood can be seen as a necessity neither to window, door and furniture industry nor construction industry, because in the processes of these industries, wood can be replaced with other raw materials, and the share of sawnwood price of the total product costs is often not as significant as to the customers close to the sawmilling industry (see Figure 31). It is not known that there would be any research results on sawnwood price elasticity or behaviour of this kind, but it can be assumed that there may be a difference in price elasticity or behaviour between those customers that have sawnwood as their chief material, and those that have not sawnwood as their chief material.

Sawnwood price depends on market structure, which is influenced by competition between sellers and buyers. Correspondingly, competition between sellers and buyers is influenced by the number of sellers and buyers, product properties, competition among sellers and buyers, and if the product can be replaced with another product. In addition, the quantity of sawnwood that buyers plan to buy also depends on the prices of complements of sawnwood. Sawnwood can be seen as a complement when it is used in conjunction with another good, e.g. concrete, steel or joint (Pekkarinen and Sutela 1986, Vaara 1998, Parkin 1999).

An equilibrium price for sawnwood is a price where amount demanded equals the amount supplied. To define and understand the sawnwood equilibrium price, there is a need for sawnwood supply and demand functions. The sawnwood supply function measures the total output supplied at any price whereas the sawnwood demand function measures the total output demanded at any price. However, it is not known if these sawnwood supply and demand functions have been defined and analysed for markets of Scandinavian sawnwood (Varian 1992).

It is not known whether any sufficient scientific research results exist that could show information of sawnwood market competition. However, some alternatives can be excluded from the theoretical structures of sawnwood trade by theory limitations. There may not be a perfect competition on sawnwood market, because the sellers' products – sawnwood - are not equivalent but depend on e.g. (1) quality of wood material, which depends on quality of local forest resources, and (2) technical properties (dimension accuracy, properties from drying). There is not either any monopoly on the sawnwood market, because there is more than one seller on the market. On the other hand, there is no oligopoly on the sawnwood market because there is a large number of sellers and buyers on the market. Oligopoly is the study of market interactions with a small number of firms (Varian 1992).

It is likely that the sawnwood market type can be a form of monopolistic competition with some limitations. Monopolistic competition is market structure in which a large number of sawmills compete by making similar but slightly different sawnwood and other products. Making a sawnwood product slightly different from the sawnwood products of competing firms is called product differentiation. What matters is that customers of sawnwood perceive sawnwood products to be different. For example, various brands of sawnwood may be of fairly similar material and technical properties but they may differ in the packaging, transportation and customer service level. On the other hand, in monopolistic competition each sawmill is assumed to take the prices charged by its rivals as given, i.e. a sawmill ignores the impact of is own price on the prices of other sawmills. From this perspective, there are serious limitations if sawnwood market is seen as monopolistic competition (Parkin 1999, Krugman and Obstfeld 2000).

### 2.1.7 Consumption environment

According to Roadmap 2010 (2004), the woodworking industry is accounting for almost €150 billion in sales and employing 1.6 million people in Europe in 2001. The most prominent subsector is the Furniture industry, accounting for 55% of the sales, followed by Building components (e.g. Windows, Doors, Flooring, Trusses etc.) (15%), Sawing, planing and impregnating (12%), Wood-based panels (9%) and Packaging (3%).

From the coniferous sawnwood (CSW) demand perspective, Roadmap 2010 (2004) suggests that there are three overall features that apply to the European woodworking industry colouring its position and performance: (1) A comparably low level of wood products demand in an international perspective, (2) An increasing dependency on intra- and interregional trade, (3) A slowing growth in demand.

Roadmap 2010 (2004) suggests that the per capita consumption of primary wood products – including sawnwood - is typically lower in Europe than in other industrialised regions in the world, albeit there are significant variations to its extent between specific wood products (Figure 16).

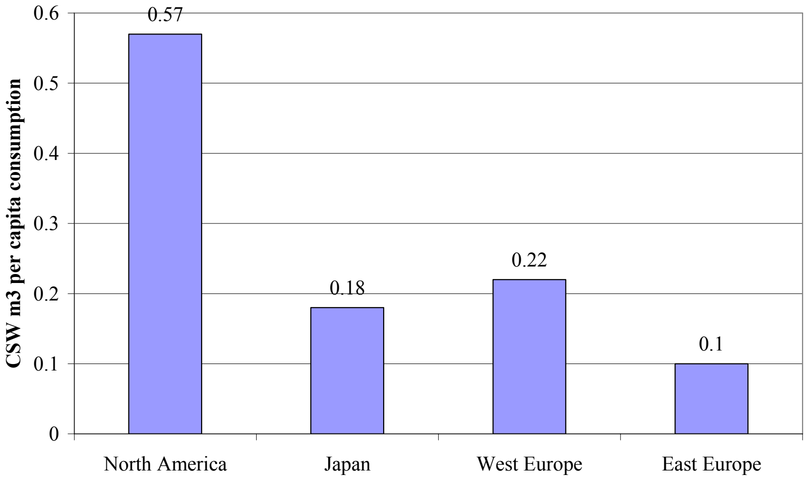


**Figure 16. Sawnwood (CSW) consumption ($m^3$) per capita by region. Data adapted from Roadmap 2010 (2004). West Europe = EU15+EFTA, East Europe = CEEC (Central East Europe Countries).**

Of total European CSW production in 2002, 13% (12 million m$^3$) was shipped to markets outside Europe. The annual growth rate of CSW (m$^3$) between 1995 and 2002 was 2% in Europe, about 1.5% in West Europe and 5.5% in East Europe. The annual growth rate of CSW (m$^3$) between 2002 and 2010 is expected to be 1% in Europe, 0.5% in West Europe and 3% in East Europe. From per capita perspective (Figure 17), the CSW consumption in Europe is estimated to grow (Roadmap (2004).

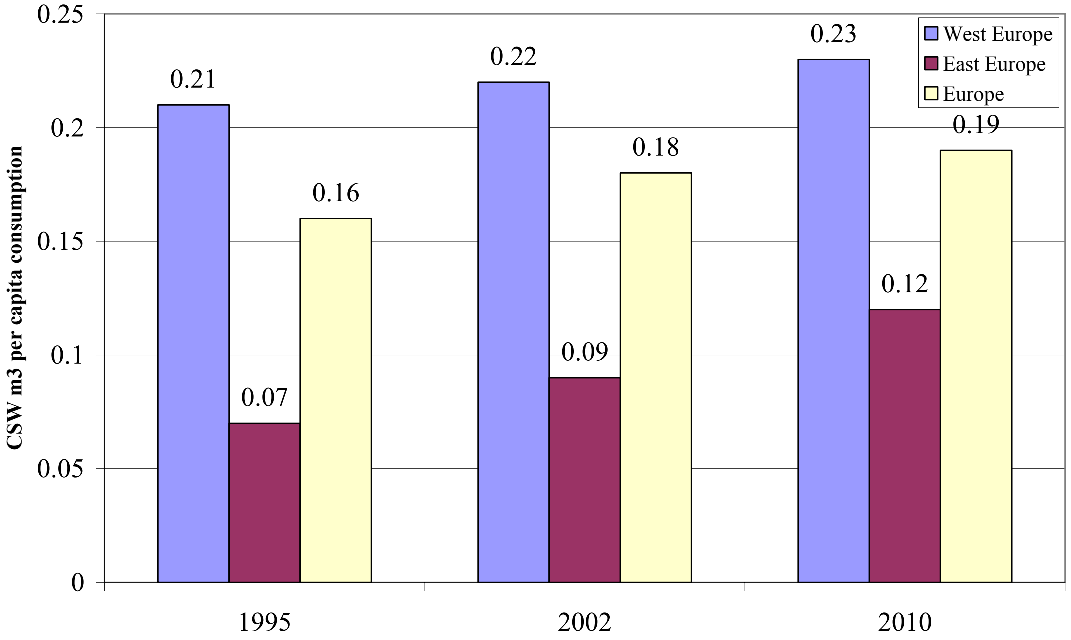


**Figure 17. CSW consumption (m$^3$) per capita in Europe. Data adapted from Roadmap 2010 (2004).**

Concerning other references to CSW consumption environment, it was not possible to find any both relevant and useful scientific references of geographical area and CSW consumption environment as well as CSW prices.

## 2.2 *Sawmilling industry*

### 2.2.1 Situation from historical perspective

In the 1860s, there was a start for a significant growth in development for the Finnish sawmilling industry. According to Tasanen (2004), almost all limitations on sawmill production for the Finnish sawmilling industry were lifted by 1861. The development started from the premises that wood use limitations were removed, steam was allowed to be used as source of power for the industry, and sawnwood demand increased. In addition, there was simultaneous strong growth in sawnwood demand. As a consequence of this, the sawmilling industry was able to grow fast when there was plenty of inexpensive raw material, labour and energy (Paloposki 1970, Putkisto 1970). Simultaneously, a new stage began in the chain of the development of the sawmilling industry (Table 13). According to Paajanen (1997), traces from over 100 years could be recognised in the Finnish sawmilling operations until the beginning of 1990s when compared with the traditional operational principles from the 19th century (Table 13).

**Table 13. Seven traditional operational components and principles in the Finnish sawmilling industry from the 19th century. Based on Paajanen (1997), Klus and Hirvensalo (1997). Modified by author.**

| Operational component | Role and relevance |
|---|---|
| **1. Buyer and agent** | defined the price and needed product properties based on the products' need or competitive products. This was possible, because products were general qualities and sizes that were available from different sources. |
| **2. Producer** | tried to reach the market price by increasing labour productivity and by cheaper and better quality raw material. |
| **3. Technology and skills needed for sawing** | was at first imported to Finland and was realised in a similar way in all companies. |
| **4. Other development contribution** | than raw material use and labour productivity were needless cost factors for competitiveness. |
| **5. Information about the end use of a product** | was not important, because product properties and prices were decided by buyer or his representative. |
| **6. Price formation** | was a zero sum game with market price. When product prices were determined by the market situation, there was often a zero sum game between buyers and sellers, because a potential higher price for the seller decreased the profit of the buyer and vice versa. The profitability of the seller varied based on price levels and demand fluctuations. |
| **7. Coniferous sawnwood trade multi stage structure** | increased price and demand fluctuations when all players aimed at maximising their profit in market situations. Product transportation and distribution were directed by buyers or their representatives. |

The sawmilling industry has historically been, from the Finnish perspective, a significant industrial employer and forest income payer especially in scattered settlements in countryside. The sawmilling industry as a business has traditionally sought locations near raw material (see Figure 18), wood, because raw material and transportation costs are the largest cost factor in many countries. Furthermore, stumpage earnings obtained from timber sales are essential to the livelihood of those living in sparsely populated rural areas. In 1999, the industry paid more than 1.5 billion € in stumpage costs to private forest owners, which was 69% of annual variable costs for purchased wood (see Figure 19). About half of the annual roundwood removal consists of saw logs for use by the wood products industry, the price of which is 2.5 times higher than for pulpwood. About 70% of the stumpage earnings of forest owners are derived from the wood products industry where the sawmilling industry has the largest portion (see Figure 19) (Key to Finnish Forest Industries 2000).

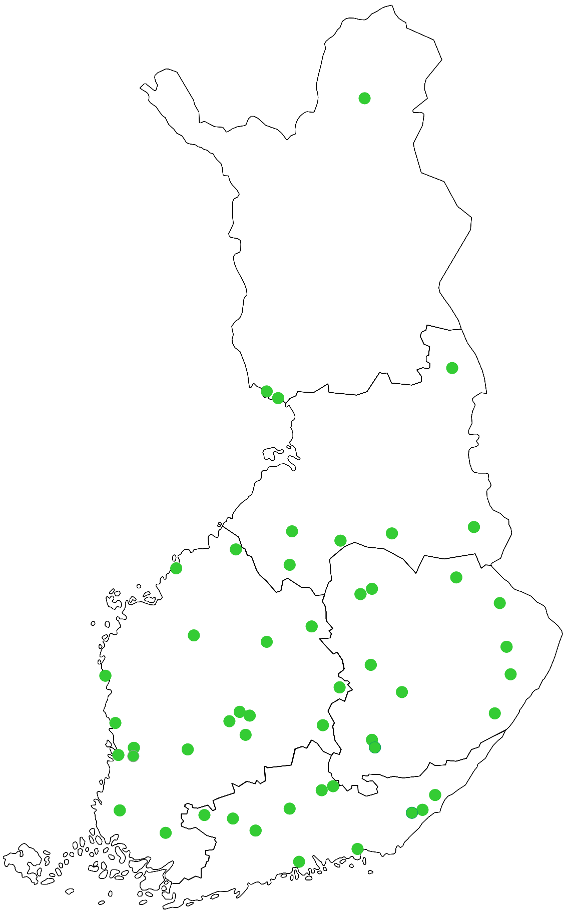


**Figure 18. Member sawmills of the Finnish Forest Industries Federation 2004 (Finnish Forest Industries 2004).**

The sawmilling industry was the largest exporter from Finland until 1929 as estimated by export value. During the era between the World Wars 1 and 2 (1918–1939), the forest industry company Enso-Gutzeit was both the largest sawmilling company in Finland and the largest company in Finland (Lamberg 2001). From 1929 till the beginning of the 1960s, the Finnish sawmilling industry was the second largest exporter after pulp and paper industry until, during the 1960s, the export value of metal industry exceeded the export value of the sawmilling industry (Ahvenainen 1984). In the beginning of the 1950s, the Finnish forest industries represented some 80% of the export value of Finland. In 1999, the sawmilling industry had a 13% share of the total export value of Finland, and the equivalent share of all the Finnish forest industries amounted to 29% (Key to Finnish Forest Industries 2000).

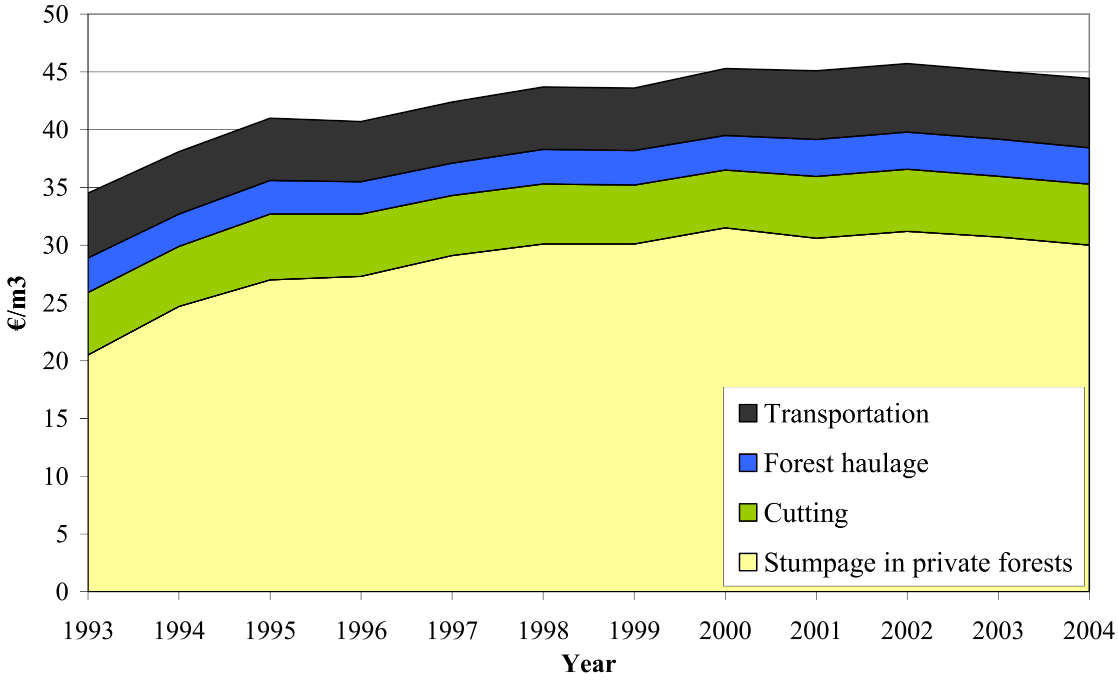


**Figure 19. Annual variable costs for purchased wood in Finland. Stumpage in private forests is based on wood grades weighted according forest inventory data (Finnish Forest Industries 2004).**

From another perspective, the Finnish sawmilling industry belongs to the forest cluster that accounted in 1999 for about 10% of Finland's GDP, 30% of its industrial production and almost 40% of net export income. It is likely that no other industrialised country had such a strong and diversified range of forest-based enterprise and expertise in 1999 (Key to Finnish Forest Industries 2000).

The Finnish sawmilling industry is still an industry which brings high net export income to Finland when compared with other industries, due to domestic raw material, labour and energy. The sawmilling industry needs less import inputs in its production than other export sectors. The most important raw material, wood, is purchased mainly from Finland. Thus intermediate consumption has been some 70% or more of output of Finnish wood industry (see Figure 62). Thus, the Finnish wood industry – including the sawmilling industry – brings much output to forestry and other sectors of Finnish economy. In addition, the share of energy produced domestically used in Finnish forest industries is high when compared with other industries.

Roadmap 2010 (2004) sees that the future structural development will likely lead to polarisation, where global or Pan-European companies dominate the scene, but where smaller niche-oriented companies thrive through qualitative competitive advantages and clustering. Global or Pan-European companies will have their production located according to low cost on a global or Pan-European scale, but smaller niche oriented companies are defined by geography as well as product offering, quality and customer type.

The starting point for competitiveness of the sawmilling industry is applicable raw material for production. Furthermore, there must be enough raw material available for the sawmilling industry with a competitive price. The Finnish sawmilling industry may not increase the use of domestic wood raw material any more, but raw material supply for base production must be ensured in a competitive way also in future. The structure of raw material for sawmills in Finnish forests will probably be in 20 years somewhat similar to the current one (Paajanen et al. 2004a). From the Finnish sawmilling industry perspective, there are also other indispensable prerequisites in addition to the raw material supply. These sawmilling prerequisites include a stable position for investments in the society, working transportation systems and skilled labour force. However, the conclusive point will be the cost competitiveness of the Finnish sawmilling industry, which is determined by the international market. The future of the sawmilling industry in Finland is determined by how it can meet the challenges of competitiveness.

The Finnish sawmilling industry history is characterised by big and sometimes also drastic changes. The sawmilling industry has always faced economic fluctuations but large structural changes have also belonged to its history. Big and drastic changes have often brought problems to the sawmilling industry. One of the biggest has been the question of raw material price and price ratios (e.g. see Figure 19). From a broader view, there has been the question of sawmill profitability (Ahvenainen 1984). The Finnish sawmilling industry (Figure 18) has traditionally answered to the question by producing more CSW volume in fewer sawmills (Finnish Forest Industries 2002). Furthermore, starting from 1990s, the Finnish sawmilling industry has expanded through mergers into neighbouring countries and elsewhere in Europe. The process of concentration (see Table 14) in the sawmilling industry is, in fact, a global phenomenon (Key to Finnish Forest Industries 2000).

**Table 14. Indicators of the Finnish sawmilling industry in 2001 (Finnish Forest Industries 2002).**

| Basic indicators | Value | Production indicators | Value | Production indicators | Value |
|---|---|---|---|---|---|
| Places of business, number | 1300 | Production, $Mm^3$ | 12.7 | Top 3 of production, % | 50 |
| Employees, number | 9900 | Production value, 1000 M€ | 3.1 | Top 10 of production, % | 70 |
| | | | | Top 17 of production, % | 75 |

From the Finnish sawmilling industry viewpoint, the question can be formed as follows: how to find a profitable way to operate in a changed situation? The answer requires both views brought by experience and practical tools with which the operation alternatives and risk can be calculated and managed in a changed situation. To monitor a changing situation in the sawmilling, the Finnish sawmilling industry follows carefully the development of raw material, productivity, labour costs and unit costs both in Finland and other important sawmilling countries (Tuottavuus 2004).

### 2.2.2 Wood and furniture industry position in Europe and Finland

The European wood and furniture industry production value reached 163 billion euro in 2000. The most important sector was furniture with 59% of the total production (see Figure 20). However, there are other materials than wood included in this furniture amount of 96 billion euro. Sawing, planing and impregnation were third in Europe with the share of 11%. Nevertheless, in Finland the sawmilling industry has the largest portion of wood product industry (CEI-Bois 2003, Finnish Forest Industries 2003, Mauno 2003).

From the demand perspective, there are differences between European and Finnish wood product industry. European wood product industry is more focused on end uses, especially in the furniture segment, while Finland focuses more on standard products such as sawnwood and wood based panels (see Figure 20).

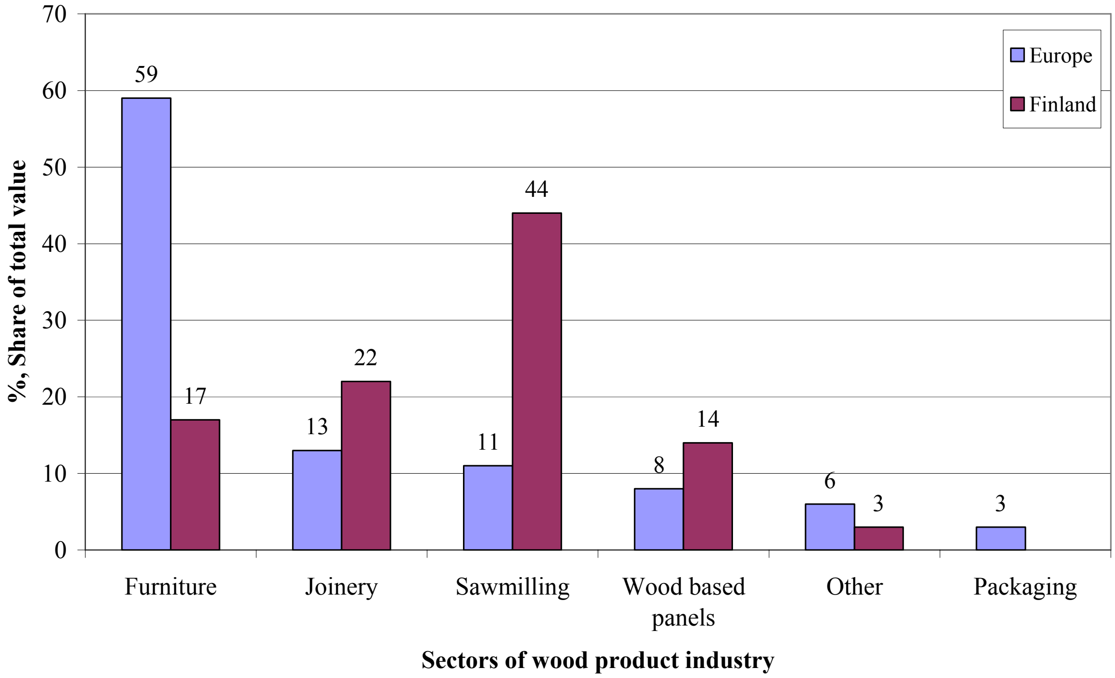


**Figure 20. Sectors of European and Finnish woodworking industry. Total value for Europe 163 billion € (2000) and Finland 6.3 billion € (2001). Sources: CEI-Bois 2003, Finnish Forest Industries 2003.**

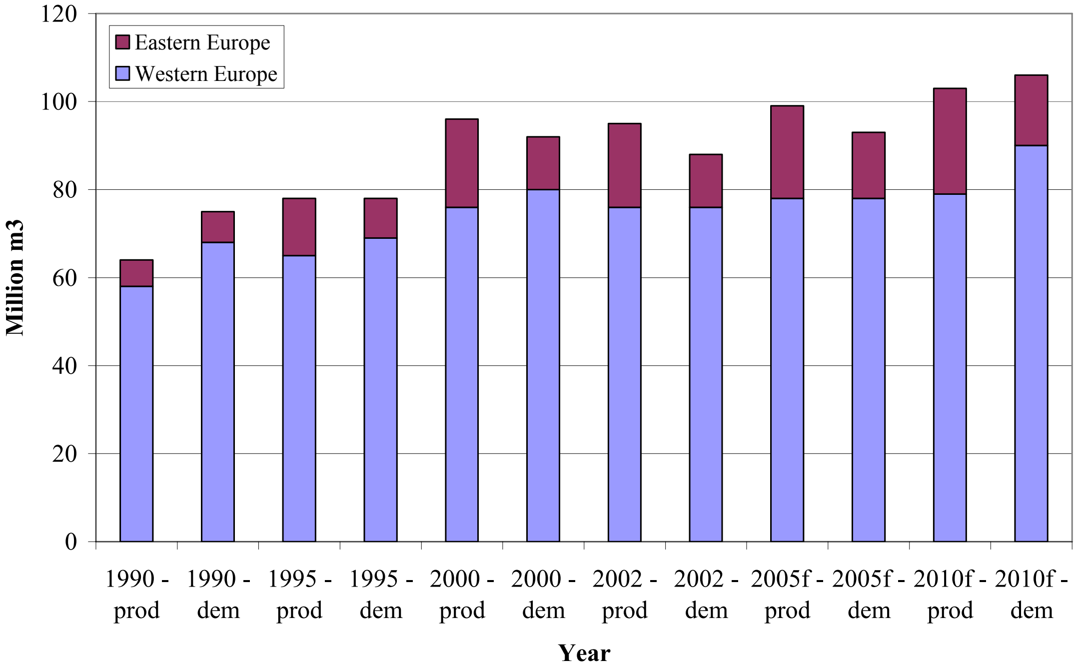
### 2.2.3 Coniferous sawnwood production outlook

According to Roadmap 2010 (2004) and JPC (2003a), softwood sawnwood production in Europe is expected to continue to increase, reaching nearly 105 million $m^3$ in 2010 (Figure 21). However, the overall annual growth is estimated to be slower than that seen during the last decade due to the restricted demand growth in West Europe and key overseas markets. The Scandinavian sawmilling industry will face increasing difficulties in domestic log procurement, resulting in stagnating output, whereas producers in the British Isles (low capacity utilisation) as well as in East and South Europe (green field investments) are expected to have an increasingly significant role in European supply.

JPC (2003a) states that further capacity increases are expected in East Europe, partly resulting from wood raw material sourcing by large integrated forest companies in the Nordic countries but also from domestic industries exploiting the production cost advantages. Martikainen (2002) supports capacity increase in East Europe by showing that CSW production of wholly or partly Finnish owned sawmills is estimated to develop from some 7 $Mm^3$ in 1991 to 24 $Mm^3$ in 2005, of which production in 2005 is 12–13 $Mm^3$ in Finland and some 11–12 $Mm^3$ outside Finland. Nevertheless, according to JPC (2003a), the tightening raw material supply in some regions, e.g. in the Baltic countries, will drive the expansion to Central and South East Europe. Increasing share of capacity in Western ownership drives the shift towards further processing and consequently enhances export outlook.

According to Roadmap 2010 (2003), the overall CSW demand in Europe is expected to increase by approximately 7 million $m^3$ by 2010, supported by the improving business environment and enhanced local processing as well as growing local demand within the East European countries. According to JPC (2003a), the growing European production and the increasing imports from East Europe are expected to create a significant oversupply in West Europe, spurring exports to overseas markets, the scope and destination of which are dependent on the exchange rate development. The leading supply countries Sweden, Finland

and Austria are expected to retain their roles as major net exporters in West Europe, which will depend on their competitiveness in the change of Europe.



| | CAGR | 1990–1995 | 1995–2000 | 2000–2002 | 2002–2005 | 2005–2010 |
|---|---|---|---|---|---|---|
| **Production** | **WE** | 2.1% | 3.1% | -0.2% | 1.1% | 0.3% |
| | **EE** | 17.4% | 8.3% | -1.2% | 2.8% | 2.2% |
| | **Total** | 4.0% | 4.1% | -0.5% | 1.4% | 0.8% |
| **Demand** | **WE** | 0.5% | 3.1% | -2.2% | 0.8% | 0.3% |
| | **EE** | 7.1% | 6.5% | 2.2% | 3.5% | 3.0% |
| | **Total** | 1.1% | 3.5% | -1.6% | 1.2% | 0.7% |

**Figure 21. Coniferous sawnwood production (prod) and demand (dem) in Europe. WE = West Europe, EE = East Europe. f = forecast (e.g. 2005f). CAGR = period of growth. Source: Roadmap 2010 (2003). Modified by author.**

## 2.2.4 Sawmilling industry structure

There are unique structural features in the European sawmilling industry. Traditionally, perhaps, the most important features for the sawmilling industry have been economy of scale with low profits, scattered industry structure, raw material high relative share of sawnwood price, sawmill location near raw material and large market ups and downs by volume and price (Figure 22).

The Finnish sawmilling industry has long lived with economic fluctuations and a number of small sawmills. Luther (1986a) estimated the size of household and small sawmills to be some million m$^3$ during the boom time in Finland. Siekkinen and Pajuoja (1990) estimated CSW production from small sawmills to be 1.237 Mm$^3$ in Finland. From 1990 to 2001, there were four price peaks for CSW export prices – the years 1990, 1995, 1998 and 2000 – and one short peak at the end of year 1992. The Finnish sawmilling industry previously profited temporarily from devaluations of Finnish mark, because domestic raw material and change in export prices improved the competitiveness of the sawmilling industry.

According to Diesen (1998), economy of scale can be defined as the cost advantage achieved by using large and growing unit sizes in the manufacturing process. Economy of scale is a common feature for the sawmilling industry as well as most large scale industries like paper or car industries (see e.g. Diesen 1998). This has lead to larger and larger production units, merged large volume distributors and cost efficient operations in the whole product chain.

Kairi (2005, Figure 21) shows that increase in volumes improved the earning capacity in the Finnish sawmilling industry between 1980 and 2000.

One reason for the sawmilling industry economy of scale is that the coniferous sawnwood export price remained nominally on the same level but in fact decreased from the price level of 1990 (Figure 22). This may indicate lower price competitiveness for Finnish sawnwood. On the other hand, the price development shown in Figure 22, may not reveal anything new, because Ahvenainen (1984, p. 441) suggests that almost all 1970s CSW deflated export prices remained on the same level.

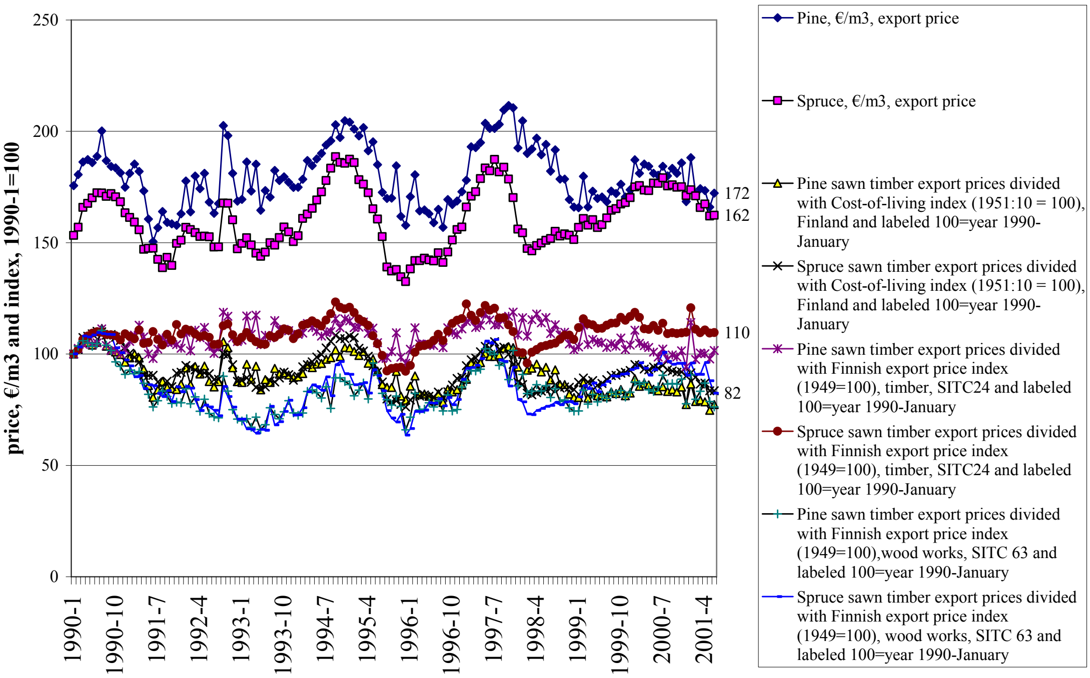


**Figure 22. Finnish coniferous sawnwood monthly export prices for pine and spruce (€), FOB (January 1990-June 2001, Foreign Trade Statistics 2002 from Finnish forest industries 2002) together with prices divided with Cost-of-living index and export price indices in Finland (timber and wood works, STAT 2004). Modified by author.**

The Finnish sawmilling industry can be grouped into three groups based on ownership. In Finland there are (1) large integrated groups of sawmills – in 2004, West Europe's three largest sawmilling companies (Stora Enso Timber Ltd., United Sawmills Ltd. and Finnforest Ltd.) are fully or partly Finnish, (2) independent, family-owned not integrated sawmills, (3) a heterogeneous group of small and often local family-owned sawmills. The first groups (1 and 2) are often represented by both Finnish Forest Industries Federation and Finnish Sawmills. In 2000, there were from 130 to 170 industrial sawmills in Finland depending on the method of assessment. These sawmills exported over 70% of their production. The three largest integrated groups of sawmills covered almost 50% of the CSW production in Finland in 1999. Independent, family-owned small and medium sawmills have increased their share of CSW production in Finland during the 1990s (Key to Finnish Forest Industries 2000).

The sawmilling industry can also be divided into three groups by volume in Europe. There are (1) few large volume sawmilling companies, (2) some medium size companies, (3) many small and often local sawmilling companies. The Finnish sawmilling industry is similar in this respect, as there are three large corporate groups that are powerful on European level, some medium size companies (SMEs) and a large number of small sawmills (Peura 2001). At any rate, Finnish sawmills have been more export oriented than most European sawmills.

Simultaneous price development for pine and spruce may indicate that they have partly the same user segments. Ups and downs took place within the same periods of time. However, pine had a larger price fluctuation on a monthly basis than spruce, but both have similar trends. Price level did not increase from 1990 to 2001 but average price difference between the species has become smaller. For the first time, the spruce average price got higher than the pine price in December 2000. This may refer to constant changes of sawnwood demand and use.

## 2.2.5 Economic overview of the Finnish sawmilling industry

The volumes of the Finnish sawmilling industry increased almost throughout the 1990s, but practically regressed to the same level in 2000–2004 (see Figure 23). The amount of produced spruce sawnwood remained higher than pine through the period from 1990 to 2004. Particularly in the periods of rapid growth, such as the years 1994 and 2000, the growth was mainly due to the larger amount of produced spruce sawnwood. It is interesting to note that the difference between pine and spruce equalised during some years after the latest growth period (i.e. years 2001 to 2003, Figure 23).

The amounts of coniferous sawnwood exported from Finland increased in the period between 1990 and 1998 but regressed in 1999 to 2004. Spruce exports decreased from 1999 to 2004, whereas the amounts of pine were practically constant. In 2004, the amounts of pine and spruce exported from Finland were almost equal. The most important changes that took place between 1990 and 2004 are listed in Table 15. The growth of production as well as the export of both sawnwood and planed sawn goods levelled in 2000–2004 (Figure 23). In conclusion, economic indicators of the Finnish sawmilling industry for pine and spruce (Table 15 and Figure 23) point out that there is probably a need for strategic change in the Finnish sawmilling industry.

**Table 15. Economic indicators of the Finnish sawmilling industry for pine and spruce. Data for domestic consumption of sawnwood in 2004 were not yet published. Data: Finnish Forest Industries (2004) and FAOSTAT data (2004). Modified by author.**

| Indicator | 1990 | 2000 | 2004 |
|---|---|---|---|
| **Production of sawnwood, Mm$^3$** | 7.40 | 13.32 | 13.46 |
| **Export of sawnwood, Mm$^3$** | 3.94 | 7.46 | 7.36 |
| **Domestic consumption of sawnwood, Mm$^3$** | 3.28 | 5.18 | - |
| **Export of planed sawn goods, Mm$^3$** | 0.21 | 0.93 | 1.04 |

Between 2000 and 2004, amounts of production and export remained constant or regressed in the Finnish sawmilling industry (Figure 23). This indicates three alternatives for the sawmilling industry for the coming years: 1) volume (m$^3$) increase, 2) cost (€/m$^3$) decline, 3) increase (m$^3$) of value added products. Volume increase is possible only by increasing amount of imported logs, which is rather uncertain. Thus, the probable alternatives are cost decline and increase of value added products.

Cost decline leads to lower sawing volumes and cost factors. Lower sawing volumes (for instance between 2000 and 2001 in Figure 23) give a fast way to react to cost decline. In practice, some sawmills would be closed down and the sawmilling industry would refrain from investments.

Nevertheless, the log price is the biggest cost factor in the Finnish sawmilling industry. It is possible that the log pricing system will change. It will possibly be more linked with quality and added value from products. In addition, the log price will be divided to more accurate groups. It is also possible that there will be new sawing concepts that will react to changes in raw material price and quality.

Increase of value added products (e.g. planed sawn goods in Figure 23) requires understanding of customer segment needs. The customers will pay only for the added value to their business. Therefore, increase of value added products may be slow.

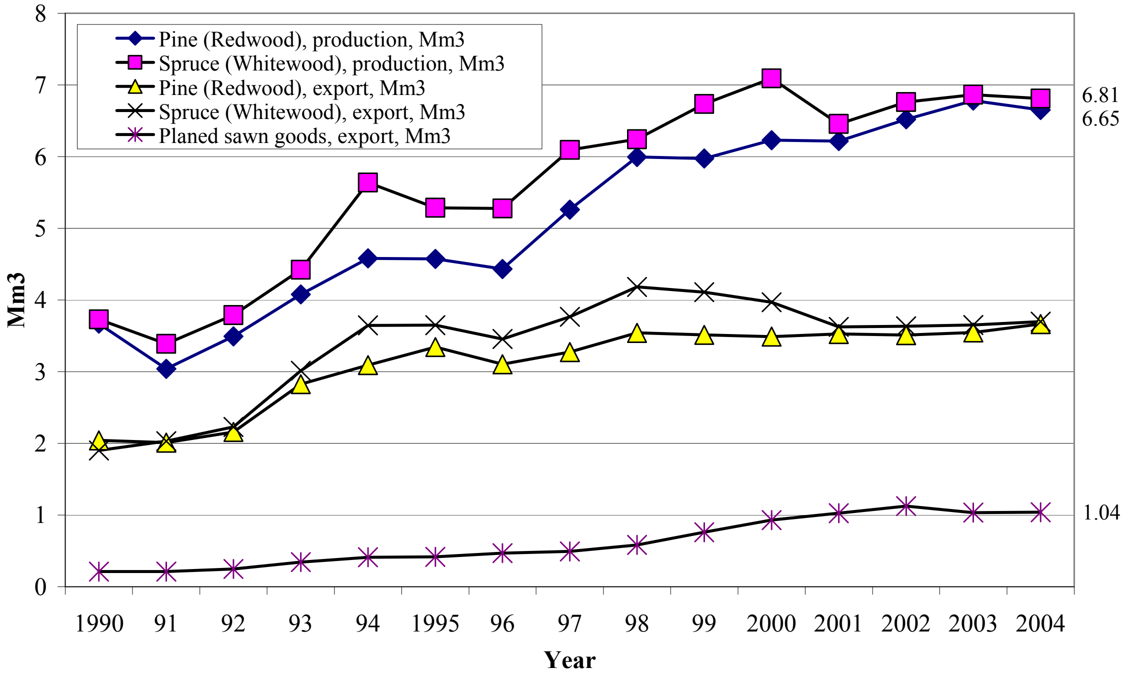


**Figure 23. The Finnish sawmilling industry – volume overview (Finnish Forest Industries 2004). Modified by author.**

The export prices of Finnish sawnwood and planed sawnwood have remained nearly at the same level from 1990 to 2004 (see Figure 24). Interestingly, the export prices of sawnwood and planed sawnwood changed mostly in the same direction at the same time. The only exception was the change between the years 2003 and 2004, when the export prices of sawnwood went down and those of planed sawnwood went up a little (see Figure 24).

For profitability analysis, the only source available was the general profitability development of the Finnish forest industries from the years 1992 to 2004. The profitability of the sawmilling industry was not specified in the data. Therefore, the development of the profitability of the forest industries probably does not fully correspond to that of the sawmilling industry. However, if the profitability data of the Finnish forest industries give some indication of the profitability of the sawmilling industry, two things become apparent. Firstly, the general profitability of the forest industries had a great annual variation during the years 1992–2004. Secondly, the profitability of the forest industries and operating margin of wood product industries had no connection to the prices of sawnwood and planed sawnwood.

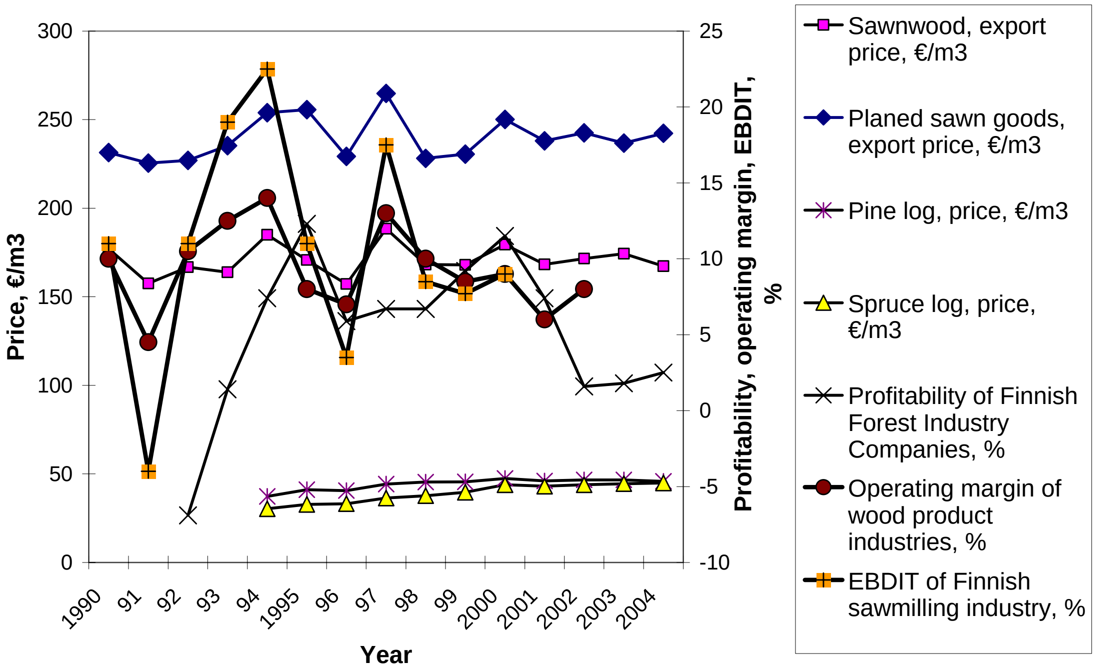


**Figure 24. The Finnish sawmilling industry – price and profitability overview. Profitability (result before extraordinary items/turnover, %) values do not include only the Finnish sawmilling industry but all Finnish forest industries. Operating margin (turnover – operational costs/turnover, %) does not include only the Finnish sawmilling industry but all Finnish wood product industries. EBDIT = Earnings before Depreciation, Interest and Taxes. Sources: Finnish Forest Industries 2004, Finnish Statistical Yearbook of Forestry 2003, Kairi 2005.**

The prices of pine and spruce logs were quite stable according to Figure 24. At any rate, from the perspective of the Finnish sawmilling industry, the economic situation looked worse in 2004 than in the 2000. Spruce log price increased significantly from 1993 whereas whitewood (spruce) sales price in Finland decreased (Figure 25).

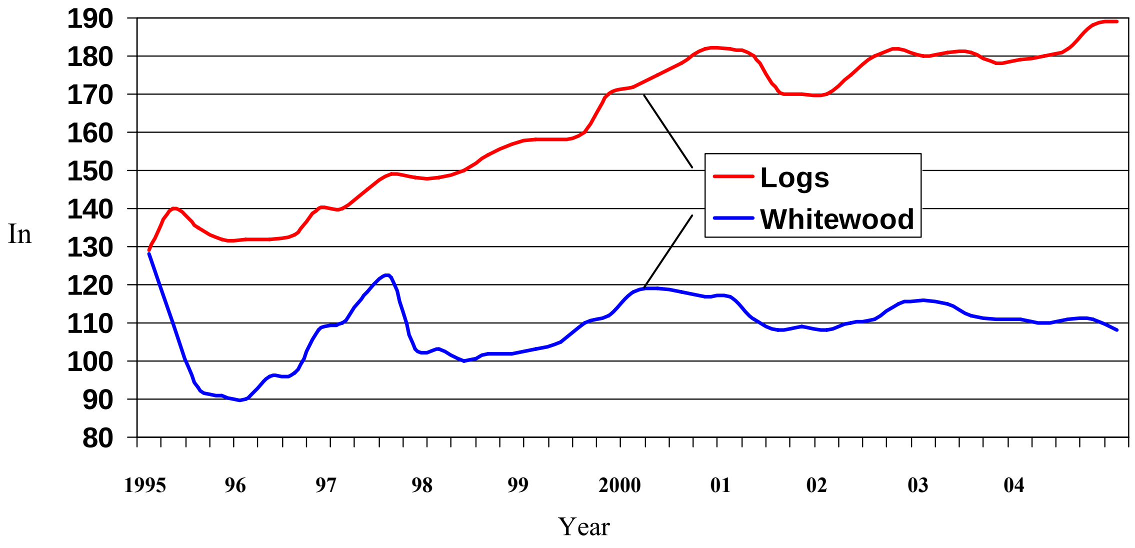


**Figure 25. Development of spruce log price and whitewood (spruce) sales price in Finland. In = Index, 1/1993 = 100. Modified by author. Source: Stora Enso Timber (2005).**

The development of the sawmilling industry's customer segments was on the rise in Finland during the reviewed period from 1995 to 2002 (see Figure 26). Prefabricated wooden housing, joinery and furniture industries increased substantially from 1995 to 2001. In the year 2001, however, the volume of prefabricated wooden housing industry decreased a little but the volumes of joinery and furniture industries (M€) remained steady or increased only slightly (see Figure 26).

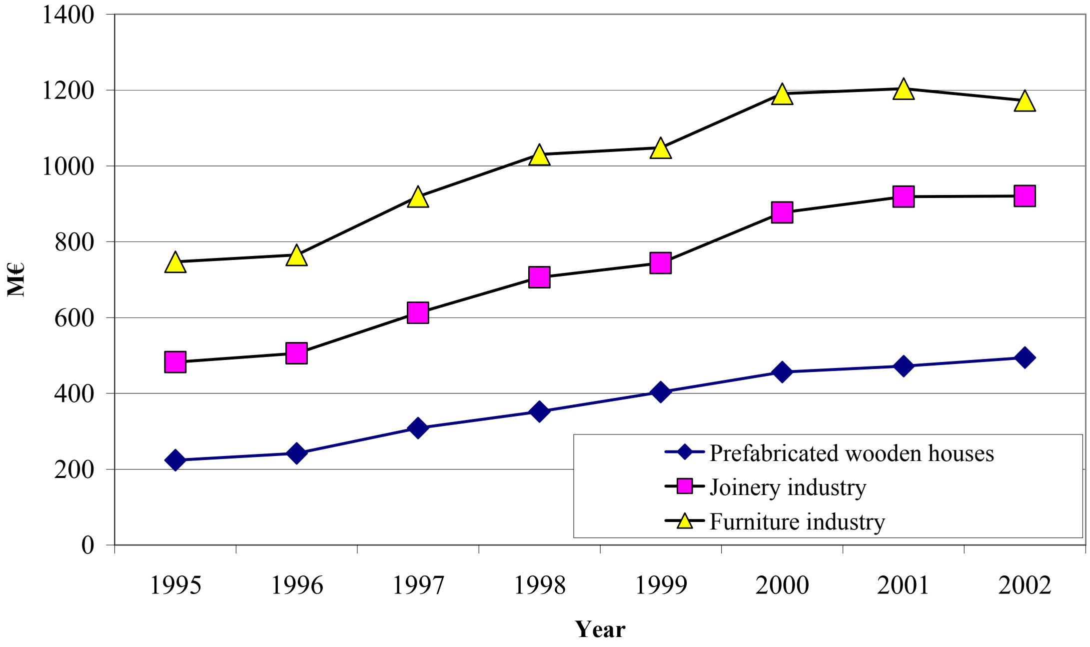


**Figure 26. The Finnish sawmilling industry – customer segment overview of three segments in Finland. Gross values of production of the prefabricated wooden housing, joinery and furniture industries (Finnish Forest Industries 2004).**

Construction industry is the most important customer segment of the sawmilling industry. The development of construction in Europe is heavily dependent on the changes in GNP (see Figure 27). According to Tervo and Janatuinen (1988), interest rates, construction orders, and housing starts were most often the leading indicators of sawnwood imports and Finnish sawnwood exports. Tervo and Janatuinen (1988) found that GDP and value series of the construction industry were predominantly lagging behind the sawnwood imports and export series. They also found that the time series seem to be the most promising database for short term forecasting of the fluctuations in the Finnish sawnwood exports (Tervo and Janatuinen 1988). Moreover, the relative timing of the cyclical fluctuations and the size of cross correlations describe the economic activity of the total economy of West Germany, as well as its construction industry. Likewise, the financial changes of the Finnish sawmilling industry also follow the general economic trends reflected by the changes of GNP.

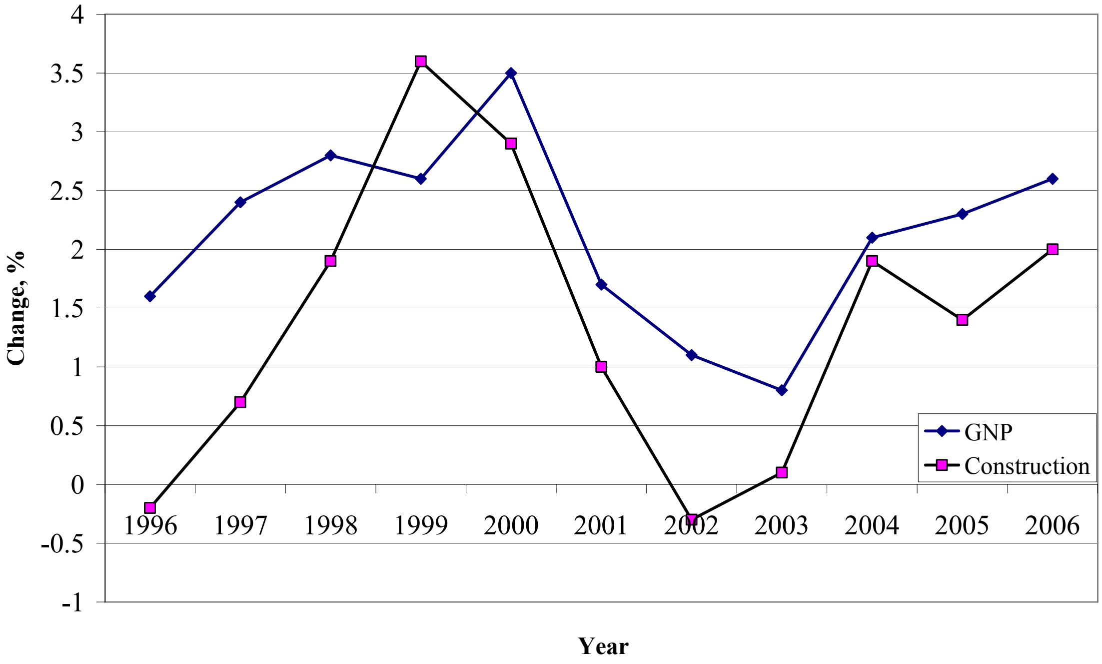


**Figure 27. Change in GNP and construction in Europe. Years 2004, 2005 and 2006 are estimates (Euroconstruct 2004).**

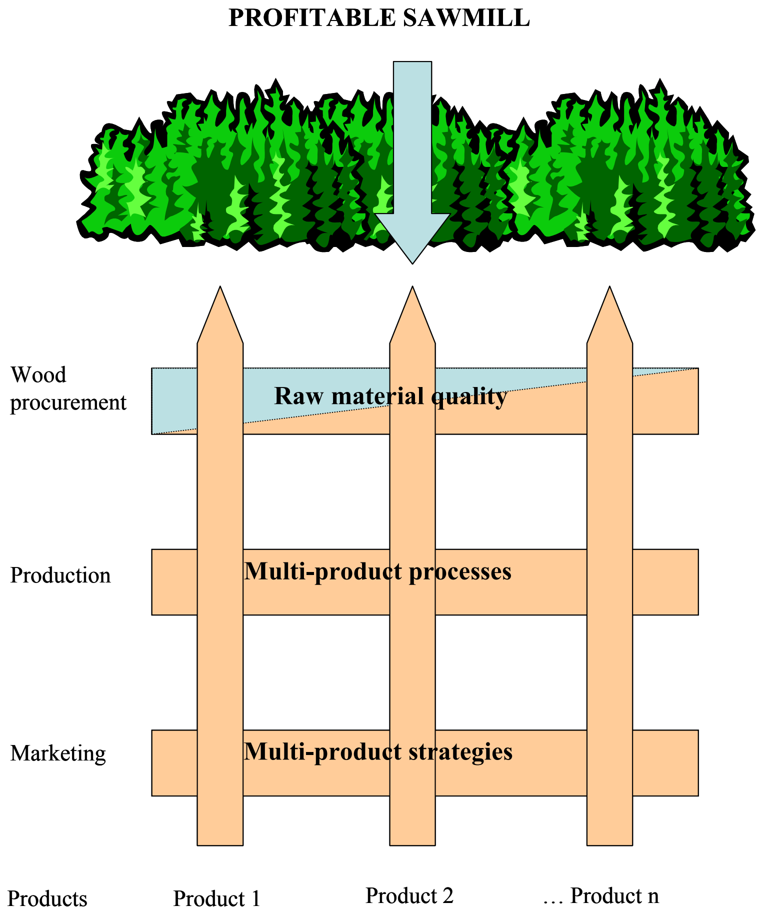
The time series presented in this section show that the economic environment of the sawmilling industry changed significantly in the years between 1990 and 2004. As any other factors related to the structural or cyclical economic changes can have a considerable impact on the results, substantial reservations must be taken for the period analysed later in this work, the years from 1995 to 2000.

### 2.2.6 Trends in sawmill competitive environment

According to the Vision 2010 by Klus and Hirvensalo (1997), Finnish Forest industries (1999) and Roadmap (2003), there are many trends that have an effect on the Finnish sawmilling industry. The trends can be classified into two main groups: (1) business trends and (2) technology trends.

In the competitive environment of sawmills, perhaps the most important business trend is globalisation. The sawmilling industry is becoming supranational due to globalisation (see e.g. Kozak and Spelter 2003, Palo 2004). Standard products from the sawmilling industry are sold in a large number of countries with the world market price based on price competition. Simultaneously the business structure of the Finnish forest industries is changing. The former classification into mechanical and chemical forest industries still exists in Finland. Concurrently, there are signs of a new classification into mechanical, chemical and energy wood processing industries. The importance of wood energy has increased during the past 15 years in Finland due to relatively high energy prices. In addition, ecological perspectives are becoming more prominent in the sawmilling industry.

Several technology trends can be seen in the competitive environment of sawmills. Diffusion in information society penetrates to sawmills. In brief, faster and more reliable information networks are becoming more common in new solutions. These include the commerce and business between sawmills and their customers. The technology in the forest-sawmill-customer chain is becoming a part of a business chain (see Figure 28). This can be seen in the more cost-efficient production, utilisation of logistic technologies and electronic commerce. Furthermore, network communication and the use of customer interfaces are increasing in sawnwood sales (e.g. building projects and new construction systems).



**From multi-product strategies to product based**
**- production systems**
**- raw material and price choices**
**- wood procurement models**
**controlled by product group strategies**

**Figure 28. Profitable sawmill model by Puun mekaanisen jalostuksen teknologiaohjelma (1997). Modified by author.**

In Finland, examples of the process of improving sawmill competitiveness have been national research and technology programmes by Tekes and sawmilling industries (PMT programme 1995, Klus and Hirvensalo 1997, Wood wisdom 2002, TEKES 2003). The PMT programme was divided into four main parts: (i) redesign of wood processing industry operation chain, (ii) production development for standard products, (iii) improvement of wood competitiveness (see Figure 28), and (iv) technology development for new products and wood refining technology (PMT programme 1995, Klus and Hirvensalo 1997). The main goals of PMT and PLT programs were (Puun mekaanisen jalostuksen teknologiaohjelma 1997):

1. Independent strategic development of mechanical wood industry
2. Rational utilisation of forest resources.
3. Renewal of operational and development structure of the mechanical wood industry

Nevertheless, the main goals of PMT programme were on the practical implementation level:

1. The strategic changes in the wood product industry from traditional modes of logging, producing and marketing towards product and customer segmentation (see Figure 28).
2. The competitiveness of the sawmilling industry has improved due to the increased use of modern technology.

Vision 2010 was created by Finnish Forest industries (1999) to express a common strategic goal for Finnish wood product industries including sawmilling. Vision 2010 underlines (1) customer orientation and (2) focusing on systems of wood in construction and living instead of standard products. According to the Vision 2010 (Paajanen et al. 2000), construction industry will remain the main customer for wood products. This applies to sawmilling, too. Therefore it is natural that one strategic area of wood products industry and research is building with wood. Wood products are not only demanded in construction but also considered in a social context. Thus the other strategic area of the wood products industry has been defined to be living with wood. All resources in the wood products industry will be concentrated on these two strategic areas (Key to Finnish Forest Industries 2000).

Improved efficiency in the forest-sawmill-customer chain often has required Finnish sawmills both to have production growth and to adjust their strategies in 5–8 year intervals, e.g. from standard product strategy to value added product strategy. It has been estimated that production growth for Finnish sawmilling companies in the 2000s will take place outside Finland, particularly in East Europe, but the Finnish sawmills need growth in value added production, too (see Table 16).

**Table 16. Efficiency-improving tasks and their estimated consequences in the forest-sawmill-customer chain for Finnish sawmills in the 2000s (Martikainen 2002).**

| East Europe | West Europe |
|---|---|
| - Ensure raw material adequacy in future (selling taxes, import customs)<br>- Low raw material and labour costs<br>- Presence in future markets<br>- Most greenfield investment project for standard production | - Supplementary refining to present product range<br>- Integration with distribution systems<br>- Acquisitions, fusions and joint ventures both in standard and refined products |

To be more specific, development of the Finnish sawmilling industry can perhaps be seen through the following trends in last 20 years. These trends still continue:

1. Decreased quality/price ratio for sawnwood
2. Improved sawmills' reaction to customers' demand
3. Improved customer orientation through refining and product orientation
4. Improved efficiency in forest-sawmill-customer chain
5. Increased environmental consciousness

It is questionable if sawnwood competition environment can be simplified to these trends. For instance, the principal markets for the Finnish sawmilling industry have been in Europe (Key to Finnish Forest Industries 2000). Now the domestic markets for the Finnish sawmilling industry are gradually changing from Finland to Europe, and the world outside Europe becomes the export market for CSW. However, this is included in trend 2 – improved customer orientation.

#### 2.2.6.1 Decreased quality/price –ratio for sawnwood

Decreased quality/price ratio for sawnwood means that customers demand sawnwood with improved quality and often for a cheaper price, too. This market demand has forced sawmills to seek means to improve their process and product quality as well as their productivity. Simultaneously, sawmills are forced to cut their costs and to focus on cost-efficient production strategies (PMT programme 1995, Wood wisdom 2002).

Decreased quality/price ratio for sawnwood can be seen in the increase of CSW quality requirements and customer service expectations. Decreased quality/price ratio means probably an increase of fresh knot and sawfalling (SF) qualities, because CSW sawfalling quality class often includes qualities of large, fresh knots. Pöyhönen (1991) supports the idea of quality/price ratio by presenting a sawmill of quality production as an alternative for the

Finnish sawmilling industry. In addition, decreased quality/price ratio is often connected to market areas. Uotila (1994) divides the Finnish CSW export countries to Europe, Arab countries and overseas markets. According to Uotila (1994), in the CSW markets of Arab countries, price elasticity is the only operational method, whereas in the European markets, the quality plays a significant role, too.

#### 2.2.6.2 Improved reaction of sawmills to the demand of customers

Sawmills have worked to improve their quality and raise their productivity by developing drying processes, moving out from log water storage and investing into machine vision grading systems. The aim to simultaneously improve quality and reduce costs is typical for sawmilling in other parts of the world, too. Sinclair (1992) says that production cost reduction and the growing importance of quality were strategic trends in forest industries in the USA in 1990s. Paajanen et al. (2004b) support Sinclair (1992) but state that the changing position of Finnish sawmills and other wood product companies in European turning point may lead to a situation where sawmills must compete through prices in traditional product groups, seek partners both in Finland and other countries and face tightening multi-level competition on all markets and in Finland, too (see Figure 29).

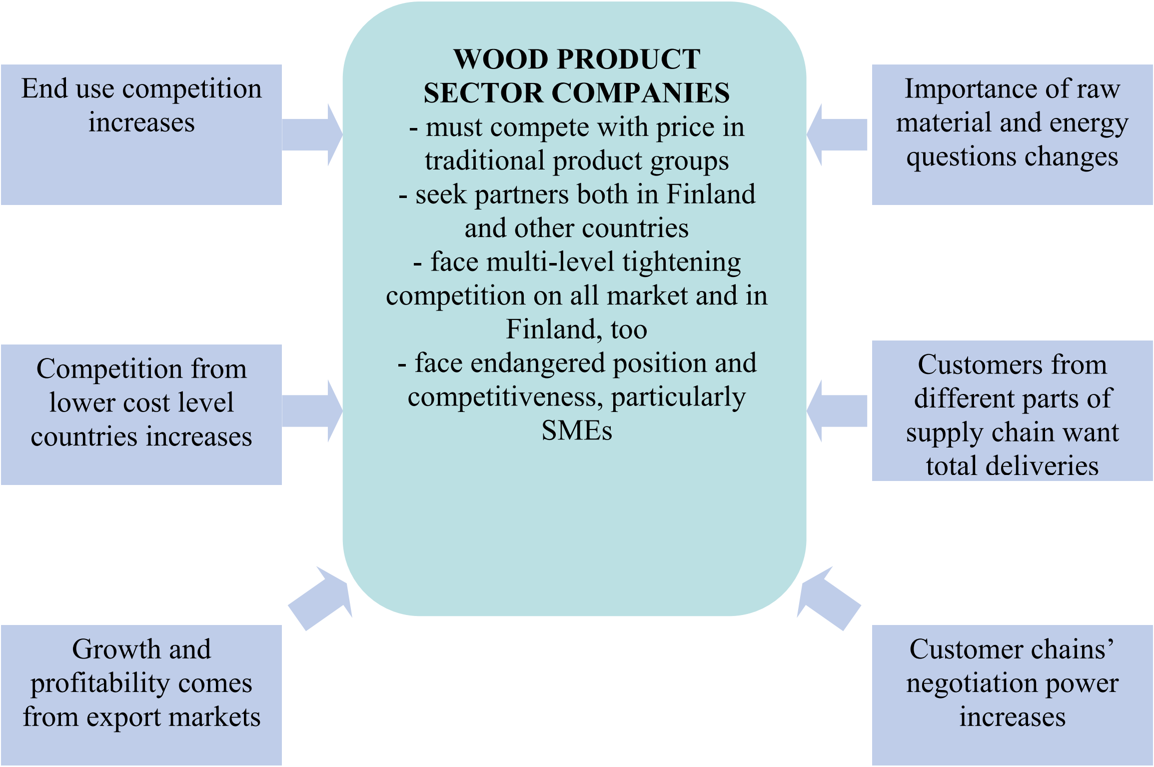


**Figure 29. The changing position of Finnish sawmills and other wood product companies in European market. The section "Importance of raw material and energy questions changes" includes environmental and energy issues (EU 1999, Paajanen et al. 2004b). Modified by author.**

Paajanen (1988) says that the importance of kiln drying in sawmill process has significantly grown from the mid 1980s. The reason is in the growing demand of sawnwood end moisture contents (MC) of joinery (MC < 13%) and other than export moisture content (MC 18%). On the other hand, there is a customer need to decrease sawnwood fissures, deformation and other drying defects. Kiln drying is one of the most expensive sawmill processes, too. Some 80–90% of sawmill thermal energy and half of the electricity is used for drying (Paajanen 1988). In practice, the development of sawnwood drying has meant the following development projects in the sawmilling industry: i) new drying methods for channels, chambers, low pressure and high temperature; ii) creep modelling; iii) software for drying schedule optimisation (PMT programme 1995).

Most Finnish sawmills have moved out from log water storage because customers in the joinery segment want sawnwood that has not been produced from water storage logs. Log water storage can change wood permeability, which may increase wood absorption of paints, glues and impregnation components. This causes uneven visual surface and other quality defects (Rydell 1992, Sågverken 1993).

### 2.2.6.3 Improved customer orientation through refining and product development

Improved customer orientation through refining and product development can be seen in the increase of special and customer grading, aim to better quality, increased refining, and increase of market oriented thinking in the sawmilling industry. Customer demand for sawnwood is moving from traditional sawnwood standard products like U/S standard dimension to special and customer tailored products where quality and dimensions are fitted to end use. Share of special and customer products increased from 10% in early 1980s to 25–30% of mid 1990s (Nordiskt träteknik 1993, Johansson et al. 1994a, Johansson et al. 1994b, Profitable Sawmill 1994, Lehto 1995). Information technology has an important role in the development of improved customer orientation (see Figure 30).

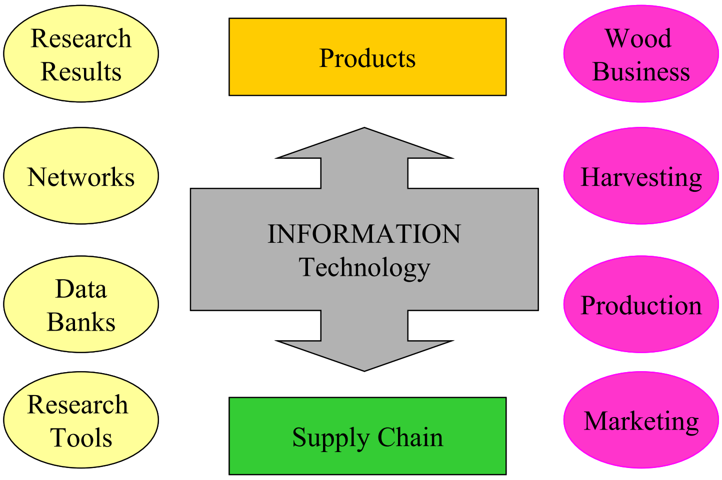


**Figure 30. Information technology between the supply chain and customer oriented products (Usenius 2005).**

Improved customer orientation can be seen in the product brand strategies of the sawmilling industry, too. Both standardised and special products are built to uniform sets where brand is attached to both product and company features. Examples of this are sawnwood brands like Wisa®, Finnforest® and Stora Enso Timber as well as Stora Enso Timber special products like WoodHeart® (Wisa 2004, Stora Enso Timber 2004, Finnforest 2004). On the other hand, the Swedish sawmill Iggesund has registered Monolit® brand to sawnwood product with no pith and direction of annual year rings perpendicular to grain (Nordiskt träteknik 1994).

Improved customer orientation can be seen as a feature of late-industrial operating mode. Hartikainen (1997) suggests that late-industrial operation mode applies business philosophy of differentiation or economies of scope responsiveness instead of industrial business philosophy of economies of scale. As the criteria for choosing a supplier, the late-industrial operating mode includes variety, costs, timing, specifications, quality and service instead of standards, volumes and costs. Hartikainen (1997) proves that those joinery or furniture manufacturers that are more late-industrial also are likely to use more component-type wood material and to appreciate customer-oriented technical precision. The change is towards the use of late-industrial sawnwood materials and late-industrial supplier relationships. This could be expressed as in Figure 31.

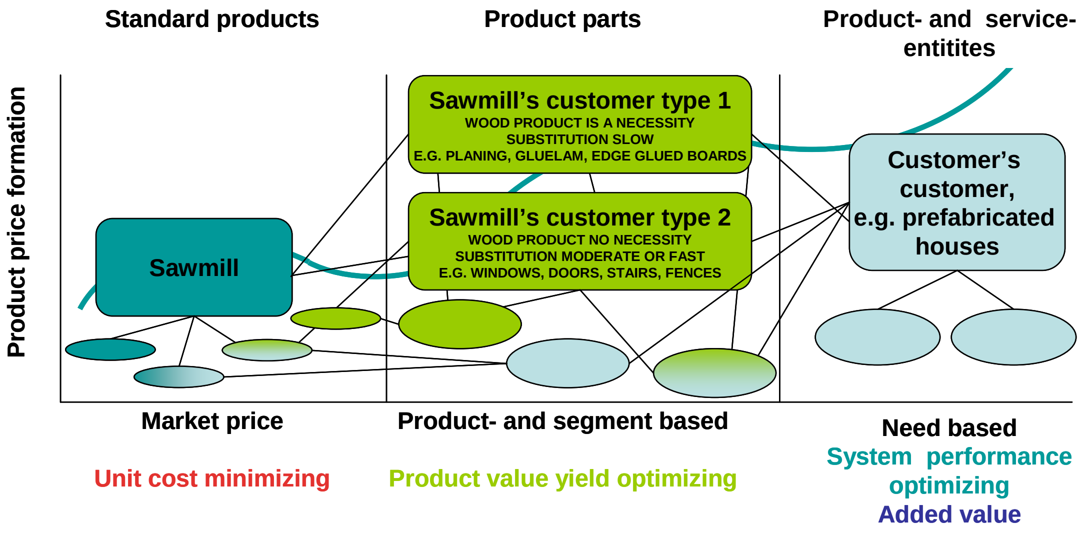


**Figure 31. Value chain of improved customer orientation (Paajanen et al. 2004a). Modified by author.**

Paajanen et al. (2004a) suggests that all three parts of value chain (standard products, product parts, and product- and service entities) need successful wood product companies of different sizes and networks between them. According to Paajanen et al. (2004a), this will ensure competitiveness of wood product industry in the future.

### 2.2.6.4 Improved efficiency in forest-sawmill-customer –chain

The Finnish sawmilling industry is characterised by the integration of different, mostly contiguous stages of production. In integrated production, the sawmill co-operates closely with the forest sector, pulp and paper mills as well as sawnwood customers, which all form the production chain. Thus the use of raw materials and energy is efficient and production economical. However, one significant obstacle to integrating the forest-sawmill-customer chain has been the lack of appropriate information about the forest stands (Uusitalo 1995).

The production structure of the Finnish sawmilling industry is based on the wood species distribution of Finnish forests. The Finnish wood species are well suited for the integrated processes of both the sawmilling industry and other forest industries (see Figure 32). The largest parts of pine and spruce are refined to sawnwood. Moreover, spruce is used along with birch as raw material for plywood. Pine chips, a by-product of the sawmilling industry, are used as fibre wood, which is raw material for chemical pulp. In the same way, spruce chips are used to produce mechanical pulp, ground wood pulp and refiner mechanical pulp (Key to Finnish Forest Industries 2000).

Improved efficiency in the forest-sawmill-customer chain means moving from the traditional way of thinking, concentrated on raw materials and production, towards new, market-centred thinking and value added chains (Laine et al. 2001). According to the report Profitable Sawmill (1994), the use of forests, wood procurement and development of sawing have been based on taking maximum advantage of the log part of stem. As a consequence, the sawmills have ended up with a multi-product process, where a large variety of products and different quality items are produced.

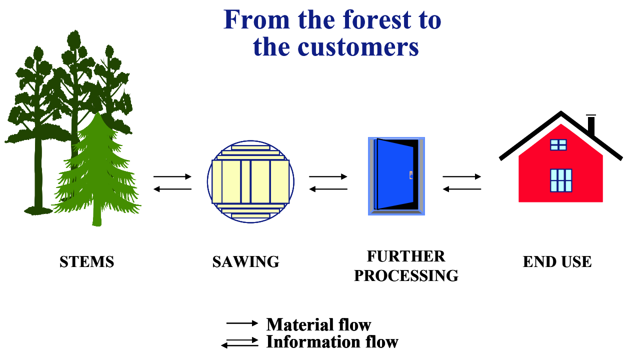


**Figure 32. The forest-sawmill-customer chain (Usenius 2002a).**

The modern Finnish sawmills have become all-purpose production plants for sawnwood. Their technical solutions are based on utilising almost all log size roundwood with the highest raw material ratio possible. In practice, this has meant adapting the sawing processes and methods of processing sawnwood so that all sizes and qualities can be processed. From the marketing perspective, this has meant a large number of products. Sawmills are using multiple levels of various marketing channels and placing the whole product range into several market areas. Thus the relationship between the sawmill and its customers may have remained distant.

As a solution for sawmills to become more customer oriented, Profitable Sawmill (1994) states that the sawmilling industry moves from multi-product based marketing and sales strategies and processes towards product group based production methods, raw material's quality and price alternatives as well as wood procurement models. According to Kairi (2005), The Profitable Sawmill project (1994) – also called KANSA project – was a central contributor to the strategic change within the sawmilling industry. The outcome of the project lead to the following implementations (Kairi 2005):

- specialising in product groups as compared to the traditional bulk production of sawmills
- concentrating on product-focused, selective wood procurement and harvesting automation
- sawmills using only one wood species
- integrated information systems to enable sawmills to better manage the entire delivery chain from forest to products

A parallel solution to Profitable Sawmill (1994) is suggested by Sinclair (1992): it suggests the industry to transfer to customer orientation by taking steps in product development and better quality. According to Uotila (1994), it is useful for particularly small sawmills to specialise in specific customer segments. They can do this by targeting specific raw material and developing their production's flexibility. On the other hand, Niemelä (1993, 1994) has stated that some large Finnish sawmills had more customer-based market strategies in late 1980s and early 1990s than large sawmills had in West coast North America.

Juslin and Hansen (2002) suggest that there are several basic product strategies that a company can pursue. Companies can choose to emphasise (1) commodity products, (2) special products, or (3) custom-made products. Commodity products meet basic overall industry standards and are not adapted or specialised. Special products have been adapted to fit the specific needs of an individual sector by e.g. quality or size. Custom-made products have been developed to meet the individual needs of a customer.

Sawmills have made significant changes in their product strategies since the early 1980s from commodity to special or custom-made products (Table 17). According to Juslin and Hansen

(2002), the trend continues as the industry customises its products for specific end-uses or end-users.

**Table 17. The product strategy trends of sawmills (Juslin and Hansen 2002, Juslin and Naylor 2004).**

| Product strategy | Early 80s | Late 80s | 1989–90 | 1992 |
|---|---|---|---|---|
| **Commodity** | 89% | 79% | 71% | 64% |
| **Special** | 11% | 14% | 19% | 24% |
| **Custom-made** | 0% | 7% | 10% | 13% |

Sources: Juslin and Tarkkanen (1987), Niemelä (1993), Martikainen (1994), Toivonen (1995)

This trend is supported by Olkkonen (1996). European customers of the Finnish sawmilling industry were asked about the weaknesses of the Finnish sawmilling industry. Two of the weaknesses mentioned were (1) inflexible specifications and lengths and (2) lack of specialisation and customised products (Olkkonen 1996 through Juslin and Hansen 2002).

One method to improve efficiency in forest-sawmill-customer chain has been to monitor wood raw material flow, obtain information and using this information in the other parts of the chain. Usenius (2002b) presents a method to control wood material flow from forest to the sawmill, during the manufacturing process and further to the end products and end-users by marking the saw logs and products and then later by identifying markings in the different phases of the conversion chain (see Figure 33).

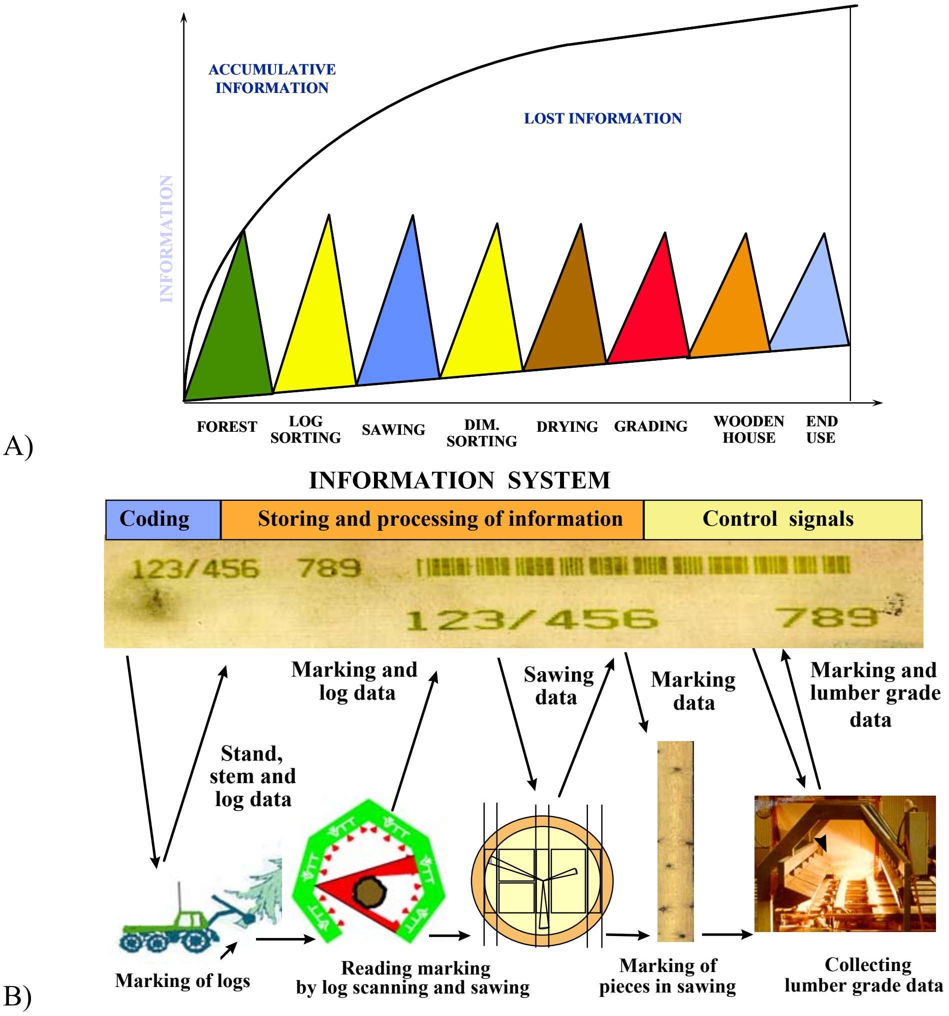


**Figure 33. A) Recorded and lost information in the conversion chain. The accumulative curve shows where the information will be available in later phases. B) The MRI (Marking, Reading, Information processing) control system (Usenius 2002b).**

Usenius (2002b) shows that the information in the conversion chain is used only locally and after the phase dumped. Therefore it has been impossible to link the final products, raw materials and processing parameters together. By using the methods Usenius (2002b) presents, there can be a new system for advanced control of the forest-wood chain by marking of wood pieces, reading the marking and data processing.

#### 2.2.6.5 Increased environmental consciousness

Increased environmental consciousness means in practice that sawmill's customer is more often interested in the environmental image of a country, a company or products. The environmental image means that the customers ask sawmills for information about the origin of wood, sustainable forest use and management as well as environmental impacts.

On the other hand, if the Finnish sawmilling industry cares for its environment development properly, it has all the prerequisites to connect CSW in marketing with the image of an environmentally friendly and ecological building product (Profitable Sawmill 1994, Ympäristönsuojelun vuosikirja 1995, Forest 2004). Kärnä (2003) supports this by saying that most forest industry companies in his sample emphasised environmental issues in their values, marketing strategy and its implementation. One example of this is in Forest (2004), where it has been stated that the Finnish forest industry uses every means at its disposal to prevent illegal logging. One method that has proved useful is voluntary forest certification, an idea that has been vigorously promoted (Forest 2004).

As a natural product, the environmental impacts of sawnwood are probably in a different class than those of competing building materials. CSW is produced from renewable raw material, the production of CSW requires some energy, wood products bind carbon dioxide ($CO_2$) for a long period of time and, at the end of its life cycle, CSW can be easily recycled or produced to waste (Mater 1994, Mater et al. 1992).

The Finnish sawmilling industry has responded to the increased environmental consciousness by e.g. calculating environmental impacts and sawmills' energy consumption and emissions. Sawmills publish sawmill-specific environmental reports. Furthermore, an updated environment report has been created for Finnish CSW, based on CSW life cycle analysis (Ympäristönsuojelun vuosikirja 1999, 2000).

## 2.3 Analyses and models of sawnwood and sawmilling industry

### 2.3.1 Analyses of product supply and demand

The development of analyses of product supply and demand is typically motivated by lack of supply or demand information, a change in a products' supply or demand situation or the availability of such a new method for product analysing that the new method gives a new perspective or new information of the research object.

Kangas and Baudin (2004) present a multiple equation framework that is developed to model demand, supply and trade of coniferous sawnwood and other forest products in the nine European countries. The projections prepared by Kangas and Baudin (2004) for 37 European countries suggest that (1) consumption of sawnwood is growing, but slower than the economy as a whole, and (2) projections of sawnwood consumption to 2030 is significantly characterised by the increasing role of countries currently having economies in transition. An increasing share of sawnwood is expected to be produced in Central and East European States (CEEC) as well as in the Commonwealth of Independent states (CIS). Kangas and Baudin (2004) also show their results of demand and supply elasticities for coniferous sawnwood.

Juslin and Naylor (2004) show in Table 17 on p. 55 that development of product strategies of Finnish sawmills during the 1980s has increased both supply and demand of special and custom-made sawnwood products. This supply and demand change required new marketing structures and functions as Table 18.

**Table 18. Development demands for marketing structures and functions (Juslin and Naylor 2004).**

| Structures | Functions |
|---|---|
| - Channels facilitating closer contact to customers.<br>- More advanced information systems. More sophisticated information capture, handling and sharing. | - Closer contact to customers.<br>- More information about customers.<br>- More systematic product planning. |

Korhonen and Niemelä (2004) present findings that imply that the three most common objectives of the leading wood-industry companies (including sawmilling companies) have been problematic to combine. These three objectives are profitability, growth and low costs. The objectives have effect to sawnwood supply and demand, too. Sawmilling companies have kept extreme focus on cost efficiency which has resulted in resource scarcity. This has led to losing competitive advantage, i.e. market credibility, which has led the sawmilling companies to focus more on high-value products and expanding the Japanese export programme.

In the short term, the supply and demand of forest products are affected by economic growth, particularly consumers' level of income and product prices (see Figure 34). In the long term, the demand is affected by population and economic growth, technology development and customers' preferences (Pajuoja and Brooks 1996). Latta and Adams (2000) present an econometric analysis of output supply and input demand in the Canadian softwood lumber industry. Their results show that the lumber supply elasticity in the British Columbia coast region may be twice as large as that in the interior or East regions. According to Latta and Adams (2000), comparison of Hicksian factor demand elasticities with earlier studies suggests that the own price elasticity of labour demand may be two or more times larger than for wood. Kangas and Baudin (2004) have estimated supply and demand elasticities for five groups of solid wood products including coniferous sawnwood. Kangas and Baudin (2004) results show that (1) there is a substitution in consumption between imports and domestic supply, (2) import elasticities are often higher than elasticities from domestic sources, (3) there is a substitution between exports and domestic markets in the export supply equations.

The most product supply and demand models approach two things: (1) Measurement of product demand determinants and (2) Improved applications. The latter includes the idea how information by measured determinants could be used for supply and demand forecasting. Toivonen et al. (2004) show that there are wood product component (or determinant) differences between supplier countries on German markets. From customer perspective, these differences on German wood product markets are based more clearly on the quality of the intangible than the tangible product components (Toivonen et al. 2004). Hence, Nordic suppliers (including Finnish sawmills) should concentrate efforts on improving the intangible product component, such as services and supplier characteristics.

Product demand model creation moves typically through the following process: (1) identification and definition of product's supply and demand determinants (e.g. growth of construction activities) according to a specific economic theory (e.g. a theory in macro or micro economics), (2) creation of a model or models based on the determinants and determinant estimation according to the selected theory, (3) tests of the model's validity and the selected theory, (4) application of the model to the research target and presentation of results. This process is followed, in principle, by e.g. Urga et al. (2003), and Katila and Riihinen (1990).

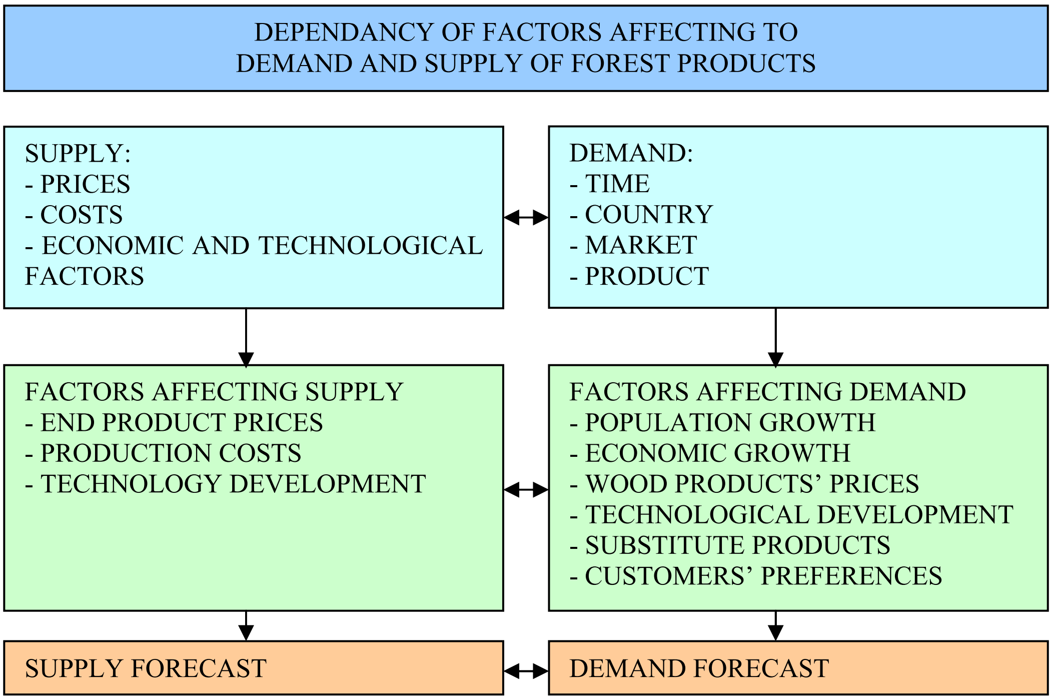


**Figure 34. Supply and demand forecast of forest products. Information from Pajuoja (1998), the figure by author.**

There are several methods used for product supply and demand estimations and analyses. In Latta and Adams (2000), the analysis employs a normalised, restricted quadratic profit function approach to estimate lumber supply and Marshallian factor demand elasticities for three Canadian regions. Cox (2002) presents how to apply data mining and modelling methods to learn predictive models of customer behaviours from survey and behavioural data. In addition, Cox (2002) presents his key insight that classification tree algorithms from data mining can be used to test conditional independence relations among variables in large multivariate data sets. Brekke et al. (2002) use multiple and stepwise regression models for demand models.

The general factors affecting forest product supply and demand depend on economic and demographic aspects, product features and customer preferences. The supply and demand estimation analyses developed so far have included parameters such as population growth, economic growth, standard of living, technological development, trade flows and price trends, according to Timwood (1998).

On the other hand, the factors affecting forest product supply include matters related to products, production and technology. Further behind these factors, there are underlying key features such as combined effects of economic and technological aspects.

The previous can be considered as the basic framework through which the supply and demand of wood products is monitored. However, in the particular case of wood products, there are some additional economic and competitive factors that affect the demand, according to Timwood (1998). This further defined frame includes the following aspects:

- Standards and legislation
- Certification procedures of forests and wood products
- Recycling and eco-labels
- Health aspects
- Trade restrictions
- Changes in the end use of products, particularly in building sector
- Changes in the important markets.

Sun (2001) has approached sawnwood demand modelling with the themes of (1) deforestation, (2) price and (3) exchange rate. (1) Exports of forest products have increased deforestation, mainly in developing countries. (2) Softwood lumber (timber, sawnwood) prices were more volatile in the 1990s than in the 1980s, with the period between 1991 and 1996 being the most volatile. Uncertainty and supply constraints under the 1996 U.S.-Canada Softwood Lumber Trade Agreement (SLA) were the primary causes of price volatility in the 1990s. (3) In estimating the export demand model, the nonstationarity of individual time series has been taken into account explicitly by employing new techniques of multivariate cointegration and error correction models. Overall, the impact of exchange rate volatility was negative and weak in the long term but the short-term dynamics depended on the specific kind of forest product under consideration.

There are a number of research projects that have approached sawnwood demand with the themes of market changes and product substitution. For instance, Martin et al. (1997) state for U.S. markets that growing demand in the U.S. market for wood products has been met in part by increasing imports from Canada and developing technology that can conserve wood inputs, use more abundant hardwood species, or integrate recycled fibre. Martin et al. (1997) comment the topic of substitution of nonwood products by writing in their report that data are inconclusive or nonexistent on the extent of substitution of nonwood products.

### 2.3.2 Analyses and models in sawmilling industry

Analyses and models used in the sawmilling industry can be classified into the following categories:

1. Analyses and models related to logs, e.g. a log scanner model by Jäppinen (2000).
2. Integrated models, e.g. models presented by Usenius (2002a).

Regarding analyses and models related to logs and raw material properties, Pinto (2004) suggests that there are two main groups of analyses and models, which are (i) growth analyses and models (models with a physiological base) and (ii) empirical analyses and models based on direct measures (on the board, log, or stem). As an example of type (ii) model, Jäppinen (2000) presents a model where logistic regression was used as the log scanner classification method, and the model's accuracy was assessed using the areas under receiver operating characteristic (ROC) curves. Models for sorting criteria based on knot size, knot type and grain distortion, like visual stress grades, showed a better predicting performance than commodity grade and MSR (stiffness) models. The results generally improved when variables generated from 3D-scanner data were used.

VTT Technical research centre of Finland has developed an advanced integrated planning and optimising system for sawmilling companies called WoodCIM (Usenius 2002a). The WoodCIM system in Figure 35 describes the whole conversion chain from the forest to the end products.

The WoodCIM system is designed for various sawmill tasks including predicting the value yield, optimisation of log classes and bucking, production planning and scheduling, value matrix for harvesting and timber request analysis. The system uses analysing techniques like simulation and linear programming (see example in Figure 36). It has been possible to increase the profit or sales value of the production by several per cent compared to more simple systems (Usenius 2002a).

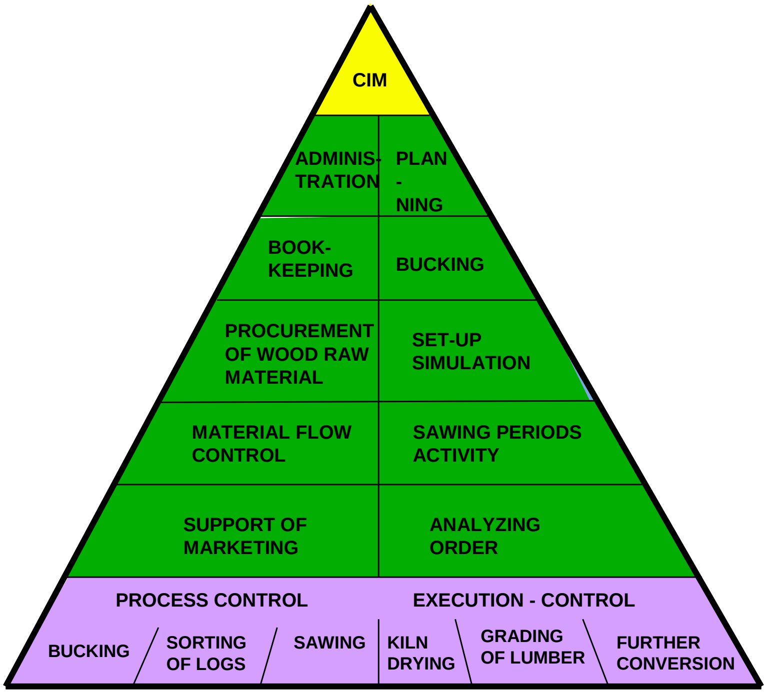
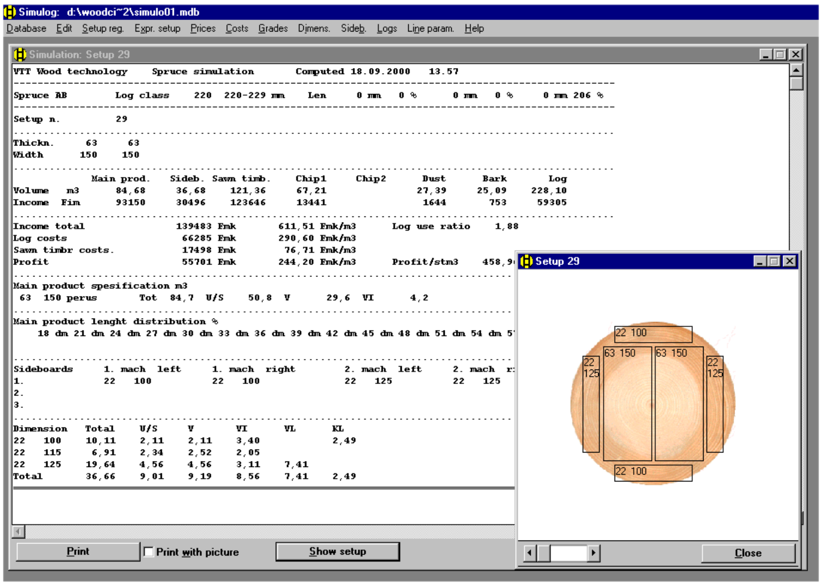


**Figure 35. WoodCIM system (Usenius 2002a).**

The benefits of a system similar to WoodCIM have been noticed also outside Finland. Griffith (2000) states that the wood industry needs linear programming in order to optimise the whole enterprise, not just production. Business decisions demand optimised enterprise. Griffith's grounds for the optimisation need of the wood industry include the idea optimisation makes it possible to control situations where the same log is used for multiple production lines and there are multiple cutting options for some logs (e.g. see example in Figure 36). Hakala (1992) built sawmill and log related analyses to show financial result of sawing pine logs as influenced by top diameter and other associated factors. Johansson and Rosling (2002) have presented and applied new costing methods for sawnwood products and particularly for the timber cost of a board.



```
VTT Wood technology     Spruce simulation       Computed 18.09.2000    13.57
--------------------------------------------------------------------------------
Spruce AB          Log class     220   220-229 mm     Len       0 mm    0 %       0 mm    0 %       0 mm 206 %
--------------------------------------------------------------------------------
Setup n.           29
................................................................................
Thickn.      63      63
Width       150     150
................................................................................
                  Main prod.    Sideb. Sawn timb.     Chip1      Chip2       Dust       Bark        Log
Volume   m3        84,68      36,68     121,36      67,21                  27,39      25,09     228,10
Income  Fim        93150      30496     123646      13441                   1644        753      59305
................................................................................
Income total                  139483 Fmk        611,51 Fmk/m3       Log use ratio     1,88
Log costs                      66285 Fmk        290,60 Fmk/m3
Sawn timbr costs.              17498 Fmk         76,71 Fmk/m3
Profit                         55701 Fmk        244,20 Fmk/m3       Profit/stm3     458,9
................................................................................
Main product spesification m3
 63  150 perus        Tot  84,7  U/S    50,8  V       29,6  VI       4,2
................................................................................
Main product lenght distribution %
    18 dm 21 dm 24 dm 27 dm 30 dm 33 dm 36 dm 39 dm 42 dm 45 dm 48 dm 51 dm 54 dm 5


................................................................................
Sideboards      1. mach  left      1. mach  right        2. mach  left      2. mach  r
1.              22   100           22   100              22   125           22   125
2.
3.
................................................................................
Dimension    Total     U/S      V        VI       VL       KL
22   100     10,11     2,11     2,11     3,40              2,49
22   115      6,91     2,34     2,52     2,05
22   125     19,64     4,56     4,56     3,11     7,41
Total        36,66     9,01     9,19     8,56     7,41     2,49
```

**Figure 36. An example of analysing technique. Graphic sawing simulator predicting component output (Usenius 2002a).**

# 3 CONCEPTS AND METHODS OF RESEARCH

## *3.1 Thesis concepts*

### 3.1.1 Supply, demand and consumption concepts

In the thesis, the supply concept is defined as the total amount of a good (e.g. sawnwood) or service available for purchase. The demand concept is defined as the desire to possess a commodity (e.g. sawnwood) combined with the ability to purchase it. Demand can be seen also as the amount of a commodity (e.g. sawnwood) that customers are ready to buy for a given price. Supply and demand are the two key determinants of price. Consumption is defined as apparent consumption, which is a proxy measure for consumption of a product or material. Apparent consumption is defined as production plus imports minus exports of the product or material (United Nations 1997).

The concept of sawnwood supply and demand can be approached from at least six (6) alternative perspectives:

1. Adequacy of suitable forest resources for supply and demand. A typical question of this approach is how sawnwood demand would be affected if there were a shortage of supply of raw material, sawnwood logs. This perspective has been applied by e.g. The First European Wood Conference (2002).
2. Sawnwood market research. Typical questions of this approach are related to volumes, prices, competition and trends. The approach has been applied by e.g. Timwood (1998) or Roadmap 2010 (2004), and can be seen as Kotler (2000) sees market demand for a product.
3. Sawnwood demand analysis derived from construction activities and other main user areas. Typical questions of this approach are related to construction activities and their effect on sawnwood demand. This has been explained by e.g. Shutt (1995) and applied by e.g. VTT (2004a).
4. Sawnwood time series analysis linked with economics. Typical questions of this approach are related to export, substitution or economic indicators like change of GNP. This has been applied by e.g. Kanniainen and Kuuluvainen (1984), Enroth (1986), Hänninen (1998), Toppinen (1998), Hetemäki et al. (2001), Hänninen et al. (2004).
5. The cost competitiveness and portfolio models of forest products. Cost competitiveness influences sawnwood demand because of the material and production costs, the existing competition between sawnwood, other construction materials and sawnwood suppliers. An example of allocating the timber costs to sawn products is shown by Johansson (2004). An exploratory study of substitute competition of floor covering materials in UK is presented by Jonsson (2004). Forest products portfolio models are used to determine the optimal technology and product mixture given the risk-return preferences of the investor (e.g. Hilli et al. 2004).
6. Sawnwood supply and demand related to the dynamics between mills (e.g. sawmills), markets and customers. Typical questions of this approach are related to supply and demand dynamics of volumes, prices and various quality aspects. The thesis is an example of this approach using database analysis. Another kind of study using this approach is the demand, supply and trade analysis and long-term projections for the European forest sector by Kangas and Baudin (2004).

Sawnwood (CSW) supply distribution is affected by demand. According to Timwood (1998), the two single most important sawnwood demand factors until the year 2010 are (1) housing starts and (2) repair and remodelling (called R&R). Moreover, sawnwood (CSW) demand is affected by the prices of CSW, the substitute good y and the complementary good z. Thus a market demand function for CSW might be specified as in Equation 1.

$$Q_{csw} = f(HS, RR) = f(E_G) = f(I, IR, C_C, C_{BL}, N_{HS}, N_{RR}, P_{csw}, P_y, P_z)$$

**Equation 1. Market demand function for CSW.**

where

| | | |
|---|---|---|
| $Q_{csw}$ = total quantity demanded of CSW | $I$ = available income | $N_{HS}$ = need for new construction |
| $HS$ = housing starts | $IR$ = interest rate | $N_{RR}$ = need for repair and remodelling |
| $RR$ = repair and remodelling | $C_C$ = construction costs | $P_{csw}$ = price of CSW |
| $E_G$ = economic growth | $C_{BL}$= building land costs | $P_y$ = price of substitute product y |
| $P_z$ = price of complementary product z | | |

Timwood (1998) says that these two driving factors (HS and RR) are behind the changes towards 2010. The report underlines that there is an increased trend for industrialisation of building process in countries like the USA, Japan, France, Germany, the Netherlands and UK. This trend increases the prefabrication of building elements or whole houses. However, there are differences in demand for wooden building parts between Germany (DE), UK and France (FR) (see Figure 37).

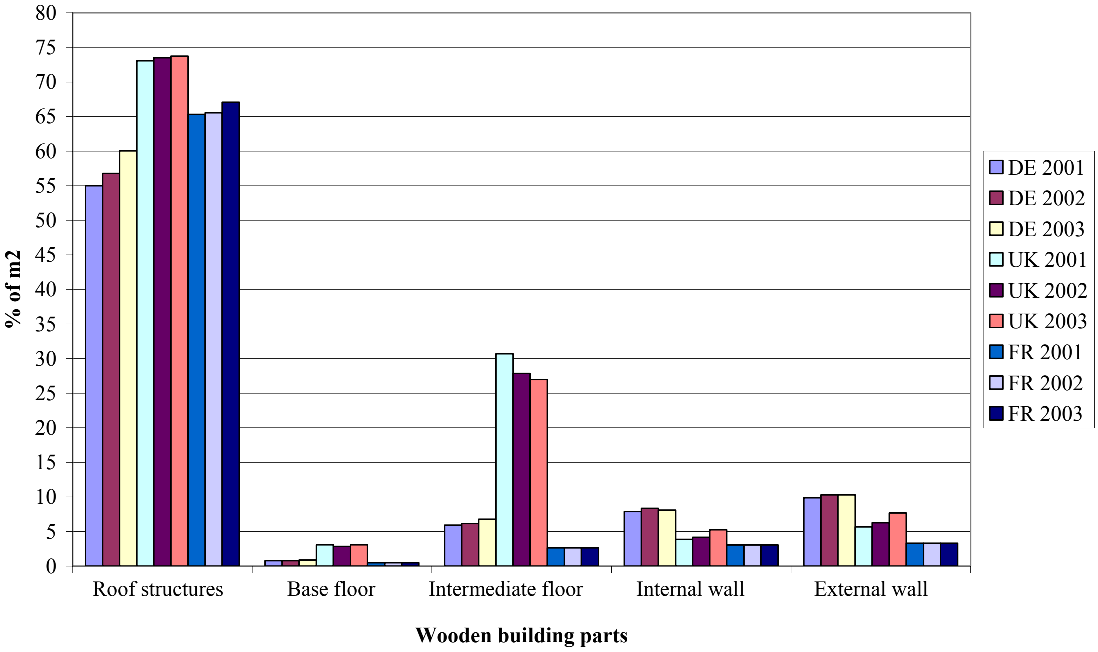


**Figure 37. Market share (% of m$^2$ of buildings) in wooden building parts in Germany (DE), UK and France (FR) 2001–2003 (VTT 2004b). Modified by author.**

Timwood (1998) does not emphasise the importance of CSW prices, substitutes or complementary products for CSW demand. Nevertheless, the relationship between prices, substitutes and complementary products is evident but approached only on a limited scale. In addition, the two demand factors (housing starts and R&R) as well as other factors are taken as such in the thesis (see an example in Table 19).

**Table 19. Economic indicators of the Finnish construction industry indicating changes of sawnwood supply and demand. E = Estimated. Source: Confederation (2004, 2005).**

| Indicator | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004E | 2005E |
|---|---|---|---|---|---|---|---|---|
| **Gross Domestic Product. change of volume. %** | 5.3 | 4.1 | 5.1 | 1.1 | 2.3 | 2.0 | 3.2 | 3.5 |
| **Euribor. 3-month. %** | 3.6 | 3.0 | 4.4 | 4.3 | 3.3 | 2.3 | 2.1 | 2.4 |
| **Index of wage and salary earnings. change. %** | 3.5 | 2.8 | 4.1 | 4.5 | 3.3 | 3.9 | 3.5 | 3.0 |
| **Building cost index. change. %** | 2.3 | 1.4 | 2.9 | 2.5 | 0.8 | 1.8 | 2.0 | 2.0 |
| **Construction. change of volume. %** | 7.1 | 0.5 | 2.2 | –2.9 | 2.5 | 1.3 | 3.0 | 3.0 |
| Building construction | 7.0 | 0.2 | 4.3 | –3.6 | 3.0 | 1.6 | 3.0 | 3.0 |
| Building renovation and modernisation | –5.6 | –6.7 | 1.9 | –3.7 | 4.9 | 2.2 | 2.0 | 3.0 |
| Civil engineering | 7.6 | 1.6 | –4.9 | –0.4 | 0.7 | –0.1 | 4.0 | 2.5 |
| **Building starts. mill. $m^3$** | 36.4 | 38.0 | 39.7 | 37.8 | 35.0 | 35.9 | 36.2 | 35.7 |
| Residential buildings | 11.4 | 12.9 | 12.3 | 10.7 | 11.1 | 12.7 | 13.1 | 13.0 |
| Commercial buildings | 5.3 | 6.5 | 7.2 | 5.7 | 4.8 | 5.9 | 5.5 | 5.7 |
| Public buildings | 2.6 | 2.7 | 2.7 | 3.0 | 3.8 | 2.7 | 3.0 | 3.0 |
| Industrial and warehouse buildings | 9.7 | 8.5 | 10.4 | 11.6 | 7.9 | 7.8 | 8.0 | 7.5 |
| Agricultural buildings | 4.8 | 4.6 | 4.0 | 4.1 | 4.4 | 3.6 | 3.3 | 3.3 |
| Other buildings | 1.8 | 1.7 | 2.0 | 2.7 | 3.0 | 3.2 | 3.3 | 3.2 |
| **Housing starts. number of dwellings** | 31,597 | 34,590 | 32,309 | 27,625 | 28,154 | 31,377 | 32,000 | 31,500 |
| privately financed | 18,597 | 23,090 | 21,809 | 14,525 | 19,454 | 25,477 | 27,000 | 27,000 |
| state subsidised | 13,000 | 11,500 | 10,500 | 13,100 | 8,700 | 5,900 | 5,000 | 4,500 |
| **Employment in construction sector. persons** | 139,000 | 149,000 | 149,000 | 145,000 | 148,000 | 151,000 | 148,000 | 150,000 |
| **Unemployment in construction sector. persons** | 31,700 | 27,800 | 24,100 | 23,000 | 24,000 | 23,000 | 23,000 | |
| **Value of international operations of construction companies. bill. €** | 0.61 | 0.53 | 0.87 | 0.79 | 0.91 | 1.30 | 1.70 | 1.90 |
| **Exports of construction products. bill. €** | | 4.1 | 4.5 | 4.5 | 4.5 | 4.5 | 4.6 | 4.7 |
| **Operating profit before depreciation of construction companies. %** | 4.1 | 5.7 | 6.8 | 5.8 | 5.2 | 5.8 | 6.2 | |
| **Operating profit before depreciation of construction product companies. %** | 16.0 | 12.7 | 13.4 | 10.2 | 9.8 | 7.7 | 8.0 | |

Generally, the most important supply and demand factor for forest products is the economic growth, which appears to affect CSW demand through the growth of available income for households. Hetemäki et al. (2001) suggest that sawnwood exports can be forecasted by the development of GNP and building permissions.

The economic growth increases construction activities and above all housing starts as well as repair and remodelling of houses. The two driving factors (HS and RR) are thus affected by available income, interest rate, construction costs, building land cost, need for new constructions due to social changes and need for repair and remodelling of existing buildings (European 1996). Other CSW user segments like joinery and furniture are included in housing starts and repair and remodelling, because they are closely linked with the two driving factors.

### 3.1.2 Analysing concepts

In the thesis, analysing concepts include three areas:

1. Description of readers (analysers of the sawmilling industry)
2. Data mining
3. Database approach

The thesis is based on the idea to provide the user with fast and relatively correct statistical information of patterns of the sawmilling industry. The aim is to help analyser can explain those patterns and construct information. In contrast, the thesis does not aim to create sophisticated and often complicated classical statistical models. These models often give the correct answers but are difficult to apply in the sawmilling industry.

This concept of analysers of the sawmilling industry is based on one of the learning theories, constructivism. With this theory, analysers can be described as active persons that collect information and construct their own mental models. These models help analysers to discover the new environment of the sawmilling industry (Phillips and Soltis 1998 and Laine 2003). Every analyser of the sawmilling industry is influenced by his or her history, which is defined as a unique combination of experiences and facts. Based on this combination, the analyser is able to construct unique mental models to analyse the sawmilling industry.

Data mining is the main analysing concept for databases in the thesis. According to Bingham (2003), data mining is a name used for a variety of computational methods and techniques for analysing large data sets. Data mining aims to capture patterns out of large data sets with various statistical algorithms (Lacroix and Critchlow 2003). Thus, data mining is used to describe the data either in a global or a local level. Global descriptions include clustering, joint probability density estimation, or visualisation of the data. Local descriptions might be repeating or exceptional patterns in the data or statistical dependencies between the variables.

Although data mining is closely related to traditional statistical data analysis, it has some distinguishing characteristics (Bingham 2003):

1. The data are not originally aimed for a particular study and so the analyst cannot affect the process of data collection
2. The data set is often so large that its storage and retrieval must be carefully designed
3. The emphasis is on local aspects in addition to global behaviour in the data.

However, there are several problems with the database approach. These include problems of sampling and model parameter estimation as well as the case when the number of possible relationships is large. In spite of these problems, data mining can be used to discover new knowledge about a data set or to validate a hypothesis with restrictions (Lacroix and Critchlow 2003). Some data mining tools and techniques are listed in Table 20. In the thesis, regression is the most important of these.

**Table 20. Data mining tools and techniques (Gibas and Jambeck 2001).**

| What you do | Why you do it | What you use to do it |
|---|---|---|
| **Clustering** | To find similar items when a classification scheme is not known ahead of time | Clustering algorithms, self-organising maps |
| **Classification** | To label each piece of data according to a classification scheme | Decision trees, neural networks, support vector machines |
| **Regression** | To extrapolate a trend from a few examples | Regression algorithms, neural networks, support vector machines, decision trees |
| **Combining estimations** | To improve reliability of prediction | Voting methods, mixture methods |

One way to mine data from databases is to use the CRISP model approach (CRISP-DM 2005). The CRISP model approach was selected as the main analysing concept in the thesis, and particularly in Chapter 5. A similar concept has been applied by e.g. Laine (2003).

The CRISP model (see Figure 38) provides an approach that can be used for interpreting sawnwood databases. In order to apply the model effectively, one must understand sawnwood business and not just data. The traditional database models have often emphasised modelling over the need to understand the object of study. In addition, it has often been assumed that sufficient knowledge about the object of study already exists. However, it is not advisable to overlook the importance of understanding the business when analysing data about sawnwood business, in this case data from a sales database.

Knowing the nature of sawnwood business is a prerequisite to analysing and modelling data from sawnwood sales databases. Data analysis in the CRISP process consists of the following stages: business understanding, data understanding, data preparation, modelling, evaluation and deployment (Figure 38). This process can shed light on sawnwood business, which in turn can fuel another analysis cycle. An analyst is more likely to be able to present reliable conclusions about the possible phenomena suggested by the data when he understands sawnwood business.

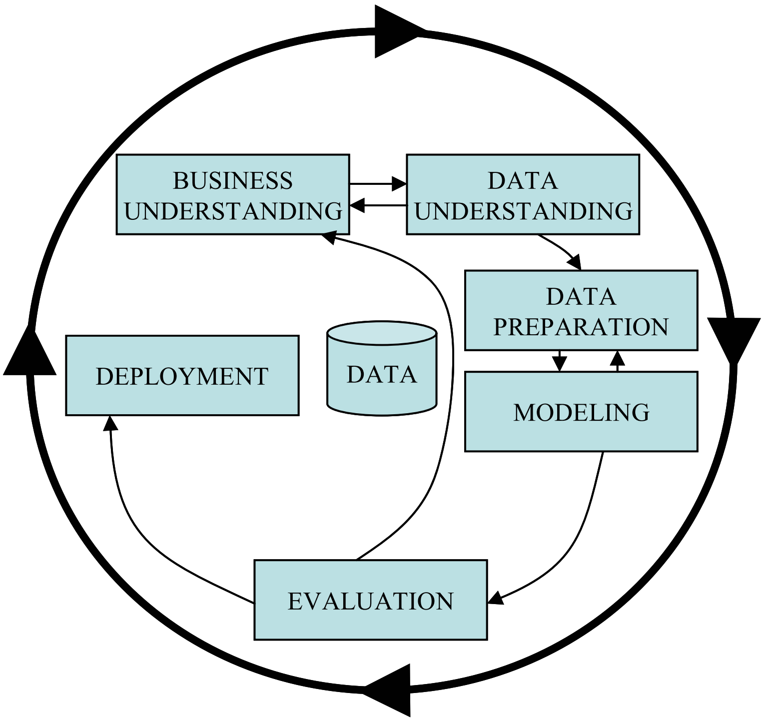


**Figure 38. The CRISP process model (CRISP-DM 2005).**

The process was developed to help in focusing the questions related to sawnwood business, so that an analyst can look at the issue at a sufficiently accurate level. A significant point is that the CRISP process was not applied in the thesis just for creating models from sawnwood data, as can be the case with traditional statistical models. The process is similar to the learning cycle where learning leads to action, which leads to more learning (Figure 39). In addition, the process is similar to the information technology approach by Usenius (2005) in Figure 30.

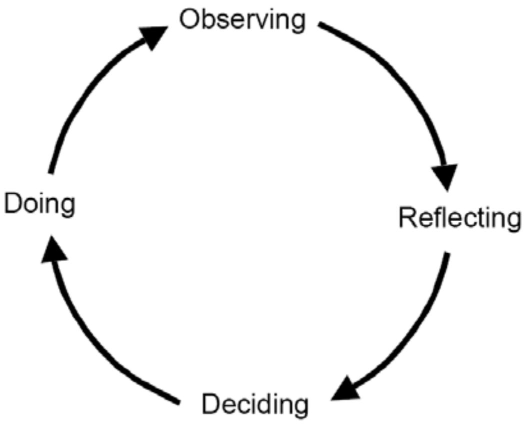


**Figure 39. The wheel of learning. Source: Senge et al. (1998) through Laine (2003).**

The thesis approaches the sawnwood supply distribution through databases. Sawnwood resembles other industries in that much data are collected for the databases but its analysis often remains superficial. The database approach was selected as an analysing concept for the following reasons:

1. Many of the databases mentioned in the thesis or other similar databases are used in forest industries.
2. Databases are expected to reveal new and useful information.
3. Combining business processes and existing and new databases may improve the competitiveness of the sawmilling industry.

When analysing sawnwood and other sales databases, a significant point is that a large portion of the sales data is classified. The analysis also requires information of restrictions and applications of certain known methods in a new environment.

## 3.2 Empirical reference framework of the thesis

Analysing sawnwood demand is divided into three sections (see Figure 40): (1) CSW demand environment, (2) CSW demand situation and production, and (3) factors affecting CSW demand. The empirical reference framework explains the thesis with three aspects: (1) how it is going to be analysed, (2) what are the limits of analysis, and (3) how analysis is linked with methods. The empirical reference framework is based on research areas, which are presented in Figure 40 with their principal codes.

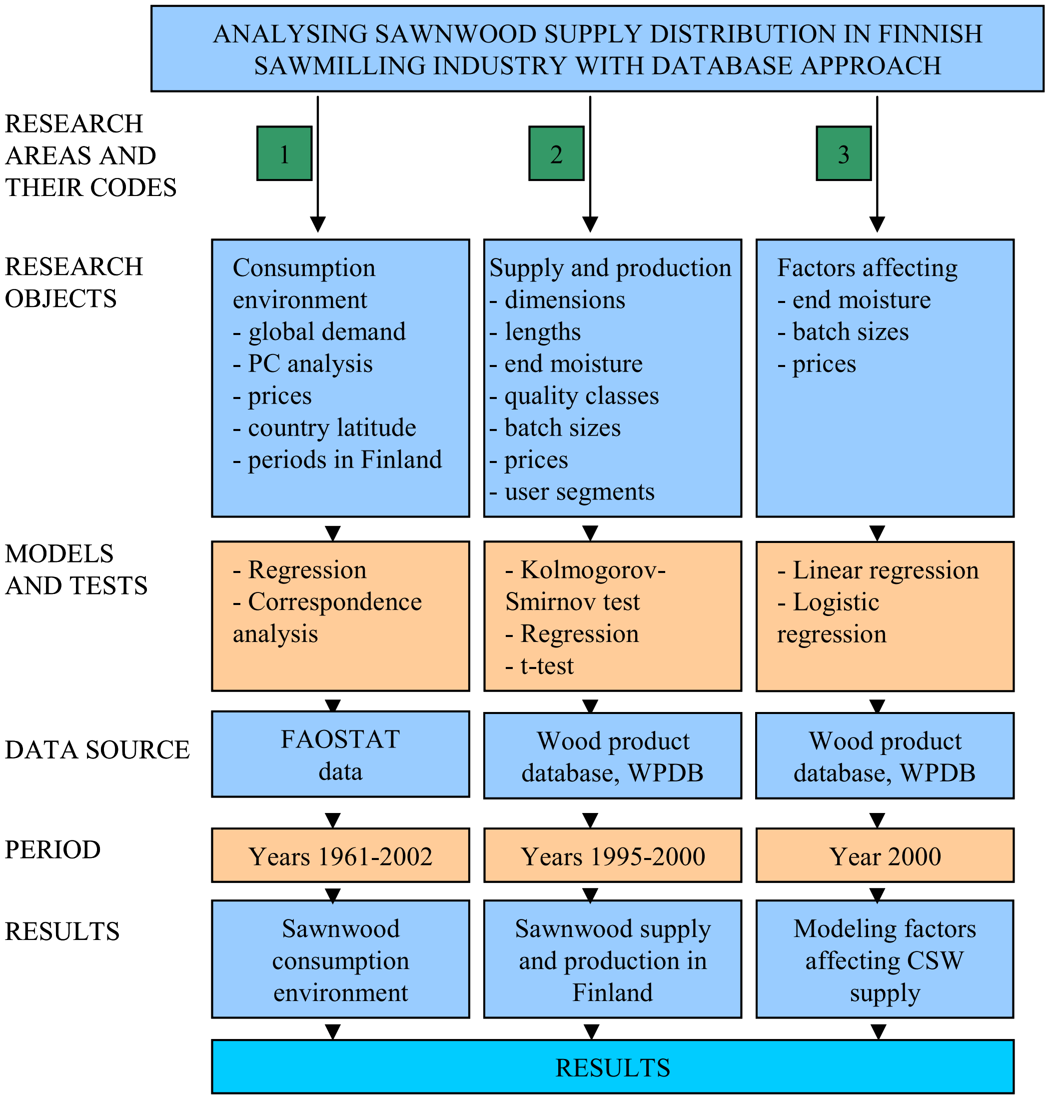


**Figure 40. Empirical reference framework of the thesis.**

The demand environment in Chapter 4 describes and briefly analyses CSW global demand, Per capita (PC) analysis information and price development as well as the significance of the country's geographical area to CSW demand and demand periods in Finland. Chapter 5 analyses the CSW demand situation between sawmills and their customers by dimensions, lengths, end moisture contents, quality classes, batch sizes, prices and user segments. Section 5.8, Factors affecting CSW supply, analyses correlations between sawmills and customers through supply analyses.

From the perspective of methodology, the empirical reference framework of the thesis (Figure 40) looks versatile. There are many theses that use only one or two methods. In the thesis, there are more than six methods, tests or model types that are applied to analysing data. Correspondence analysis is used for the significance of a country's geographical area – latitude – to CSW demand. The Kolmogorov–Smirnov test is used for dimension distribution comparisons. The t-tests are used for length distribution comparisons. Moreover, the thesis includes both linear and logistic regression analyses. Use of regression depends on the nature of data, the character of the research object as well as the intended application. The method of stepwise regression is used for variable selection.

## 3.3 Thesis propositions

The tested propositions are based on the three hypotheses in the section 1.3. These propositions are the following:

1. Changes in sawnwood consumption can be found in Finland during the time periods between 1961 and 2002. It is possible that the CSW consumption in Finland in 1961–1996 was significantly different from the CSW consumption in the years 1997–2002 and 1961–2002.
2. For sawnwood produced in Finland in 2000, sawnwood trade was concentrated on main dimensions. Simultaneously, the number of dimensions was large. The Pareto principle assumption and its 20–80 rule applied to sawnwood dimensions.
3. The importance of large pine dimensions, as concerns sawnwood exported from Finland, decreased in the UK markets due to thickness approach between 1995 and 2000.
4. For sawnwood delivered from Finland, dimensions had big differences specific to country and species of sawnwood between 1995 and 2000. The dimensions of pine and spruce differed by country.
5. There was a market trend towards smaller batch sizes in sawnwood delivered from Finland between 1995 and 2000.
6. Differences of length between pine and spruce sawnwood delivered from Finland were relatively small in 2000.
7. The development of end moisture content and quality distribution remained rather stable for both pine and spruce in the Finnish sawmilling industry in the years 1995–2000.
8. A logical sawnwood price system can be found for a set of sawnwood dimensions and species in Finland in 2000. In this system, a specific pine dimension of 50 x 150 mm (or close to this) set a basis price, and the prices of other dimensions could be derived from the basis price. Both pine and spruce pricing used the basis price system but it was more dominant with pine.
9. In the predominant quality classes (U/S, V, VI), a small number of special lots was priced differently in Finland in 2000, with a few lower and higher price classes.
10. Sawnwood supply distributions consisted primarily of the supply of standardised sawnwood in Finland in 2000. The number of special products was still small. Sawnwood supply can be estimated with both logistic and linear regression analyses.
11. Sawnwood supply can be analysed by end moisture contents as well as batch sizes and prices. It is possible to create logistic and linear regression analyses for sawnwood supply distributions with the database approach.
12. A country's geographical area can be assessed as a factor for coniferous sawnwood consumption in Europe in 1999.
13. Sawmills had not completed their user segmenting strategies in Finland in the years 1998–2000. They used a user segment system in their sales but still divided most of their production into the distribution segment as a general segment instead of more specified joinery, furniture, planing and strength grading segments.

## 3.4 Data collection

Data collection was organised to form two databases, Wood product database (WPDB) and FAOSTAT data (2004) (see Figure 40).

Wood product database (WPDB) is based on company information. The data were collected by asking relevant data for research uses from Finnish wood product industry companies between 1999 and 2001. The thesis uses only a part of WPDB, which covers CSW sales information between 1995 and 2000 from Finnish sawmills (see Section 3.4.1).

FAOSTAT data (2004) were collected from the information of FAO between 1998 and 2004. The thesis uses only the part of FAOSTAT data (2004) that covers coniferous sawnwood (x1) production, (x2) imports, and (x3) exports as well as population data in selected countries or geographical areas. CSW demand (y) in a country or geographical area was calculated by y = x1 + x2 – x3. The period of data was 1961–2002, except in some cases where there was no data available because of political changes (see Section 3.4.2).

## 3.4.1 Wood product database - WPDB

### 3.4.1.1 Database purpose

There are many good market research studies of the sawmilling industry. Most of these approach markets with behavioural science methods. In contrast, there are few if any known product-based research methods applied to the sawmilling industry. Thus it is difficult to find product distributions or other relevant information of sawnwood products.

One reason for this may be that sawnwood companies do not often give their sales information to be analysed for research purposes. In case they do, they expect researchers to preserve the confidentiality of their product privacy. However, this confidential sales information used in cooperation between companies and wood product researchers could help to generate business analyses and raise useful questions for the sawmilling industry's everyday business.

For this need a product database was created and named Wood Product Database, WPDB. The WPDB is a numeric type product database containing many categorical fields. It can be seen as data warehouse database, which is a database where data are collected for the purpose of being analysed. WPDB corresponds to the definition of a data warehouse database, as it is a subject-oriented, integrated, time-variant and non-volatile collection of data in support of management's decision making process (Inmon 1990).

This unique and large database information with 63,774 sales and deliveries of over 19 million $m^3$ sawnwood from years 1995 to 2000 is perhaps the largest sawnwood sales and deliveries database ever collected in the history of global sawmilling industry. Nevertheless, there are two reasons why the size and quality distributions in the sawnwood sales databases do not accurately describe the sawnwood demand structure in Europe. Firstly, the database only covers export and domestic sales from Finland. From the sawnwood production perspective, there are other significant countries as well. Secondly, the Finnish sawmills have traditionally exported the better qualities.

Simultaneously with wood product database (WPDB), much plywood and particleboard sales information was gathered. However, the thesis is focused only on coniferous sawnwood and leaves plywood product sales for potential future research. Main variable classes were quantity ($m^3$), price (€) and quality (e.g. dimensions, quality class, end moisture content).

### 3.4.1.2 Coverage of products and producers

The material for the wood product database has been gathered mainly from companies in Finnish wood product industry and research organisations acting in this field. The data were collected by asking for relevant data for research uses from Finnish wood product industry companies between 1999 and 2001.

The database covers the time scale from 1995 to 2000 for coniferous sawnwood. For other product information, the coverage of the database varies. For information such as volumes and prices, the database covers years from 1961 to 2000. Wood product groups in Table 21 are included in the WPDB database.

**Table 21. Wood product database (WPDB) product groups. Grey colour means the information is not included in the thesis.**

| | | |
|---|---|---|
| Coniferous sawnwood | Particleboard | Timber merchants and trade |
| Refined (further processed) sawn goods such as finger jointed timber, panels and DIY-products | Glued boards including edge glued boards | Plywood |
| Non-coniferous sawnwood | Fibreboards including MDF | Parquet |

The database also covers major Finnish wood product companies, for example 114 Finnish sawnwood producers. Although the area covered is mainly Finland, for some years both Finland and Sweden are covered. In addition to the product-related information, the wood product database includes a short form of financial statement for Finnish sawmills and wood product companies. Furthermore, WPDB contains some demographic statistics and information on economics and construction output in OECD countries.

### 3.4.1.3 Data collection and coverage of coniferous sawnwood

The data collection procedure for coniferous sawnwood of WPDB was as following:

1. Several Finnish sawmilling industry companies were contacted and asked to provide product sales information for research analysis purposes. They were asked for data with the field and variable types stated before.
2. Fragmented data covering all the requested variables were obtained from large sawmilling companies. However, a variable's period of time varied much. For instance, an exact price data sample is only from year 2000 and a length data sample only from 6 months in 2000. Despite this, a large CSW sales database was collected.
3. WPDB was formed as a data warehouse database. This means that all or significant parts of the data of a sawmill's various business systems are collected into WPDB.

The sawmill coverage of WPDB for coniferous sawnwood database varied between 18% and 34% of Finnish sawnwood production from 1995 to 2000 (Table 22).

**Table 22. Wood product database (WPDB) and share of CSW production in Finland, share of the sample ($m^3$ and %).**

| Species | Indicator | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | Total |
|---|---|---|---|---|---|---|---|---|
| Pine | WPDB sample, $m^3$ | 760,714 | 1,040,388 | 1,408,887 | 2,128,101 | 2,227,353 | 2,306,641 | 9,872,083 |
| | Finland export, $m^3$ | 3,343,559 | 3,103,926 | 3,273,923 | 3,541,467 | 3,514,018 | 3,489,357 | 20,266,250 |
| | Amount of sales in WPDB, N | 1546 | 2798 | 3550 | 7793 | 9754 | 10721 | 36162 |
| | Average sawnwood sales in WPDB, $m^3$ | 492 | 372 | 397 | 273 | 228 | 215 | 273 |
| | Standard deviation for CSW sales in WPDB, $m^3$ | 1017 | 976 | 1061 | 799 | 678 | 686 | 797 |
| Spruce | WPDB sample, $m^3$ | 1,023,669 | 992421 | 1,288,083 | 2,019,541 | 2,058,318 | 1,968,162 | 9,350,194 |
| | Finland export, $m^3$ | 3,648,026 | 3,457,371 | 3,765,167 | 4,181,182 | 4,109,173 | 3,970,390 | 23,131,309 |
| | Amount of sales in WPDB, N | 2,369 | 2,262 | 2,936 | 6,333 | 6,762 | 6,950 | 27,612 |
| | Average sawnwood sales in WPDB, $m^3$ | 432 | 439 | 439 | 319 | 304 | 283 | 339 |
| | Standard deviation for CSW sales in WPDB, $m^3$ | 1,179 | 1,323 | 1,277 | 1,023 | 987 | 892 | 1,058 |
| All | WPDB sample, $m^3$ | 1,784,382 | 2,032,809 | 2,696,969 | 4,147,642 | 4,285,671 | 4,274,803 | 19,222,277 |
| | Pine, share of sample, % | 43% | 51% | 52% | 51% | 52% | 54% | 51% |
| | Spruce, share of sample,% | 57% | 49% | 48% | 49% | 48% | 46% | 49% |
| | Finland production, $m^3$ (FAOSTAT data 2004) | 9,860,000 | 9,710,000 | 11,360,000 | 12,240,000 | 12,708,000 | 13,320,000 | 69,198,000 |
| | WPDB sample share of production in Finland, % | 18% | 21% | 24% | 34% | 34% | 32% | 28% |
| | Finland export, $m^3$ | 6,991,585 | 6,561,297 | 7,039,090 | 7,722,649 | 7,623,191 | 7,459,747 | 43,397,559 |
| | Pine, share of export,% | 48% | 47% | 47% | 46% | 46% | 47% | 47% |
| | Spruce, share of export,% | 52% | 53% | 53% | 54% | 54% | 53% | 53% |
| | Export,% of total production | 71% | 68% | 62% | 63% | 60% | 56% | 63% |
| | Amount of sales in WPDB, N | 3,915 | 5,060 | 6,486 | 14,126 | 16,516 | 17,671 | 63,774 |
| | Average sawnwood sales in WPDB, $m^3$ | 456 | 402 | 416 | 294 | 259 | 242 | 301 |
| | Standard deviation for CSW sales in WPDB, $m^3$ | 1,118 | 1,145 | 1,164 | 906 | 820 | 774 | 920 |

In WPDB, the information from different fields and sources was merged. As the database is considerably large, the information was grouped in order to keep it easily accessible. Sawmill variables can be divided into the categories given in Figure 41. According to McClave et al. (2005), quantitative data are measurements that are recorded on a naturally occurring numerical scale. These are used in the samples of the thesis. Qualitative data are measurements that cannot be measured on a natural numerical scale; they can only be classified into one of a group of categories (McClave et al. 2005).

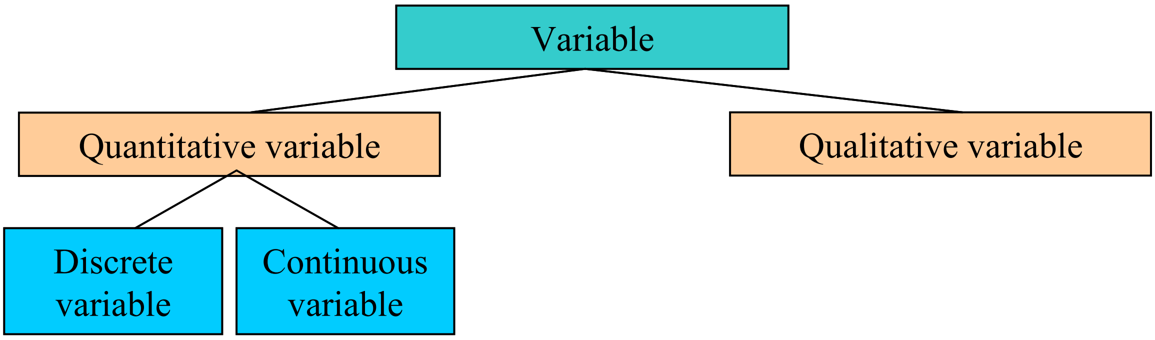


**Figure 41. Types of random variables based on Berenson et al. (2002 p. 11) and modified by author. All categorical variables are both discrete and qualitative.**

According to McClave et al. (2005), quantitative data can be subclassified as either interval data or ratio data. For interval data, the origin (i.e., the value 0) has no meaning, but it is a meaningful number for ratio data. Consequently, interval data can be added and subtracted but not multiplied or divided. Qualitative data can be subclassified as either nominal or ordinal data. The categories of an ordinal data set can be ranked or meaningfully ordered, but the categories of a nominal data set cannot be ordered. In addition, Cho (1997) presents that nominal and ordinal scales are categorical data. Interval and ratio scales are seen as continuous data. Categorical data having unordered scales are called nominal scales, and categorical data having ordered scales are called ordinal scales. Rank is an example of an ordinal scale. Continuous data having interval scales are called interval scales. Continuous data having both equal intervals and an absolute zero point are called ratio scales.

Continuous numerical random variables yield numerical responses as quantity ($m^3$) of sawnwood sales. Discrete numerical random variables produce numerical responses that arise from counting process as years. Sawmill variables can be named quantitative and qualitative, as in Figure 41 or Vuorilehto (2001), instead of numerical and categorical. As for field and variable types for coniferous sawnwood, the wood product database covers the types listed in Table 23.

**Table 23. Wood product database variables for sawnwood.**

| **Variable class** | **Variable data type** | **Level of measurement** |
|---|---|---|
| **Destination country** | Categorical | Nominal scale |
| **End moisture content class** | Categorical | Ordinal scale |
| **Length class** | Categorical | Ordinal scale |
| **Price** | Numerical continuous | Ratio scale |
| **Quality class** | Categorical | Ordinal scale |
| **Quantity** | Numerical continuous | Ratio scale |
| **Sawmill location** | Categorical | Nominal scale |
| **Species** | Categorical | Nominal scale |
| **Thickness** | Categorical | Ordinal scale |
| **User segment** | Categorical | Nominal scale |
| **Width** | Categorical | Ordinal scale |
| **Year** | Numerical discrete | Interval scale |

Categorical variables that yield categorical responses, such as yes or no answers, or that belong to a category, e.g. quality class, are common in sawmills, as can be seen in Table 23. The categorical data from sawmill sales are measured with either nominal or ordinal scale as in Table 23. According to Berenson et al. (2002, p. 11–13), a nominal scale classifies data into various distinct categories in which no ordering is implied. An ordinal scale classifies data into distinct categories in which ordering is implied. Correspondingly, the numerical data from sawmill sales is measured with either interval or ratio scale. An interval scale is an ordered scale in which the difference between measurements is a meaningful quantity that does not involve a true zero point. In contrast, a ratio scale is an ordered scale in which the ratio between measurements is a meaningful quantity and where the measurement scale has a true zero point.

One of the reasons for the large number of categorical data in sawmills may be the variations in wood as raw material for sawnwood. These variations lead to subjective values, typically assessed by humans as stated by Vuorilehto (2001). These can also be measured by machines, as end moisture content, but later, for historical or other reasons, they may be simplified and transformed to a category (e.g. end moisture content class).

### 3.4.1.4 Database applications

Wood product database applications can be listed under general applications, tool applications and integrated applications. General WPDB applications cover a wide range of product decisions. The WPDB gives a basis to analyse sawnwood profitability, competitiveness and strategic position on the market. For example, sawnwood trade in Finland between 1995 and 2000 can be evaluated with WPDB. Moreover, one can evaluate, with a limited scope, future wood product volumes and product specifications and create price estimates for products.

The WPDB tool gives a user the following process:
1. Pivot and filtering tool
2. Regression or other analysis based on phase 1.

The tool can be applied to product assortment design and business analysis design when a sawnwood producer has a broad product assortment and lots of parameter classes (e.g. dimensions or qualities).

The integrated application is designed to work as a part of the VTT research entity, Building and transport. WPDB produces source data for VTT Building and transport, which in turn uses the data for an integrated optimisation model. The model has been created to meet the needs of the conversion chain of wood products. WPDB is linked to the process in that it shares the common goal of adding value to wood products.

## 3.4.2 FAOSTAT data

FAOSTAT data (2004) were collected from the following information: coniferous sawnwood (x1) production, (x2) imports and (x3) exports. CSW demand (y) was calculated by $y = x1 + x2 - x3$. This CSW demand (y) is commonly referred to as apparent consumption and used analogously with demand in FAOSTAT data (2004) database approach. Nevertheless, the concept of apparent consumption is more general, while demand is often more connected to certain end use structure. The period of data was 1961–2002, except in some cases where there were no data available because of political changes. The data were collected from the following geographic areas and countries in Table 24.

Furthermore, FAOSTAT data (2004), which provides statistics on imports and exports of woods and paper, covers in the thesis the coniferous sawnwood export and import prices for areas and countries presented above. The database also has data on population, plywood, particleboard and fibreboards. Still, only the information on coniferous sawnwood demand, prices and country-based population is used in the thesis.

**Table 24. FAOSTAT data (2004). List of geographic locations or economic areas and countries used in the thesis.**

| Geographical location | Countries | | |
|---|---|---|---|
| World | Canada | Estonia | Romania |
| Europe | USA | Faeroe Islands | Russian Federation |
| Europe and Baltic | Finland | Gibraltar | Slovakia |
| East Europe | France | Greece | Slovenia |
| OECD | Germany | Hungary | Spain |
| Asia | UK | Iceland | Sweden |
| Asia Developed | Albania | Ireland | Switzerland |
| Asia Developing | Andorra | Italy | Ukraine |
| USA and Canada | Austria | Latvia | Yugoslavia SFR |
| | Belarus | Lithuania | Yugoslavia 2) |
| | Belgium-Luxembourg | Macedonia 1) | Japan |
| | Bosnia and Herzegovina | Malta | China |
| | Bulgaria | Moldova | Algeria |
| | Croatia | the Netherlands | Egypt |
| | Czech Republic | Norway | Libya |
| | Czechoslovakia | Poland | Morocco |
| | Denmark | Portugal | Tunisia |

Ref: 1) The former Yugoslavia republic. 2) Federal Republic of

## 3.5 Research areas and periods

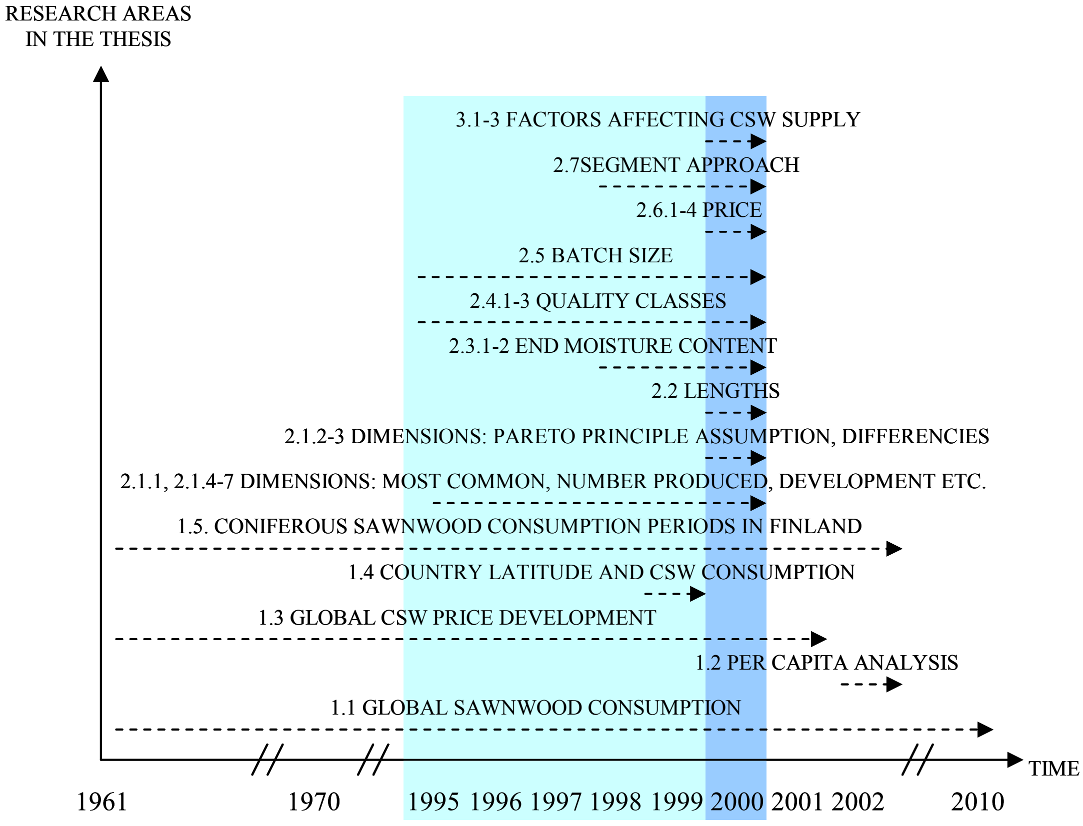
The main research areas are linked with research objectives. Sawnwood demand is analysed in three sections, which are (1) sawnwood demand environment, (2) demand and production and (3) factors affecting CSW demand. Research areas and their codes, periods of sample and data sources as well as sample descriptions are listed in Table 25.

**Table 25. Research areas and their codes, periods of sample (Period), data sources (Data) and sample descriptions (Sample).**

| Research area | | | | Period | Data | Sample |
|---|---|---|---|---|---|---|
| 1 | 1 | | Global sawnwood consumption | 1961–2002–2010 | F | consumption ($m^3$), 51 countries |
| | 2 | | Per capita analysis in selected countries | 2002 | F | consumption ($m^3$), 51 countries |
| | 3 | | Global CSW price development | 1961–2002 | F | price ($\$/m^3$), 41 years |
| | 4 | | Country latitude as a coniferous sawnwood consumption factor | 1999 | F | 46 countries, consumption ($m^3$) |
| | 5 | | Coniferous sawnwood consumption periods in Finland | 1961–2002 | F | 41 years, consumption ($m^3$) |
| 2 | 1 | 1 | Most common sawnwood dimensions in Finland | 1995–2000 | W | spruce: 9,350,194 $m^3$; pine: 9,872,083 $m^3$ |
| | | 2 | CSW dimensions and the Pareto principle assumption | 2000 | W | spruce: 990,673 $m^3$; pine: 887,067 $m^3$ |
| | | 3 | Difference between amount and value based dimension distributions | 2000 | W | spruce: 990,673 $m^3$; pine: 887,067 $m^3$ |
| | | 4 | Number of CSW dimensions produced in Finland | 1995–2000 | W | spruce: 9,350,194 $m^3$; pine: 9,872,083 $m^3$ |
| | | 5 | Development of dimension size distribution between 1995 and 2000 | 1995–2000 | W | spruce: 9,141,905 $m^3$; pine: 9,737,520 $m^3$ |
| | | 6 | Dimension by volumes in selected ten countries | 1995–2000 | W | spruce: 6,406,101 $m^3$; pine: 5,008,661 $m^3$ |
| | | 7 | Case UK and large pine CSW dimensions | 1995–2000 | W | pine: 1,720,232 $m^3$ |
| | 2 | | Length approach - CSW length distribution in Finland | 2000 | W | spruce: 211,657 $m^3$; pine: 267,195 $m^3$ |
| | 3 | 1 | End moisture content approach-segment approach | 1998–2000 | W | spruce: 6,252,780 $m^3$; pine: 6,474,790 $m^3$ |
| | | 2 | End moisture content approach-destination country approach | 1998–2000 | W | pine and spruce: 12,716,308 $m^3$ |
| | 4 | 1 | Main quality distribution development 1995–2000 | 1995–2000 | W | spruce: 7,917,784 $m^3$; pine: 9,872,083 $m^3$ |
| | | 2 | Importance of modified special qualities | 1995–2000 | W | spruce: 7,917,784 $m^3$; pine: 8,746,306 $m^3$ |
| | | 3 | Annual changes in quality class numbers | 1995–2000 | W | spruce: 9,350,194 $m^3$; pine: 9,872,083 $m^3$ |
| | 5 | | Sale size - does CSW have a trend to smaller sizes | 1995–2000 | W | pine and spruce: 19,222,277 $m^3$ |
| | 6 | 1 | Basis price analysis | 2000 | W | spruce: 990,673 $m^3$; pine: 887,067 $m^3$ |
| | | 2 | Species price comparison | 2000 | W | spruce: 990,673 $m^3$; pine: 887,067 $m^3$ |
| | | 3 | Quality price comparison | 2000 | W | spruce: 990,673 $m^3$; pine: 887,067 $m^3$ |
| | | 4 | Price behaviour by number of sales | 2000 | W | spruce: 990,673 $m^3$; pine: 887,067 $m^3$ |
| | 7 | | Segment approach | 1998–2000 | W | spruce: 1,745,799 $m^3$; pine: 1,423,587 $m^3$ |
| 3 | 1 | | Factors affecting CSW end moisture content | 2000 | W | spruce: 1,081,155 $m^3$; pine: 1,398,959 $m^3$ |
| | 2 | | Factors affecting CSW batch size | 2000 | W | spruce: 1,081,155 $m^3$; pine: 1,398,959 $m^3$ |
| | 3 | | Factors affecting CSW price | 2000 | W | spruce: 990,673 $m^3$; pine: 887,067 $m^3$ |

In table: F = FAOSTAT data (2004), W = Wood product database

Research area periods with research area codes are listed in Figure 42. Each of the three sections describes one aspect of phenomenon in the thesis. The arrows between the blocks describe the relationships as well as connections of interest. The arrows 1–3 are first described separately and later screened for the purposes of analyses.



Number before a theme refers to research area codes

**Figure 42. Periods and codes of research areas linked to Table 25. The colours highlight the most important period of the thesis.**

## *3.6 Methods of analysis*

### 3.6.1 Data mining as method principle

The Finnish sawmilling industry as well as other sawmilling industries today tend to capture and store vast quantities of data annually. Finding and analysing the patterns, trends, and hidden information in these data sets can be considered one of the grand challenges of the sawmilling industry when it strives for improve its competitiveness. This path leads in the thesis to the method principles that can be called data mining.

According to Witten and Frank (1999), data mining is the extraction of implicit, previously unknown, and potentially useful information from data. On the other hand, data mining is about solving problems by analysing the data already present in databases of the sawmilling industry. Data mining is defined as the process of discovering patterns of data. These patterns of sawmilling data contain problems, too. Many of the patterns will be uninteresting, spurious, contingent on accidental coincidences or economic cycles, or even banal. In addition to this, in the sawmills the data – sales, production, other – is imperfect and thus the discovered patterns will be inexact. There will be exceptions to every rule and cases that are not covered by any theory or practice.

The principle that the theory must be the guide to any model building must be applied with limitations when there is no relevant theory for the discovered patterns of data of product and sales information. As sales data can be characterised as recorded facts of sales, information of sales can be defined as set of patterns or expectations that underlie the data. This sales information describes patterns of sawnwood according to product, product range, customers, quality, destination country and other. The sales information databases of sawmilling companies possess large volumes of precisely recorded data, which is potentially valuable for predictions. This is one of the starting points for the method selection of the thesis.

### 3.6.2 Method selection

Method selection for the analysis and its implementation was guided by the purpose of the study, the concepts of supply, demand and consumption, the thesis framework, the empirical reference framework of the thesis, the limitations of data and software, data mining principles and the framework of analysis. The analyses were done using the following software programs: Statistix® (1992), NCSS® (2000), SPSS® (2003) and Microsoft® (2002). All these software applications set limits for use, e.g. Microsoft® (2002) performs only a limited amount of statistical tools and only 65536 rows are available per sheet, which often caused troubles with a large database of more than 63000 rows and more than 30 columns of data.

The main authors guiding the principles and use of methods have been Sharma (1996), Hosmer and Lemeshow (1989), Milton and Arnold (1995), and Witten and Frank (1999). However, it must be clear that statistical methods are needed only if they can add significant value for the research. Method selection strategy was based on the following criteria:

1. At least one method should be suitable for database analysis.
2. At least one method should present the trends of 1995–2000 and other periods of time.
3. At least one method should give elasticity approach for database variables.
4. The principle of parsimony was applied.

In addition, Gujarati (1992) recommends that in the search of a theoretically correct model several practical criteria should be kept in mind, such as (1) parsimony, (2) identifiability, (3) goodness−of−fit, (4) theoretical consistency, and (5) predictive power. These all may apply to method selection, too.

According to McClave et al. (2005), a parsimonious model is a model with a small number of statistical parameters. In situations where two competing models have essentially the same predictive power, it is recommended that the more parsimonious of the two should be chosen. This method strategy is sometimes called a proxy method for proxy information. Proxy information is often collected for incomplete variables in studies to avoid a situation of missing data (e.g. Huang and Carribre 1999). This strategy aims at easy use, practical approach and giving answers with less (but hopefully optimal) accuracy than could be reached with other methods.

### 3.6.3 The Pareto principle assumption

The thesis also uses the Pareto principle assumption which is applied to sawnwood dimensions in Section 5.1.3. The Pareto principle assumption states that in any population that contributes to a common effect, a relative few of the contributors−the vital few−account for the bulk of the effect. The Pareto principle assumption is often used with 20% of the causes usually accounting for 80% of the effects. The Pareto principle assumption is also known as 20/80 rule, the 80–20 rule, the law of the vital few and the principle of factor sparsity. The principle was suggested by Joseph M. Juran. It was named after the Italian economist Vilfredo Pareto, who observed that 80% of property in Italy was owned by 20% of the Italian population (Juran and Godfrey 1999). In the thesis, the Pareto principle assumption is defined so that a small number of causes (20%, e.g. dimensions) is responsible for a large percentage (80%) of the effect (e.g. volume, $m^3$).

The Pareto principle assumption is that most of the results in any situation are determined by a small number of causes. An important characteristic of the principle is that it is testable. The Pareto principle distribution is typically true in process and product improvements. Furthermore, the following and different phenomena have been discovered to follow the Pareto principle assumption: the centralisation of land ownership, the centralisation of power in organisation, the relationship between working time used and the results of work, and the efficiency of sales organisations. The principle applies widely in human affairs. Relatively small percentages of individuals write most of the books, commit most of the crimes, own most of the wealth, and so on (Juran and Godfrey 1999).

It is essential to the Pareto principle assumption that there is an idea of the ratio of centralisation to the achieved possession or result. The rule is not primarily bound to have the numerical ratio of 20/80, as the ratio may also be, for example, 10/90 or something between 20/80 and 10/90. Observations often show that the majority of problems stem from relatively few causes (The Pennsylvania State University 2003).

The Pareto principle assumption has a rule-of-thumb application in many places, but it has also been commonly and unthinkingly misused. Therefore it is important that the Pareto principle assumption is always tested. From behavioural theory perspective, it must be said that the Pareto principle assumption is more a folk theorem because it does not originate from economics or business literature.

### 3.6.4 Correspondence analysis

The thesis contains some cross tabulation tables, for example in the Section 4.4. Sharma (1996) suggests that the interpretation of such a large table could be simplified if a few components representing most of the relationships between the row and column variables could be identified.

According to Sharma (1996), correspondence analysis attains this objective. In this respect, the purpose of correspondence analysis is similar to that of principal components analysis. In fact, correspondence analysis can be viewed as equivalent to principal components analysis for nonmetric data. Loglinear models and correspondence analysis can be generalised to multiway contingency tables. Multiway contingency tables are cross tabulations for more than two variables.

In a more simplified way, correspondence analysis (CAS) is a technique for graphically displaying a two-way table by calculating coordinates representing its rows and columns (NCSS® 2000). These coordinates are analogous to factors in a principal components analysis (used for continuous data), except that they partition the Chi-square value used in testing independence instead of the total variance.

### 3.6.5 Linear regression

Linear regression is a commonly used procedure in statistical analysis (NCSS® 2000). Often it is called multiple regression. Multiple linear regression analysis refers to a group of techniques for studying the linear relationships among two or more variables. One of the main objects in linear regression analysis is to test a hypothesis about the slope (sometimes called the regression coefficient) of the regression equation. However, regression analysis does not aim only at testing the effects of variables but to creating a quantitative model (Koskela 1999). Koskela (1999) states that the nonlinear dependence between the response variable and explanatory variable can often be made linear by modifying the explanatory variables. In some cases, this can be done by modifying both the response and the independent variables.

According to NCSS® (2000), theory and experience give often only a general direction as to which of a pool of candidate variables should be included in the regression model. The actual set of predictor variables used in the final regression model must be determined by analysis of the data. Determining this subset is called the variable selection problem and one of the methods used in variable selection is stepwise regression with its many variants.

Finding this subset of regressor (independent) variables involves two opposing objectives. First, the regression model is designed to be as complete and realistic as possible. Every regressor is selected so that it is at least remotely related to the dependent variable to be included. Secondly, as few variables as possible are included because each irrelevant regressor decreases the precision of the estimated coefficients and predicted values. Additionally, the presence of extra variables increases the complexity of data collection and model maintenance. The goal of variable selection becomes parsimony of the model: to achieve a balance between simplicity (as few regressors as possible) and fit (as many regressors as needed).

### 3.6.5.1 Linear regression model

Linear regression is used to analyse the value of a dependent scale variable based on its linear relationship to one or more predictors. The linear regression model assumes that there is a linear, or "straight line," relationship between the dependent variable and each predictor. This relationship is described in Equation 2 with deterministic components and a random error component (SPSS® 2003 and McClave 2005).

$$y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon$$

**Equation 2. Linear regression model.**

where $\alpha$ = constant
$\beta_k$ = coefficients
$y$ = dependent or response variable to be modelled
$x_k$ = independent or predictor variables to be used as predictors for y
$k$ = number of explanatory variables in the model
$\varepsilon$ = random error

Then the sample regression coefficients are used as estimates of the population parameters (Berenson et al. 2002 p. 552).

### 3.6.5.2 Linear regression building strategy and principles

Linear regression is applied in the thesis for the identification of trends on time series basis as well as for batch size and price analyses. The thesis includes three batch size analyses, one for both species together and one for each of the species separately. Three batch size analyses were also made: one for pine, one for spruce, and one for both species together (pine and spruce). Variable selection for linear regression batch size and price analyses was started by establishing the set of variables. There was no division to forced and non-forced variables, because there was no reason for a priori selection of variables to force them into the model.

In the batch size model, all the explanatory variables were categorical. The price model had one numerical variable (quantity). All the other variables being categorical. All the categorical variables were changed to be dichotomous, i.e. the categorical variables were only given values 0 or 1. Subsequently, a model was created for selecting the explanatory variables using the stepwise multiple regression analysis method. Then the explanatory variables for both multiple and logistic regression analyses were selected by the criterion that the *p*-values of selected variables must conform to the following stepping method criteria (NCSS® 2000):

- PIN, the probability required to enter the equation, 0.01.
- POUT, the probability required for removal from the equation, 0.02.
- A variable, not currently in the model, must have a t-test probability value less than or equal to this in order to be considered for entry into the regression equation, i.e. PIN < POUT.

The next step was to verify all the selected variables by validity criteria, and finally the statistical significance of the model was tested by a goodness-of-fit test, which is often used with the multiple regression analysis. However, the results are still left up to the users to determine if the analysis makes theoretical and practical sense. Users of stepwise regressions in sawmilling business can be seen as active and curious learners. They construct their mental models based on their old and new information and then make a decision if the analysis makes sense (Rauste-von Wright and von Wright 1998; Phillips and Soltis 1998).

#### 3.6.5.3 Problems of stepwise procedures and data mining

The term stepwise procedures often refers to the use of decisions made by computer algorithms, rather than choices made directly by the researcher, to select a set of predictors for inclusion in or removal from a linear or logistic regression model (Menard 1995). This leads to a situation where there needs to be a theory for relevant variables. Gujarati (1992) says that detecting the presence of relevant or irrelevant variables by the usual t and F tests is not a difficult task in stepwise regression. Moreover, Gujarati (1992) underlines the importance of a specific model, accepted as the true model, in the tests of specifications in stepwise regression.

The term “stepwise” often refers to the use of decisions made by computer algorithms, rather than choices made directly by the researcher, to select a set of predictors for inclusion in or removal from a linear or logistic regression model (Menard 1995). Stepwise techniques have been defended in this latter sense as a useful tool for exploratory research, which can later be seen as a part of data mining (Agresti and Finlay 1986, Hosmer and Lemeshow 1989). Studenmund (2001) presents a relevant list of the problems of stepwise procedures:

1. There can be correlation among the independent variables.
2. It becomes difficult to tell the impact of one variable from another.
3. It may be impossible to say which one of the variables is more important and thus be included first.
4. There is no necessity that the particular combination of variables chosen has any theoretical justification or that the coefficients have the expected signs.

Studenmund (2001) and Gujarati (1992) do not recommend the strategy of data mining. If a priori there was a variable Xn that belonged to the model to begin with, it should have been introduced. On the other hand, excluding a variable Xn in the initial regression would lead to the omission-of-relevant-variable bias. In other words, in data mining the analyses and models may be subject to type 1 error of regression analysis, the error of rejecting a hypothesis when it is true. Above all, Gujarati (1992) emphasises that theory must be the guide to analyses and model building; measurement without theory can lead up a blind alley. In addition, there is also a danger of type 2 error of regression analysis, the error of accepting a false hypothesis. According to Studenmund (2001), data mining may lead to a situation where the researcher has not found any scientific evidence to support the original hypothesis. Instead, prior expectations were imposed on the data in a way that is essentially misleading.

### 3.6.6 Logistic regression

#### 3.6.6.1 Why logistic regression?

Logistic regression, originally applied to survival data in the health sciences, has been developed for use with regression models. In these, it is used to predict the probability of a particular categorical response for a given set of explanatory variables (Berenson et al. 2002 p. 577). According to Statistix® (1992), logistic regression is thus the appropriate procedure, if one is interested in proportions. If count data are to be explained, one should consider either Poisson (Discrete) regression or log-linear models. If count data are to be explained and independent variables include continuous variables ("covariates"), Poisson regression is recommended.

According to Hosmer and Lemeshow (1989), logistic regression is a useful and effective data analysis tool. In particular, employing a stepwise selection procedure can provide a fast and effective means to screen a large number of variables. Simultaneously, it can be used to fit a number of logistic regression equations when the outcome being studied is relatively new and not well understood in previous scientific publications.

Product proportions (%) are one of the interests of this study, and therefore logistic regression was chosen. It is applied as described in the Section 3.6.6.2. However, there are several other advantages for logistic regression over linear regression. Logistic regression is flexible and easy to use, and it provides opportunity for meaningful interpretation (Hosmer and Lemeshow 1989, Ripatti 1996).

In all regression models, the conditional mean, expressed by E(*Y*|*x*), is the mean value of outcome variable, where *Y* denotes the outcome variable and *x* stands for the independent variable value. With dichotomous data, as most of the data in the thesis, the conditional mean, $1 \geq E(Y|x) \geq 0$, becomes an S-shaped curve as in Figure 43 (Hosmer and Lemeshow 1989, Ripatti 1996).

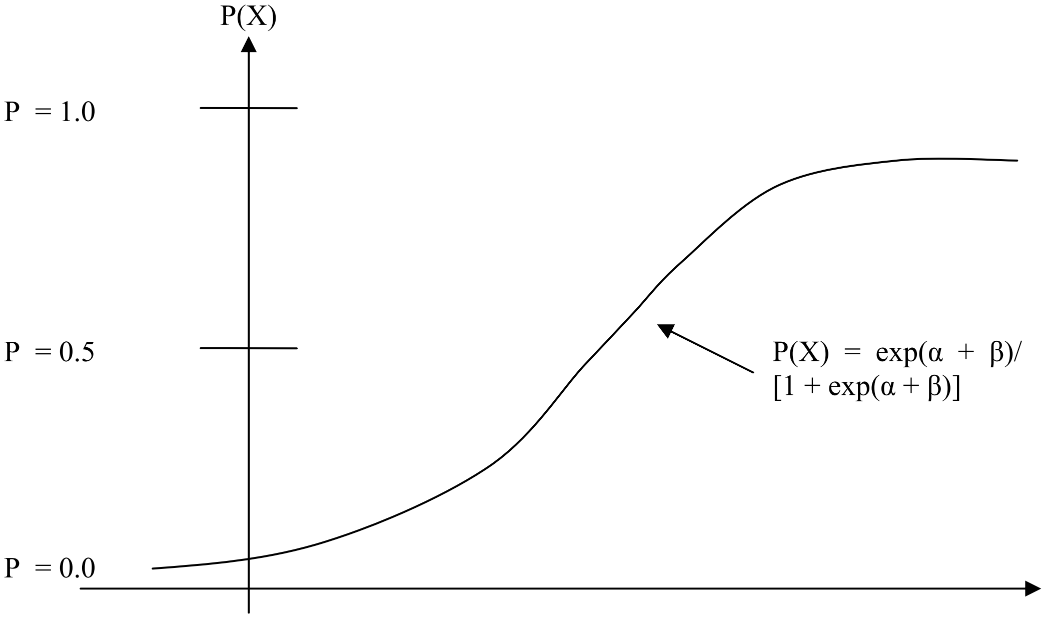


**Figure 43. S-shaped curve of the logistic model principle.**

Logistic regression has been applied to solid wood markets, too. Damery and Fisette (2001) present their results of a survey done on architects, contractors and homeowners and related to decision making in the sale of siding. In their research, they apply logistic regression to their sample. Anderson and Hansen (2004) have used binary logistic regression to identify which explanatory variables were useful in predicting membership in their group of interest.

### 3.6.6.2 Logistic regression model

The logistic regression model – or logit model – is based on the following cumulative logistic probability function (Pindyck and Rubinfeld 1998):

$$P_i = F(Z_i) = F(\alpha + \beta X_i) = \frac{1}{1+e^{-Z_i}} = \frac{1}{1+e^{-(\alpha+\beta X_i)}}$$

**Equation 3. Logistic probability function.**

where $P_i$ = probability of success or successful outcome (Studenmund 2001).
$\alpha$ = constant
$\beta$ = coefficient

Both sides of the equation are multiplied by 1 + $e^{-Z_i}$ to get

$$(1+e^{-Z_i})P_i = 1$$

Dividing by $P_i$ and subtracting 1 leads to

$$e^{-Z_i} = \frac{1}{P_i} - 1 = \frac{1-P_i}{P_i}$$

By definition $e^{-Z} = 1/e^{Z}$ leads to an equation which is used to express the odds ratio (Berenson et al. 2002 p. 577) as expressed in Equation 4. Odds ratio refer to the ratio of number of times a choice will be made divided by the number of times it will not (Studenmund 2001).

$$e^{Z_i} = \frac{P_i}{1-P_i}$$

**Equation 4. Odds ratio.**

The logistic regression model is based on the natural logarithm of this odds ratio. This model is expressed as in Equation 5.

$$\log(\textit{odds ratio}) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon$$

**Equation 5. Logistic regression model.**

where $\alpha$ = constant
$\beta_i$ = coefficients
$k$ = number of independent variables in the model
$\varepsilon$ = random error
$x_i$ = regressors (explanatory variables)

A mathematical method called maximum likelihood estimation is usually used to develop a regression equation to predict the natural logarithm of this odds ratio (Equation 6). For a set of data from a sample, equation (4) is used (Berenson et al. 2002 p. 577).

$$\log(\textit{estimated odds ratio}) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k$$

**Equation 6. Logistic regression equation.**

It can be used in simplified form to describe changes in proportions. Simplifications may use the fact that for any continuous variable x, $\Delta \log x \approx \Delta x/x$, and the fact that log(x/y) = log $x$ – log $y$ (Equation 7). Then as used in Pindyck and Rubinfeld (1998)

$$\Delta \log \frac{P_i}{1-P_i} \approx \left( \frac{1}{P_i} + \frac{1}{1-P_i} \right) \Delta P_i = \frac{1}{P_i(1-P_i)} \Delta P_i$$

**Equation 7. Logistic regression function with simplification.**

This logit model is applied for analysing CSW supply with the software SPSS® (2003) and its binary logistic regression module.

The logit model has been applied by Dubin (1986) for space and water heat system choice. It has also been applied to factors affecting fluid milk purchasing sources in Turkey by Hatirli et al. (2004) as well as dynamic, customer-oriented improvement of supply networks by Jammernegg and Kischka (2004).

### 3.6.6.3 Building strategy and the principles for the logistic regression model

The building strategy of a logistic regression model usually includes the model's aim, model type selection and variables to be included in the model. The criteria by which a specific model type and model variables are selected differ according to statistical doctrines and schools. A traditional way to build a statistical logistic regression model includes an idea to build as simple model as possible, i.e. a parsimonious model, in such a way that the model still explains the data. This method has been applied with logistic regression by e.g. Hosmer and Lemeshow (1989) and Ripatti (1996).

To build a simplified logistic regression model, i.e. a parsimonious model, requires a strategy for selecting the variables for the model as well as the methods for evaluating validity and reliability of model. The evaluation of model validity and reliability must cover both individual variables and the aggregated model. Furthermore, from the scientific perspective, the evaluation covers both the reliability and the validity of the model.

In the thesis, the possibility that a prediction of $P_i$ (probability of success or successful outcome) might be outside the probability interval of 0 to 1 was avoided by not modelling $P_i$ directly. Instead, a ratio of Equation 4 was modelled. This leads in the thesis to dummy dependent variable analysis, the binomial logit, a variant of the cumulative logistic regression, where $P_i$ is a dummy variable. A dummy variable is a binary metric variable used to represent a single category of a nonmetric variable. The binomial logit is an estimation technique for equations with dummy dependent variables that avoids the unboundedness problem of the linear probability model by using a variant of the Equation 5 where $P_i$ is a dummy variable (Studenmund 2001).

The selection of variables for logistic regression was started by forming a set of variables that covered only one numerical variable (quantity) and categorical variables (Table 26). As for linear regression, there was no division to forced and non-forced variables, because there was no ground for a priori selection of variables to force them into the model. All categorical variables were changed to be dichotomous, i.e. the categorical variables were only given values 0 or 1. The response variable ($y$), also a categorical variable, was selected from the variable set, to be end moisture content classes. The models were created for end moisture content classes to select explanatory variables by using the method of stepwise binary logistic regression analysis. From a model where a categorical variable was a response variable (e.g. end moisture content), all parallel variables (e.g. other end moisture contents) were excluded (see Table 26). After this, all variables with $p$-value lower than 0.01 were selected to be explanatory variables. A selection level of 0.01 was used because the traditional level of 0.05 may fail to emphasize important variables in logistic regression (Ripatti 1996).

**Table 26. The logistic regression model variable classes, the variables and data penetration level. Year 2000.**

| **Variable class** | **Moisture content** | **Quality** | **Thickness** | **Width** | **Country** | **User segments** | **Quantity 1)** | **Location of production** | **Species** |
|---|---|---|---|---|---|---|---|---|---|
| **Variables in class** | MC8, MC10, MC12, MC14, MC16, MC18, MC20, MC-NO INF | US, V, SF, VI, side boards, strength graded | 19, 22, 25, 32, 38, 44, 47, 50, 63, 75 | 100, 125, 150, 175, 200, 225 | DE, DK, DZ, EG, ES, FI, FR, GB, IE, IL, IT, JP, NL | DISTRIBUTION, FURNITURE, JOINERY, PLANING, STRENGTH GRADING | | South, East, West | Pine 3) |
| **Data, %, 2)** | 99% | 98% | 92% | 90% | 92% | 82% | 100% | 99% | 64% |

1) Only one variable. 2) after elimination, of number of total sales, 3) Pine is referred as 1, spruce as 0.

### 3.6.6.4 Selection, results and evaluation of the logistic regression model

The following indications were selected for results: Number of steps, Number of observations, Cox & Snell R2 statistics (R-squared), Nagelkerke R2 statistics, Hosmer and Lemeshow (HaL) goodness-of fit (gof), and *p*-value for Hosmer and Lemeshow (HaL) goodness-of-fit (*p* of gof (HaL)). Logistic regression results were obtained through SPSS® (2003).

The selected method was binary logistic regression from SPSS® (2003) with the stepwise approach of Forward (Wald). This approach uses the following statistic in Equation 8.

$$t = \frac{\hat{\beta}}{\hat{\mathrm{SE}}\left(\hat{\beta}\right)}$$

**Equation 8. Wald test statistic ratio approach from Berenson et al. (2002).**

where

$\beta$ = regression coefficient
SE ($\beta$) = standard error or the regression coefficient

The previous test (Equation 8) is closely related to two alternatives, the likelihood ratio test and the Lagrange multiplier test (Cox and Hinkley 1978). Because all the three tests are asymptotically equivalent, they will give identical test results if the sample size is allowed to increase without bound. The Wald approach was used because it was assumed to be more useful with large data sets due to its properties (e.g. test statistics).

The number of iterations was limited to 100. Probability for stepwise regression was set for entry to PIN = 0.01, and for removal to POUT = 0.02. Contrast method was indicator and reference category first. All variables were categorical except for quantity and constant.

Logistic regression does not have an equivalent to the R-squared that is found in some other regressions, where the value of R-squared means the proportion of variance explained by the predictors. Therefore, other R-squared statistics, called pseudo R-squared statistics, have been designed to have similar properties to the true R-squared statistic. In logistic regression, R-squared values do not mean the proportion of variance explained by the predictors, but the values indicate the proportion of variance accounted for. The pseudo R-squared statistics are based on comparing the likelihood of the current model to the "null" model (one without any predictors). Larger pseudo R-squared statistics indicate that more of the variation is explained by the model, from a minimum of 0 to a maximum of 1. Pseudo R-squared can be compared within a set of similar logistic regression models but needs to be interpreted with great caution (SPSS® 2003).

Cox & Snell R-squared and Nagelkerke R-squared were selected to be used as pseudo R-squared values. The maximum value of the Cox and Snell R-squared statistic is actually somewhat less than 1. The Nagelkerke R-squared statistic is a modification of the Cox and Snell statistic so that its maximum value is 1 (SPSS® 2003).

The Hosmer and Lemeshow goodness-of-fit test – $HL^2$ in Equation 9 – is a method of evaluating a probability model's calibration, or its degree of correspondence between the estimated probabilities (estimated = *e*) produced by the model and the actual experience (observed = *o*). The values can be compared within a set of similar models. *P*-value for the Hosmer and Lemeshow goodness-of-fit indicates the probability of the model by covariate grouping. The Hosmer-Lemeshow statistic indicates a poor fit if its *p*-value is less than 0.05 (SPSS® 2003).

$$HL^2 = \sum_{j=1}^{k} \frac{(o_i - e_i)^2}{e_i}$$

**Equation 9. Hosmer and Lemeshow goodness-of-fit equation.**

### 3.6.7 Kolmogorov–Smirnov Goodness-of-Fit Test

In the thesis, the Kolmogorov–Smirnov (K–S) test is used to decide if two continuous dimension distributions are statistically different. It can be used to decide whether a sample comes from a population with a specific distribution.

According to NIST (2004), the Kolmogorov–Smirnov test has several important limitations:
1. It only applies to continuous distributions.
2. It tends to be more sensitive near the centre of the distribution than at the tails.
3. Distribution must be fully specified.

That is, if location, scale, and shape parameters are estimated from the data, the critical region of the K–S test is no longer valid. It typically must be determined by simulation.

## *3.7 Reliability and validity of data and results*

Reliability is defined by Webster (2004) as an attribute of any system that consistently produces the same results, preferably meeting or exceeding its specifications. Reliability is thus linked with a system that can be software, model, machine, book or other entity. Vehkalahti (2000) defines reliability as the ratio of the true variance to the total variance.

Data reliability should be evaluated on two levels: (1) reliability of data sources, (2) reliability of data in statistical measurements. The first of these levels is often forgotten and the second often emphasised. However, to estimate data reliability, the concepts of measurement model and measurement scale are required. Vehkalahti (2000) presents the statistical measurement model that specifies the structure of the measurement, and the scale. The scale is a combination of the measured items and represents a realisation of the theoretical notions with a focus on two measures of reliability: Cronbach's alpha (Cronbach 1947 through Vehkalahti 2000), which is widely applied, and a more general measure by Tarkkonen (1987).

In the thesis, data reliability from the perspective of data source was based on the following reliability process with databases: 1) data form inspection, 2) data content inspection, 3) data unambiguity inspection, 4) database application tests, e.g. pivot and statistical analysis. After these four phases, data were allowed to be used in the thesis. Furthermore, all database changes or modifications were documented.

Data reliability can be evaluated from a company's perspective. The largest portion of data is given by sawmilling companies and has been organised into WPDB. It is possible that there are mistakes in the company information. On the other hand, the reliability of company information is based on the reliability of the legislation of Finland. The company must have a reliable accounting system, which includes sales information. Therefore, it can be assumed that there are no frauds or missing data but data reliability is on a high level. Moreover, the investors that support a company need economic and profitability information, which is a further incentive to keep all sales information up to date in the company's databases.

From the statistical measurement perspective, the reliability of data is premised on the basis of software reliability by Statistix® (1992), NCSS® (2000), Microsoft® (2002) and SPSS® (2003). Reliability was estimated by the estimates given in these software programs. The results of the reliability estimations are presented in connection with the analyses or in the relevant appendices.

Vehkalahti (2000) emphasises the importance of validity by saying that the most important property of measurement is validity. This is true in the thesis, too, because the conclusions of empirical studies are based on the values collected from research objects. It is therefore crucial to assess the quality of the measurements. From another perspective, validity cannot be solved statistically but only on basis of the nature of the research object itself.

Still, the definition of validity just as validity itself depends much on how and in which context it is applied. Webster (2004) defines validity e.g. as the (1) quality or state of being valid or power to convince, or in legal contexts (2) legal strength, force, or authority, the validity of a contract, claim, or title, or briefly (3) value. Vehkalahti (2000) states that validity is concerned with whether a measuring instrument measures what it is supposed to measure in the context in which it is to be applied.

In the thesis, validity is above all based on evaluation and expertise of research topics. Validity in statistical measurements is presented in connection with the analyses or in the relevant appendices.

Data reliability and validity testing was applied to the following source information that has been utilised in the thesis:

1. Direct company information for WPDB. This has been collected from the Finnish sawmilling industry's own databases, with the reliability and validity processes described before.
2. FAOSTAT data (2004). The reliability and validity of these data is based on (1) the reliability and validity processes of FAO (2) the reliability and validity processes applied in the thesis and described before.

The reliability and validity of FAOSTAT data (2004) is based on the Agricultural Bulletin Board on Data Collection, Dissemination and Quality of Statistics project (ABCDQ). The ABCDQ was established in 2000 to guide users that might seek information, on the sources and methods of national agricultural data collection and dissemination. The ABCDQ is an important reinforcing element for the quality of FAOSTAT database. Quality is defined by FAOSTAT data (2004) as relevance, accuracy, timeliness and punctuality, accessibility and clarity, comparability, coherence and completeness, and sound meta information. They underline accuracy and reliability aspects, analysing different kinds of errors associated with the estimates.

The reliability of the results consists of external and internal reliability, i.e. the corollaries of external and internal errors. The total error, $e_{tot}$, is the sum of external errors, $e_{ex}$, and internal errors, $e_{in}$. The external errors of the results, $e_{ex}$, mean sampling errors and describe the representatives of the results calculated from the sample. The internal errors of the results, $e_{in}$, means measurement errors, and can be considered in terms of reliability, corresponding to the accuracy of the measurement, and validity, corresponding to the ability of the measurement scales to give real information on the desired traits. The quality of measurement consists of these components as shown in Figure 44 (Ripatti 1996).

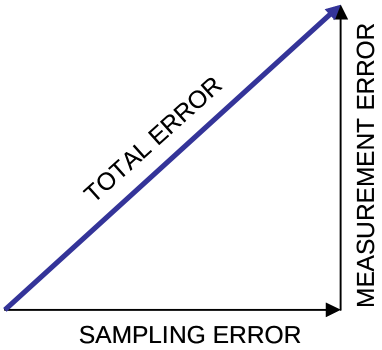


**Figure 44. The total error concept consists of sampling error and measurement error (Ripatti 1996, Blalock 1985).**

From economic perspective, there are problems related to the sawmilling data and results from 1995 to 2000 (see Table 22). The period from 1995 to 2000 can be considered a short period. Some variation of classification may be related to cyclical price and quantity fluctuations, which are, in practice, impossible to completely remove from the sample without losing relevant information, too. The year 2000 was a cyclical peak in the Finnish sawmilling industry. However, the quantity of sawnwood has remained on the same level from 2000 to 2004 (Finnish Forest Industries 2005). The cyclical peaks, ups and downs are likely to have an cyclical effect on some of the results that deal with the changes in quality classes and other changes from 1995 to 2000. In addition, the quantity of the database may not fully compensate the requirements of economic supply and demand analysis, which should include cost, production structure and other approaches, too.

# 4 CONIFEROUS SAWNWOOD (CSW) CONSUMPTION ENVIRONMENT

All the data leading to the results of this chapter are based on FAOSTAT data (2004). In this chapter, consumption is the apparent consumption. This is a proxy measure for the consumption of a product or material, defined as production plus imports minus exports of the product or material (United Nations 1997).

## *4.1 Sawnwood (CSW) consumption*

### 4.1.1 Global production of sawnwood and other wood products

Coniferous sawnwood global consumption has risen during the period of 1961–2002 from the level of under 200 million m$^3$ to almost 300 million m$^3$. The consumption ranged during the period of 1983–2002 from 250 million m$^3$ to 320 million m$^3$ (Figure 46).

The sawnwood consumption level is high compared with other wood based materials. In 2002 the global production of coniferous sawnwood was 288 million m$^3$, which is almost half of all wood products (Figure 45 and Table 27).

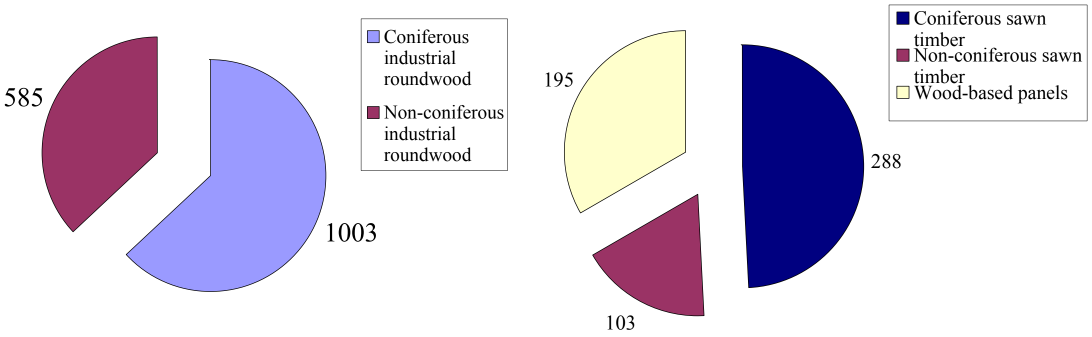


**Figure 45. Global production of industrial roundwood and wood products in 2002, million m$^3$. Data source: FAOSTAT data (2004).**

It is interesting to see the connection between coniferous sawnwood and its raw material (Table 27). If the timber recovery is assumed to be 2–2.3, as it can be assumed in the Finnish sawmilling industry, global coniferous sawnwood use of roundwood is estimated to be from 576 to 662 million m$^3$ (2 x 288 million m$^3$ = 576 million m$^3$). This is 57–66% of all the coniferous industrial roundwood global production. The estimation should be regarded cautiously, because part of sawnwood is produced by methods in which timber recovery is much weaker than 2–2.3.

**Table 27. Global production of roundwood, wood products, wood based panels and fibreboards in 2002 (FAOSTAT data 2004).**

| Product groups | Global production, million m$^3$ | % |
|---|---|---|
| Coniferous industrial roundwood | 1,003 | 63% |
| Non-coniferous industrial roundwood | 585 | 37% |
| **Roundwood, total** | **1,588** | **100%** |
| Coniferous sawnwood | 288 | 49% |
| Non-coniferous sawnwood | 103 | 18% |
| Wood-based panels | 195 | 33% |
| **Wood products, total** | **586** | **100%** |
| Plywood | 59 | 30% |
| Veneer sheets | 13 | 7% |
| Particleboard | 85 | 43% |
| Fibreboards | 39 | 20% |
| **Wood-based panels, total** | **195** | **100%** |
| MDF | 23 | 58% |
| Hardboard | 10 | 26% |
| Insulating board | 6 | 15% |
| **Fibreboards, total** | **39** | **100%** |

## 4.1.2 Global consumption overview

Regionally, the consumption of coniferous sawnwood is mainly concentrated in North America and Europe. Everywhere except in Asia, the consumption of coniferous sawnwood has increased between the years 1961 and 2002. In Asia, coniferous sawnwood is consumed on a significant level, but the consumption has decreased especially during the 1990s. In Africa, Oceania and Central and South America, the consumption of coniferous sawnwood is growing, but it is small in proportion to the worldwide consumption (Figure 46). The importance of Europe for sawnwood consumption has grown at the end of the period 1961–2002. However, there is more sawnwood consumption in North America than in other parts of the world.

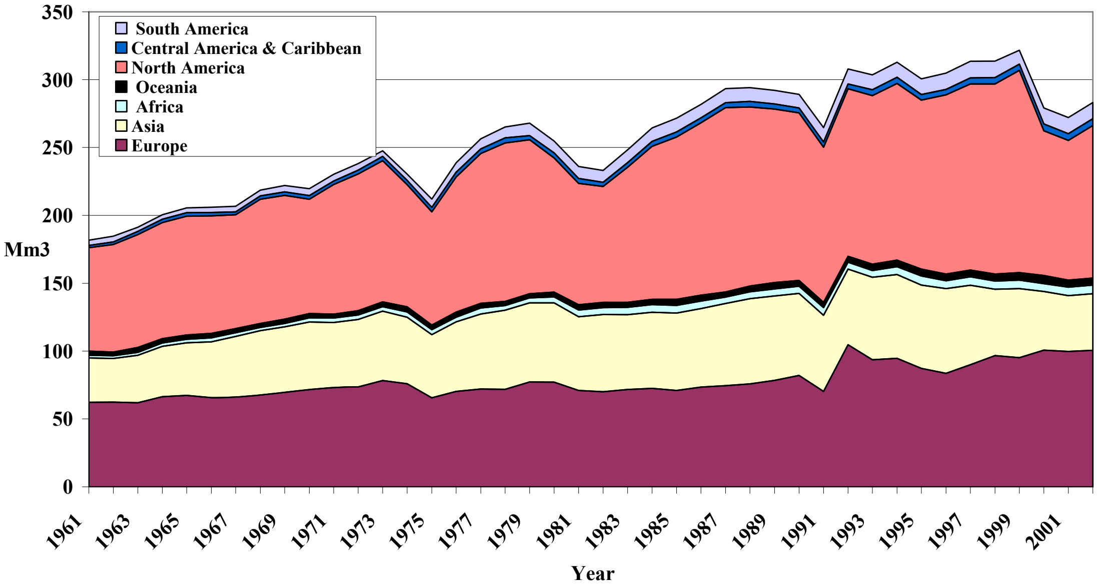


**Figure 46. Coniferous sawnwood (CSW) consumption (m$^3$) by global areas from 1961 to 2002. Data source: FAOSTAT data (2004).**

Typical features for the global consumption of sawnwood between 1961 and 2002 are large volumes, fluctuations and slow growth (Figure 46). Coniferous sawnwood use follows economic cycles, because CSW use is closely linked with construction, dwelling and some other uses. On the other hand, there are links from construction and dwelling to human basic needs. Therefore, sawnwood consumption can be seen to have many opportunities in future, if sawnwood is able to maintain its competitiveness compared to other materials.

It is interesting to see a recurrent, slow increase in sawnwood global consumption followed by a quick decrease (see e.g. year 1974 in Figure 46). Still, there has been at least twice a fast increase in CSW consumption (Figure 46). For the first time, there was a period in the early 1970s when a strong CSW consumption decrease was followed by a strong CSW consumption increase. This is probably linked with the concurrent oil crisis. The second time, there was a strong decrease in consumption in 1991. This decrease was followed by a strong consumption increase. These changes are probably linked with political changes in East Europe and particularly in the Soviet Union.

The coniferous sawnwood consumption curve resembles more a logarithmic consumption curve of regressive consumption than a linear consumption growth trend. Therefore, a logarithmic equation was fitted to sawnwood global consumption analysis. The long term consumption curves of coniferous sawnwood accept curve fitting with logarithmic equation with R2 = 0.79 (Figure 47). This can be considered typical for companies and products in a fragmentation and consolidation stage. Nevertheless, the results of this type of analysis are valid only subject to no structural changes taking place in markets between the estimation period 1961–2002 and during the forecast period. In addition, it can be asked how realistic is this assumption of no structural changes on sawnwood consumption between 2003 and 2010.

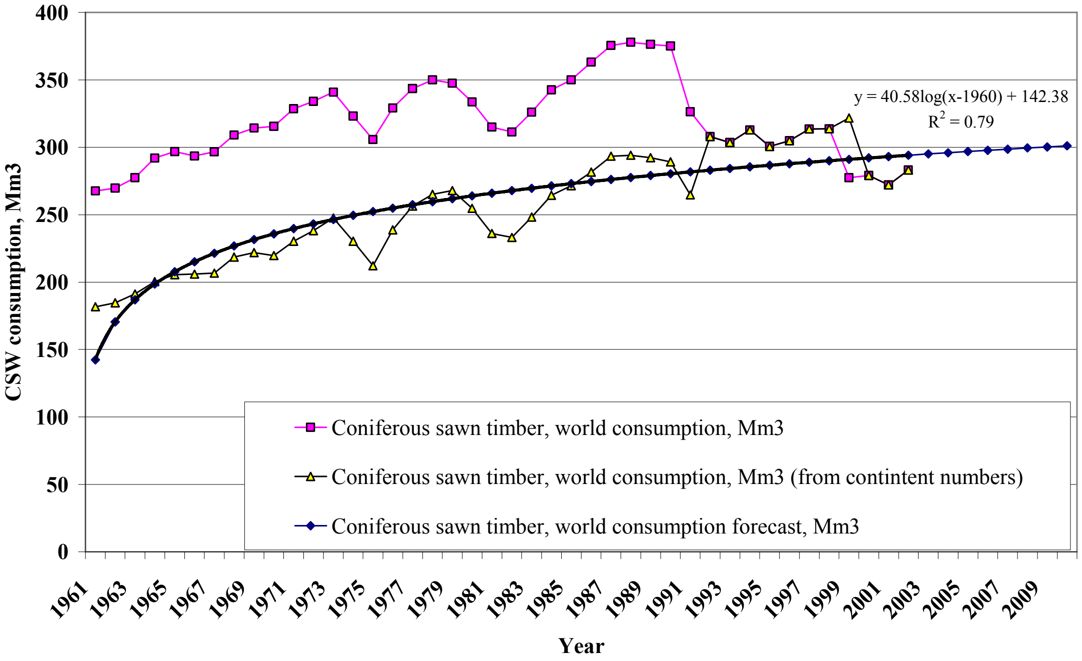


**Figure 47. CSW global consumption (m$^3$) 1961–2002 and forecast to 2010. Areas are Europe, North America, Caribbean + Central America, South America, Africa, Asia, Oceania. Data source: FAOSTAT data (2004).**

There are interesting issues of consumption series (Figure 47) when two global consumption curves are compared. Both the curves have got their data from FAOSTAT data (2004). The upper series is the global consumption given by FAOSTAT data (2004). The lower series is collected from regional areas (including the Soviet Union) based on the areas shown in Figure 46. The results indicate a statistical discrepancy in the global consumption statistics of coniferous sawnwood until 1992, when the series unite. The reason behind the statistical discrepancy lies probably in the previous statistics from the Soviet Union and their discrepancies.

### 4.1.3 Consumption in selected countries

The four leading countries of global CSW consumption in 2002 were the USA, Japan, Canada and Germany (Figure 48). In 2002, coniferous sawnwood consumption was more than five times higher in the USA than in Japan, which had the second position in CSW global consumption on country basis. A logarithmic scale has been used on the y (vertical) axis and an arithmetic scale on the x (horizontal) axis in Figure 48. The combination of a logarithmic and arithmetic scale is useful for comparing relative (percentage) changes, rather than absolute amounts of change, for a set of values. On a logarithmic scale, equal distances represent equal ratios.

There were significant changes in annual CSW consumption in all the four leading countries of global CSW consumption. In the USA, there have been annual CSW consumption changes between 1961 and 2002 (Figure 48 with logarithmic scale). In Japan, the CSW consumption has decreased from the level in the early 1990s. In Canada, there were also annual consumption changes like in the USA as can be seen in Figure 48. The CSW consumption level in Canada has increased from 1961 to 2002. In Germany, the CSW has remained in the same order of magnitude from 1961 to 2002 although there have been major political and population changes during the time frame. This is interesting because the political and population changes could have had a major effect on CSW consumption in construction and dwelling sectors in the period from 1961 to 2002. The sawnwood consumption has only weakly increased in Germany in the period from 1961 to 2002 (Figure 49).

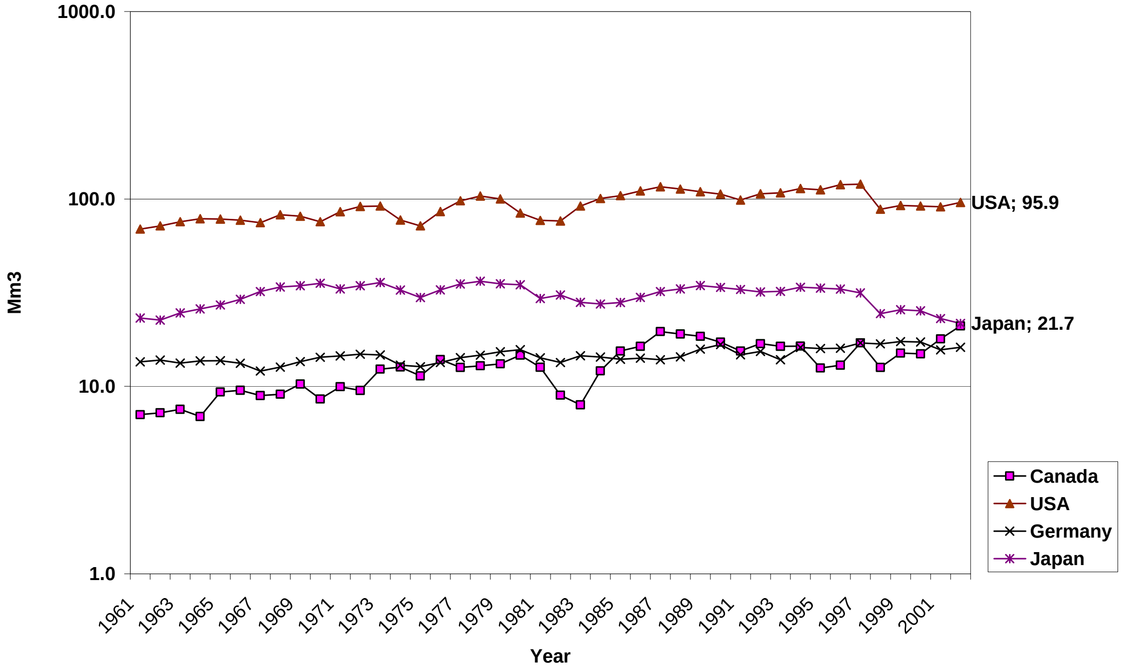


**Figure 48. CSW consumption (Mm$^3$) development from 1961 to 2002 of the world's four leading countries. The y-axis scale (Mm$^3$) is logarithmic to give more information of simultaneous changes. Germany includes both West and East Germany. Source: FAOSTAT data (2004).**

How has CSW consumption developed in other countries than in those four leading CSW countries? The development study was limited to (1) nine countries where CSW consumption was annually from 1 to 18 million m$^3$, and to (2) years from 1961 to 2002 (Figure 49). Of the countries thus selected, Germany was the only one that also belongs to the previous development study (Figure 48) of four leading CSW countries.

In **Germany**, the sawnwood consumption has increased slowly from 1961 to 2002 but it has remained between 12 and 18 million m$^3$ (Figure 49). Germany includes both West and East Germany. In **China**, CSW consumption increased from 1962 to 1985 but subsequently remained stable until 1988. From 1989 to 2000, CSW consumption has gone both up and down several times in China. In 2000, the consumption in China decreased from the 1988 peak (almost 18 million m$^3$) to less than 11 million m$^3$. In **UK**, the CSW consumption ranged from 6 to 12 million m$^3$ during the period from 1961 to 2002, except in 1976, when the CSW consumption decreased to less than 6 million m$^3$. Concurrently, the CSW consumption in **France** ranged from 5 to 10 million m$^3$ but increased to almost 10 million m$^3$ at the end of the period. In UK, the CSW consumption fluctuation has been much larger than in France (Figure 49). Nevertheless, in 2002 the CSW consumption in UK and France were close to each other, almost 10 million m$^3$.

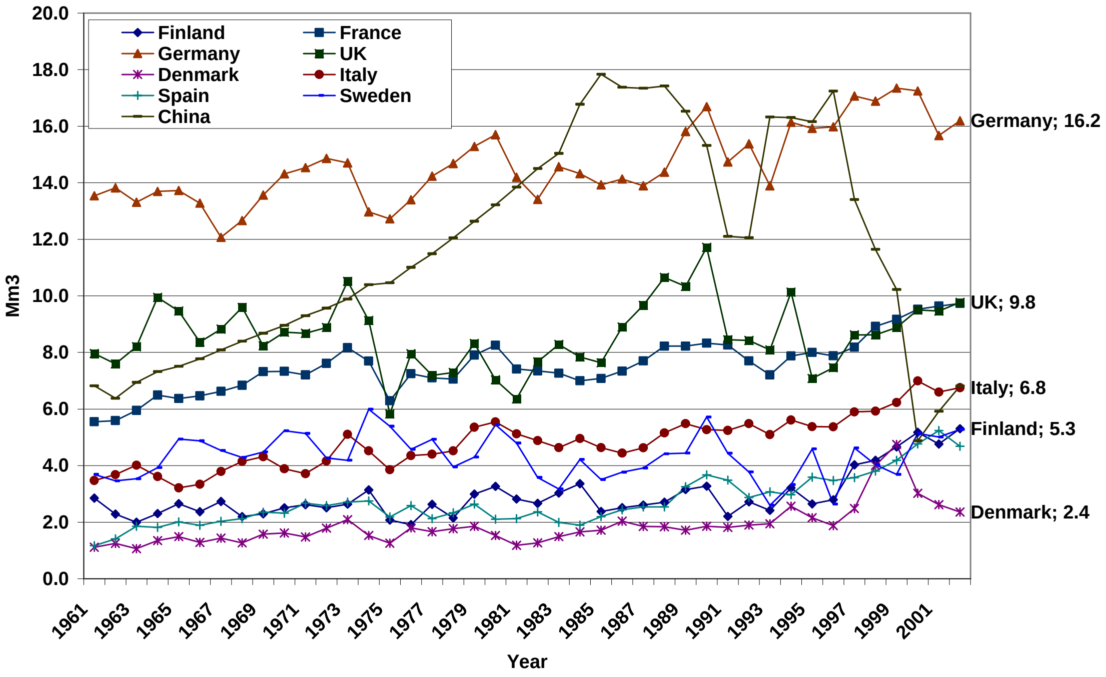


**Figure 49. CSW annual consumption in the nine selected countries between 1–18 Mm$^3$ in 1961–2002. Germany includes both West and East Germany. Source: FAOSTAT data (2004).**

In **Italy**, the CSW consumption has increased from the level of less than 4 million m$^3$ to the level of more than 6 million m$^3$. The CSW consumption in Italy is characterised by a relatively even growth with no large annual consumption fluctuations (Figure 49). In **Denmark**, the CSW consumption remained relatively even, at around 2 million m$^3$, until 1996 when the CSW consumption started growing strongly until 1999. The CSW consumption went over 8 million m$^3$ in 1999 but decreased again from 2000 to 2002. In **Spain**, the CSW consumption has increased from the level of less than 2 million m$^3$ in 1961 to the level of more than 4 million m$^3$ in 2002. The CSW consumption in **Finland** was different from most of the other countries, because the CSW consumption increased at the end of the period 1961–2002. The CSW consumption in Finland as well as in **Sweden** has ranged from 2 to 6 million m$^3$ in the period of 1961–2002.

### 4.1.4 Discussion

What do the observations and results of this section mean for future CSW consumption? The answer depends on the scientific perspective. From a traditional perspective, future cannot indiscriminately be assumed to be a continuum of the past if there are no reasons for the assumption. However, the events and logic of the past are often repeated in the future in a similar or modified form if there is no proven change in paradigm, which is the case with shown results. Therefore, the following discussion is based on the assumption that the previous observations and results can be repeated in the future.

The results of global production of coniferous sawnwood and other wood products show that CSW consumption is on such a high level that it will probably be difficult for other wood products to challenge the CSW consumption within 10 years due to position of CSW as the highest volume wood product. The global consumption of CSW was manifold (m$^3$) in 2002 compared to plywood, particleboard, not to mention engineered wood products (EWPs). For instance, the global EWP consumption grows rapidly, but it was 7 million m$^3$ in 2003, which is 40 times less than CSW consumption, which is estimated to be from 280 to 290 million m$^3$ (Rämö et al. 2003). There is no large or fast change in CSW consumption to be expected in near future in the form of a consumption transfer from CSW to other wood products or other materials. On the other hand, it is possible that a local shortage of wood raw material may cause some changes in the previous consumption analysis, transferring the consumption from CSW to other wood products, as has happened in North America (ECE/FAO 2001). As Poutanen (2000) has shown, it is also true that sawnwood has lost some of its market share to other materials, such as steel, aluminium, synthetic polymers (including plastic and PVC) and wood composites.

On the other hand, the world total supply of both coniferous and non-coniferous sawnwood has been forecasted to grow to almost 500 million $m^3$ in the period until 2010. The additional supply is expected to come mainly from planted forests in Oceania and South America (radiata pine, eucalyptus). The growth in consumption for sawnwood, still, is not expected to keep pace with production (see e.g. JPC 2003a), which will mean an oversupply of sawnwood on the world market by 2010, probably amounting to more than 20 million $m^3$. According to JPC (2003a), there is likely to be an oversupply of sawn softwood of about 2 million $m^3$ in 2010 in Europe.

Engineered Wood Products (EWPs) are manufactured from wood by gluing and used mainly for structural purposes. EWPs will win market share from CSW in the future (e.g. Rämö et al. 2003 and ECE/FAO 2001). The most important competitive assets of EWPs are their excellent technical properties, such as high strength, light weight, dimensional stability, uniform and predictable quality, and efficient use of wood. The definition of EWP includes the glued wood products for structural purposes, such as Laminated Veneer Lumber (LVL), Parallel Strand Lumber (PSL), Laminated Strand Lumber (LSL), I-beams and gluelam (glued laminated beams). The most important of these are gluelam, LVL and I-beams (Rämö et al. 2003, ECE/FAO 2001, Juslin and Hansen 2002). EWPs are made mainly in North America, where their increased use is closely linked with both a prevalence of wood frame construction (Figure 50), a need to reduce total construction costs, and more efficient use of wood (ECE/FAO 2000, Rämö et al. 2003). In comparing wood use in Europe, North America and Japan, it is interesting to see how large differences in the use of wood prevail on those markets (Figure 50).

There are huge differences between Europe, North America and Japan in how wood is used as to make frame material for housing (Figure 50). According to Poutanen (2000), one of the differences in the use of wood between Europe and North America is linked with both interior and exterior cladding differences.

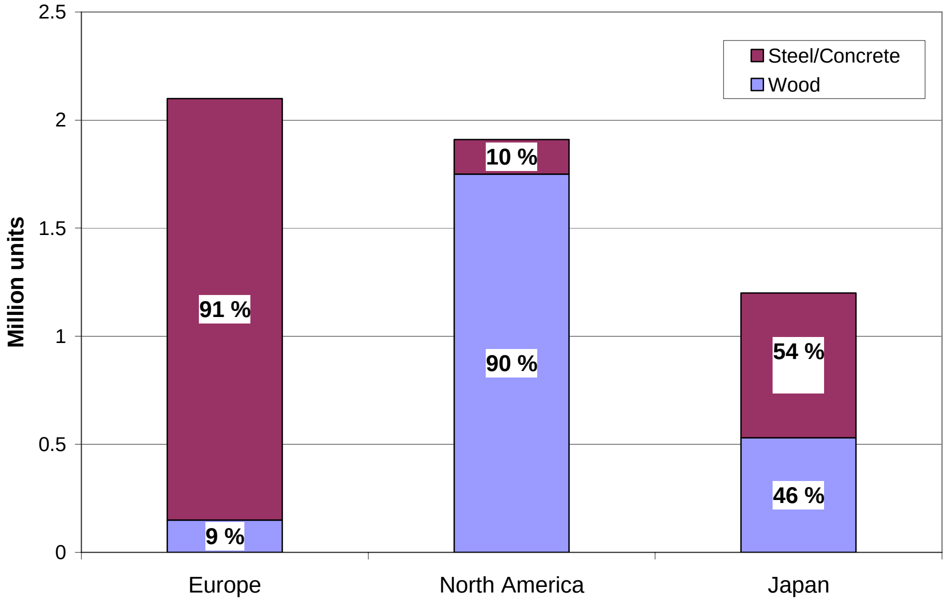


**Figure 50. Started single dwellings (in million) and their frame material in Europe, North America and Japan (Rämö et al. 2003).**

It is likely that EWP products will long remain as a significantly smaller product group than CSW on the global wood market, although the growth of EWP consumption is fast. Furthermore, it must be seen that the consumption of EWPs and CSW is linked because coniferous sawnwood is a raw material for gluelams, and CSW can be a raw material for other EWPs like I- beams as well.

Global consumption overview (Section 4.1.2) shows that on global CSW markets, the role of the USA markets needs to be emphasised due to large CSW consumption. Furthermore, it must be noticed that CSW use increases everywhere but not in Asia. There may be several reasons for this, but one of them is probably the availability of sawnwood raw material, coniferous logs. In Asia, the largest volumes of coniferous logs are located in Siberia, where timber harvesting is a challenge due to the imperfections of roads and other infrastructures as well as to environmental reasons. Therefore it is probable that they will use local hardwoods and imported coniferous sawnwood for construction in future. The assumption is supported by the estimation that sawnwood export from South America and Oceania to Asia is expected to grow significantly in the early 2000s. On the other hand, the most significant sawnwood trade flows are still from Canada to the USA and from the Nordic countries to the rest of Europe. Furthermore, the export to Japan from both Europe and North America will be important for Japan, Europe and North America, too (Key to Finnish Forest Industries 2000).

What does the observation (see Section 4.1.2) mean that there is a statistical discrepancy in the statistics of coniferous sawnwood global consumption until 1992 when the two series unite? The observation underlines the importance of data reliability but, on the other hand, it leads to look at another remarkable observation, the global CSW consumption trend.

If the CSW consumption is collected from regional areas (including the Soviet Union) based on the areas shown in Figure 46, CSW global consumption cannot be seen going strongly downward. Neither it cannot be seen that CSW global consumption would have gone 20% downward in the 1990s (e.g. Rämö et al. 2003). On the other hand, it is not unusual to observe CSW consumption forecasts to be overestimated compared to real consumption. For instance Tikka (1997) presents three estimates which all forecast CSW consumption to be much higher in 2000 than what it really turned out to be in 2000 (Pajuoja and Brooks 1996, FAO 1995, Kallio et al. 1987).

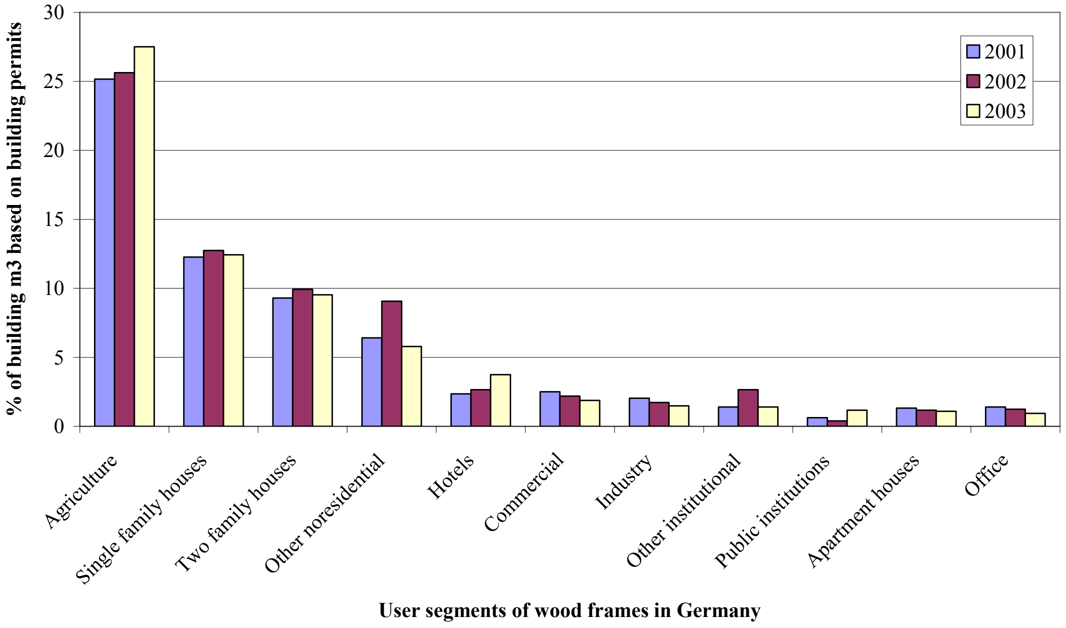


**Figure 51. German market shares in user segments of wood frames (Statistisches Bundesamt 2003).**

It is still possible to consider CSW as a product that has a slowly increasing consumption instead of a decreasing consumption. In that case, CSW could be seen as a product in the maturity stage of the life cycle, and not a product in a decline stage as it could be considered based on the global consumption curve (Figure 47). The global consumption curve (Figure 46) based on area consumption may also lead to the conclusion that CSW is a product in the maturity stage (Figure 47) instead of the decline stage. However, it must be said that CSW is not a product but a set of product groups, fragmented on the basis of species, user segments and properties.

The results of CSW consumption in the selected countries show that there are large differences between countries in CSW consumption level, user segment and variation perspective (see Figure 51). It is also interesting to note that in some countries (e.g. China) there are drastic changes in CSW consumption. This leads to consider, are the changes real, or are there possible statistical discrepancies?

## *4.2 Per capita CSW consumption overview in selected countries*

### 4.2.1 Results

One of the sawnwood consumption analysis approaches is to look at the per capita CSW consumption overview in the selected countries. This approach emphasises both the CSW consumption's connection to the population of the country and the differences in CSW use between the countries. It is interesting to compare research objects, in this context countries, through the per capita approach and CSW consumption. The comparison was limited to the most significant European countries from the CSW consumption perspective as well as to the USA, Canada, Japan and China. The sample covered altogether 39 countries (see Figure 52) in 2002.

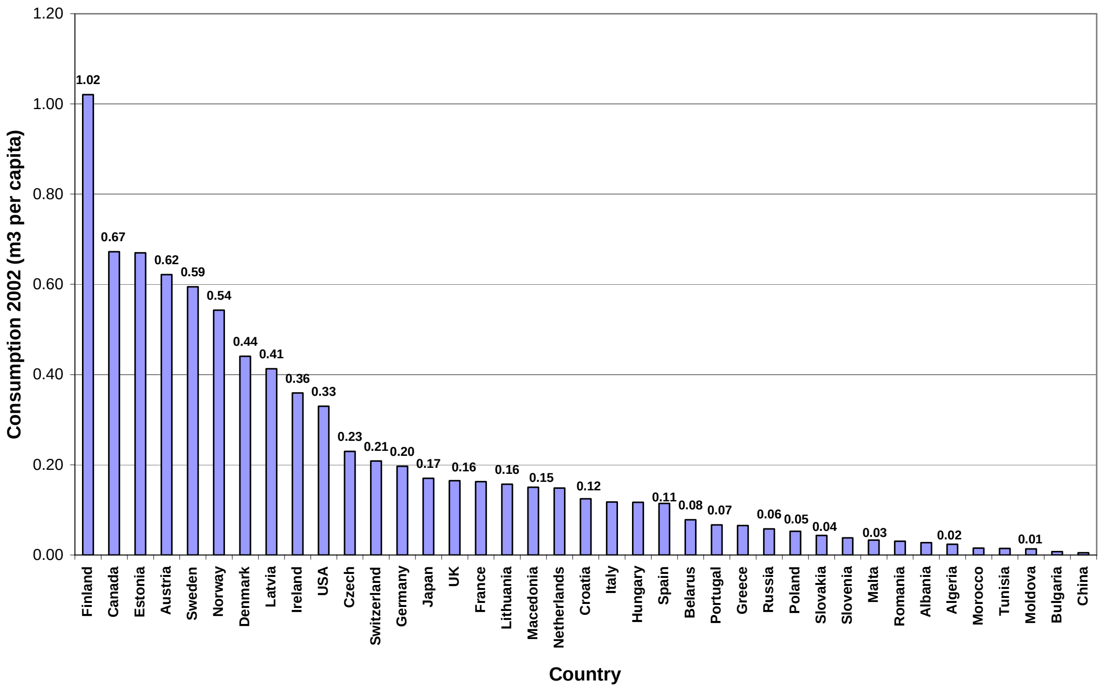


**Figure 52. CSW consumption per capita in selected countries 2002 (FAOSTAT data 2004).**

The CSW consumption per capita (Figure 52) comparison shows that there are huge differences in CSW consumption between countries. In the comparison results, Finland has a high CSW consumption per capita. However, there are also other countries with high CSW consumption per capita, like other Scandinavian countries, North America (the USA and Canada), Austria, Estonia, Latvia and Ireland.

### 4.2.2 Discussion

The large European sawmilling industry (see Figure 53, Figure 54, Figure 55 and Table 28) has set a goal to increase the consumption of CSW and other wood products from 0.15 $m^3$ per capita to 0.25 $m^3$ per capita a year. To achieve the goal, there are several sales promotion programs for CSW and other wood products in several European countries, such as Timber 2000 and Wood for good projects in UK, and projects in Germany, the Netherlands, France and Poland (Key to Finnish Forest Industries 2000).

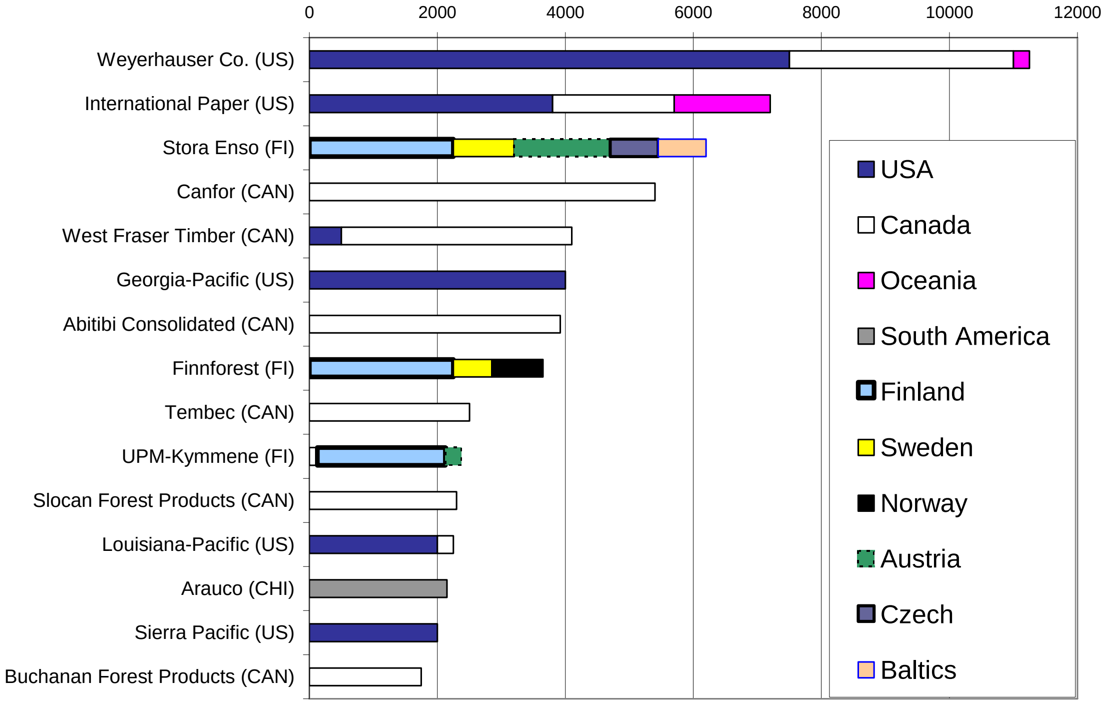


**Figure 53. Top 15 global sawmilling companies (1000 $m^3$) in the second quarter of 2003 (JPC 2003b). Modified by author.**

In Finland, the goal has been to create prerequisites for consumption increase of CSW and CSW refined products by developing wood product competitiveness in area, hall and public construction with product and method development (Key to Finnish Forest Industries 2000). As a result, there has been a success in consumption increase of coniferous sawnwood. Demand of sawn goods has reached a world-record level over the past 15 years. The Finnish forest industries explain that the high level of Finnish coniferous sawnwood consumption is a result of determined promotion of sawn goods (Yearbook 2004). For coniferous sawnwood's potential consumption increase in future, it would be interesting to obtain more accurate information on what sales promotions and development activities have succeeded in Finland and which of these could be used in other countries, too. It would also be interesting to estimate how high a level CSW consumption can reach in Finland, when the CSW consumption per capita has been on the highest level in the world in 2002. Poutanen (2000) suggests that CSW consumption in Finland will hardly increase because coniferous sawnwood is already the dominant frame material for small houses. On the other hand, per capita CSW consumption shows that it is possible to increase CSW consumption in other countries to a much higher level than it was in 2002. According to Poutanen (2000), the largest wood product consumption potential can be found in Central and South Europe, where stone (including e.g. casted concrete, clay bricks and concrete bricks) is a predominant construction material.

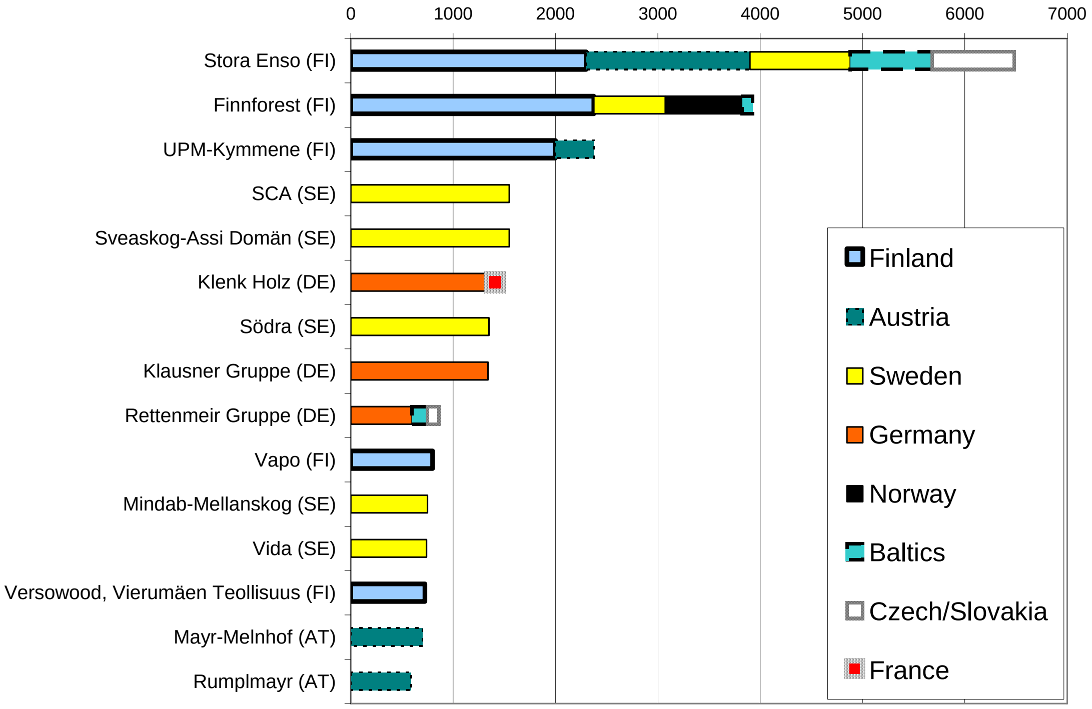


**Figure 54. Top 15 European sawmilling companies (1000 m$^3$) in the second quarter of 2003 (JPC 2003b). Modified by author.**

In the light of the results, the goal of the European large sawmilling industry (Key to Finnish Forest Industries 2000) to increase the consumption of CSW and other wood products from 0.15 m$^3$ per capita to 0.25 m$^3$ per capita a year would be possible to reach at least in many countries in Northern and Central Europe, where CSW consumption per capita is close to the consumption's starting point, 0.15 m$^3$ per capita. However, it is evident that to achieve CSW consumption growth of 40% (0.15 → 0.25) will require structural changes in CSW use, particularly in construction, in several countries. There is a need for new and improved applications in construction for CSW and refined products as well as changes in barriers (e.g. building regulations for fire-resistant materials) to allow CSW products to be used more in construction. According to Poutanen (2000), wood products could be used more in small house construction.

What are possible explanations for CSW consumption, if the consumption is estimated with the per capita approach? The results indicate that in all countries of high CSW consumption per capita there are both indigenous coniferous forests and a local wood product industry. Nevertheless, the deduction does not work perfectly in the other direction, because there are no proofs that only coniferous forests, a domestic raw material, would automatically increase CSW consumption in a country. For instance, there are huge coniferous forest resources in Russia but, at least so far, limited CSW consumption per capita (Figure 52). Nevertheless, there can be the following reasons for differences in per capita consumption between countries: (1) the tradition of CSW use in the country, especially if CSW is used as a frame material and for other construction applications, (2) latitude, which gives a rough estimation of the amount of coniferous forests in the country, and (3) the volume of versatile forest and wood product industries including component manufacturers in the country.

In general, local wood product industry (including local sawmills) feeds local consumption of wood products. In Finland, still, the situation of the sawmilling industry is different. Since 1870s, export has been important to the Finnish sawmilling industry. In the 1990s and 2000s, the local Finnish wood product industries seem to export refined products instead of crude sawnwood. Likewise, they may export the refined products rather than sell them in the domestic markets. Thus, portion of exported refined products that are based on coniferous sawnwood may have increased in Finland. This may lead distortions in comparisons like in Figure 52.

**Table 28. Top 10 global and European sawmilling companies in 2004. Source: JPC 2005. Modified by author.**

| No | Top 10 global sawmilling companies | Capacity, 1000 m$^3$ | No | Top 15 European sawmilling companies | Capacity, 1000 m$^3$ |
|---|---|---|---|---|---|
| **1** | Weyerhaeuser (US) | 11141 | **1** | Stora Enso (FI) | 7322 |
| **2** | Canfor (CAN) | 7406 | **2** | Finnforest (Metsäliitto) (FI) | 4327 |
| **3** | Stora Enso (FI) | 7322 | **3** | UPM-Kymmene (FI) | 2594 |
| **4** | West Fraser Timber (CAN) | 5745 | **4** | Setra Group (SE) | 2286 |
| **5** | International Paper (US) | 5046 | **5** | Klausner Gruppe (DE) | 2111 |
| **6** | Finnforest (Metsäliitto) (FI) | 4327 | **6** | SCA (SE) | 1595 |
| **7** | Abitibi Consolidated (CAN) | 3991 | **7** | Klenk Holz (DE) | 1556 |
| **8** | Georgia-Pacific (US) | 3545 | **8** | Södra (SE) | 1310 |
| **9** | Tolko Industries (CAN) | 2968 | **9** | Mayr-Melnhof Holz (AT) | 1193 |
| **10** | Tembec (CAN) | 2950 | **10** | Holzindustrie Pfeifer (AT) | 1081 |

Regarding CSW consumption per capita, it may be assumed that the CSW consumption could be divided into construction, industrial end-users and other consumption. The high level of CSW consumption in Finland may not necessarily come only from the construction or a change in construction but from the increase of CSW use by Finnish industrial end-users that export their products. The assumption is supported by the observation that countries that have high CSW consumption per capita (see Figure 52) also have remarkable global and European sawmilling companies (see Figure 53, Figure 54, Figure 55 and Table 28). Still, this cannot be proved in the thesis. Nevertheless, the list of top 10 global and European sawmilling companies has many changes from 2003 to 2004 (compare Figure 53, Figure 54 and Table 28). This may indicate a coming structural change in the sawmilling industry in Finland, too.

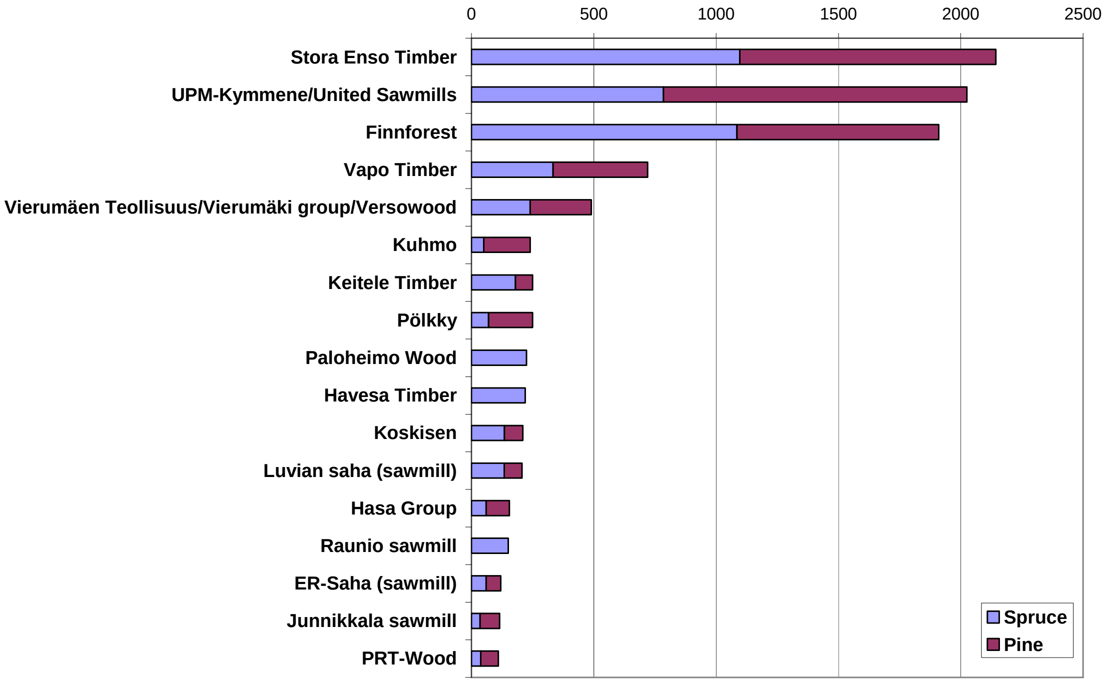


**Figure 55. Finnish Top 17 sawmilling companies from year 2001. Production in 1000 m$^3$. Source of data: Finnish Forest Industries (2002).**

## 4.3 Global CSW price development

### 4.3.1 Results

The development of a product's global market price indicates the price dynamics of a product in the supply-consumption situation. Coniferous sawnwood is a product that has several price factors influencing its market price (see the example of Figure 22). Two of these price factors are the amount of supply and a low threshold for present or new sawmilling companies to enter sawnwood markets, when compared to many other product markets.

In this section there is a brief description of the global price development of sawnwood and the relationship between global price development of sawnwood and the Finnish cost-of living-indices, year 1961 = 100, years 1961–2002 (see Figure 56). The aim is to describe the price development both as an occurred phenomenon and in relationship to the development of costs of living. The aim is not to analyse the factors behind the price development.

The price development of sawnwood can be divided into periods. In the CSW global price time series (Figure 56), there was an even period in global price development between 1961 and 1972. This even period was followed by years of price increase between 1973 and 1980. The third period started in 1981 and can perhaps be seen as a period of relatively inconsistent consumption. Coniferous sawnwood export price was 167 $/m$^3$ in 2002, which was fairly close to the price level of 1980. The global CSW price trends decreased between 1997 and 2002 (Figure 56).

Results may emphasise the nature of CSW as a volume product. On the other hand, the price development observed puts an emphasis on the nature of sawnwood as a product surrounded by price competition. Nevertheless, the development of export and import prices of CSW on global markets is compared to the consumer prices in Finland. It can be observed that the CSW prices have the following index values in 2002: 37 (import) and 40 (export), the year 1961 = 100 (see Figure 56). This observation suggests that the rise in consumer prices has mostly influenced other products, not CSW. Another interesting observation is that the price of CSW in relation to cost-of-living indices started to decrease in 1999, after a long steady period. In practice, the fall in the product price in relation to consumer prices means that the sawmills will need to decrease their costs.

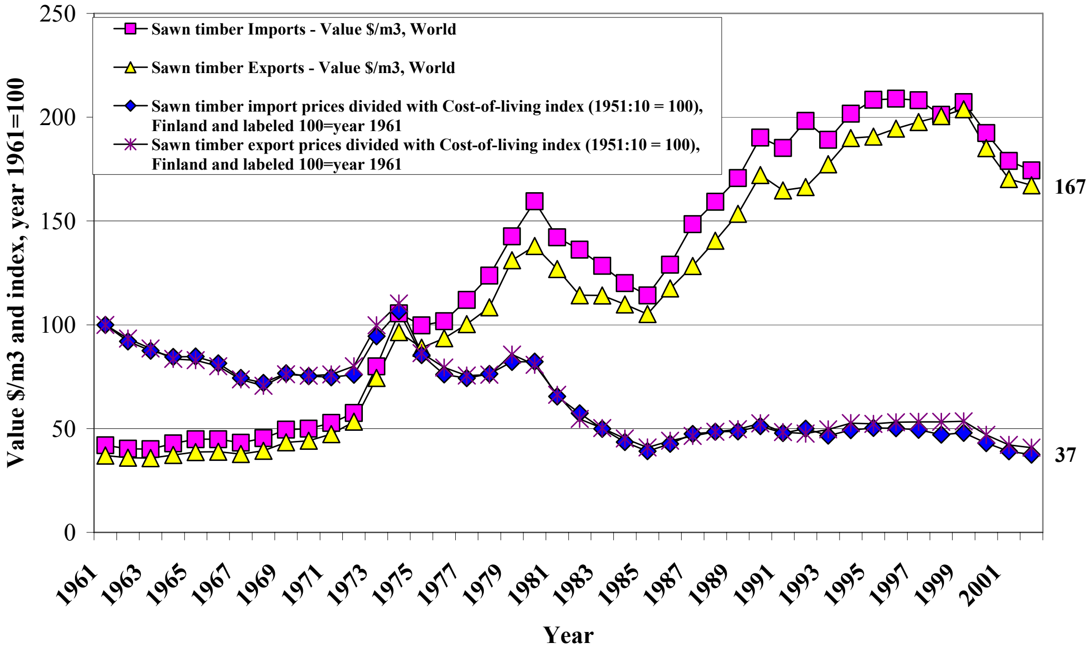


**Figure 56. The relative prices of CSW and price development divided by the Finnish cost-of-living indices in 1961–2002 (FAOSTAT data 2004; STAT 2004). Year 1961 = 100, years 1961–2002.**

### 4.3.2 Discussion

The relative fall of sawnwood market prices forces the sawmilling industry to search for ways to decrease costs per unit. The price development of products has given occasion to, for example, larger production units, cost-saving technology and company mergers.

It is not possible to draw conclusions on future price levels on the basis of the price development of sawnwood. Thus, one cannot say that the future price level of sawnwood on the global markets will be higher than in the beginning of the 2000s. Similarly, one cannot predict a fall in the price level on the basis of the results presented.

Kozak and Spelter (2003) state that globalisation is rapidly changing the production, consumption and trade dynamics of sawnwood, as new producers emerge and scale up production, leading to a world oversupply. Two regions of the world have continued to have the potential to significantly influence the global market dynamics of sawnwood in early 2000s: Russia (on the supply side with exports) and China (on the demand side with imports). According to Mäki et al. (2003), China's own forest resources are inadequate for the growing demand for wood products. Wood is, on the other hand, not a common construction material for houses in China. Thus it is not easy to increase the consumption of wood products rapidly in structural construction. Hence, it seems more likely that the export possibilities of interior wood products, especially of higher quality products, will grow the fastest (Mäki et al. 2003). From the Scandinavian perspective, the growth of CSW production in East Europe and Russia may lead to the prices either staying at the current level or falling, because the costs of raw material and production are lower than, for example, in Scandinavia.

The conclusion that the prices will remain at the current level or fall is supported by the results on sawnwood consumption presented earlier. The consumption has stabilised at the saturation point, close to 300 million $m^3$ per year. From the point of view of the Finnish sawmilling industry, it also seems probable that the prices of CSW may only rise temporarily. For example, Tilli et al. (2001) have noted that the export price of CSW from Finland and other exporting countries to Germany has not risen between 1980 and 1997, apart from temporary exceptions. However, it has generally decreased slightly. These results support the idea that sawnwood is a product at the mature stage (see Figure 47), with both internal competition and competition from other products (for example other construction materials) on the markets.

## *4.4 Geographical location as a coniferous sawnwood consumption factor*

### 4.4.1 Aim and results

The aim was to see what effect the geographical location, with an indicator of country's latitude class, has on CSW consumption in the selected countries. The point of interest in this part of the study was to find out whether the country's geographical location explains the differences between countries that were previously observed when comparing the per capita consumption of sawnwood. The proposition to be tested in this section was the following: A country's geographical area can be assessed as a factor for coniferous sawnwood consumption in Europe in 1999.

For research data, 46 countries were selected, and two variables were collected for each country from the year 1999: (1) the class of CSW consumption per capita (PC CLASS) and (2) the class of the latitude of the country's capital (NORTHERN LATITUDE CLASS). The PC CLASS variable was divided into four classes. The intervals of classes were chosen to be not equal, as the purpose was to have at least eight countries in each class. The largest class of PC CLASS variable had 15 countries and the smallest class (1–0.3) had eight countries. The NORTHERN LATITUDE CLASS variable was divided into three classes, of which the two South classes (55–45, 45–35) are equal and the third, Northernmost class (OVER 55) has no limit in the North. Thus the data were formed into a 4x3 matrix, which was entered into the correspondence analysis (CAS) section of the NCSS® (2000) program so that the rows correspond to PC CLASS variables and columns to NORTHERN LATITUDE CLASS variables.

The test hypothesis was that Northern countries with large coniferous forests use more CSW when CSW consumption is measured with consumption per capita. The correspondence analysis (CAS) was selected as the method for the analysis because (1) it could display a two-way table graphically by calculating coordinates representing its rows and columns, and (2) data were not continuous but in two sets of classes. The CAS coordinates are analogous to factors in a principal components analysis except that they partition the Chi-square value used in testing independence instead of the total variance (NCSS® 2000).

**Table 29. CSW consumption classes per capita (PC) based on the Northern latitude class of the country. N = 46 countries. Results of correspondence analysis (CAS). Data: FAOSTAT data (2004).**

| DATA SET | | NORTHERN LATITUDE CLASS | | | | |
|---|---|---|---|---|---|---|
| | PC CLASS | OVER 55 | 55–45 | 45–35 | UNDER 35 | TOTAL |
| | **1–0.3** | 6 | 1 | 1 | 0 | 8 |
| | **0.299–0.15** | 3 | 8 | 1 | 0 | 12 |
| | **0.1499–0.05** | 1 | 5 | 5 | 0 | 11 |
| | **0.0499–0** | 0 | 3 | 6 | 6 | 15 |
| | **TOTAL** | 10 | 17 | 13 | 6 | 46 |
| **RESULTS** | **Eigenvalue Section** | | | | | |
| | **Factor No. 1)** | **Eigenvalue 2)** | **Individual, %** | **Cumulative, %** | **Bar Chart** | |
| | **1** | 0.517784 | 64.75 | 64.75 | \|IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII | |
| | **2** | 0.219764 | 27.48 | 92.24 | \|IIIIIIIIIIIIII | |
| | **3** | 0.062071 | 7.76 | 100 | \|IIII | |
| | **TOTAL** | 0.799619 | | | | |

1. The number of the factor (coordinate or dimension) that is reported about on this row. Source: NCSS® 2000.
2. The eigenvalue associated with this dimension. It gives a relative size (importance) of this dimension. Source: NCSS® 2000.

On the basis of the data, CAS forms three factors whose sum is 100%. The first one explains 65% of the data and the second 27%. The differences between the factors are big, which suggests that there are considerable variances between the factor classes (Table 29).

A particularly interesting aspect of the results is that the correspondence plot (Figure 57) does not include the largest class, 1–0.3, at all. The lowest consumption class (0.0499–0) is clearly different from the rest of the data. The other two classes (0.2499–0.05 and 0.299–0.15) are fairly close to each other on the Factor 2 axis. This indicates that the lowest class is notably different from the other two classes, whereas the difference between the other two is mainly found on the Factor 1 axis. In Figure 57, what is important are the distances of the points (consumption classes PC), which are informative in that row points that are close to each other are similar with regard to the pattern of relative frequencies across the columns in Table 29.

On the basis of the results (Table 29 and Figure 57) it seems clear that the geographical location of a country explains the differences that have been observed earlier in the countries' consumption per capita statistics. In other words, the analysis justifies the statement that, from a statistical perspective, the Northern location of a country has a positive effect on the use of sawnwood in the country, if the use is measured on the basis of CSW consumption per capita.

However, there are also exceptions to this positive correlation between Northern location and intensive sawnwood use as can be seen in Figure 52. These exceptions include countries like Russia (low per capita use of sawnwood) and Japan (moderate per capita use of sawnwood). For more information see Appendix 2.

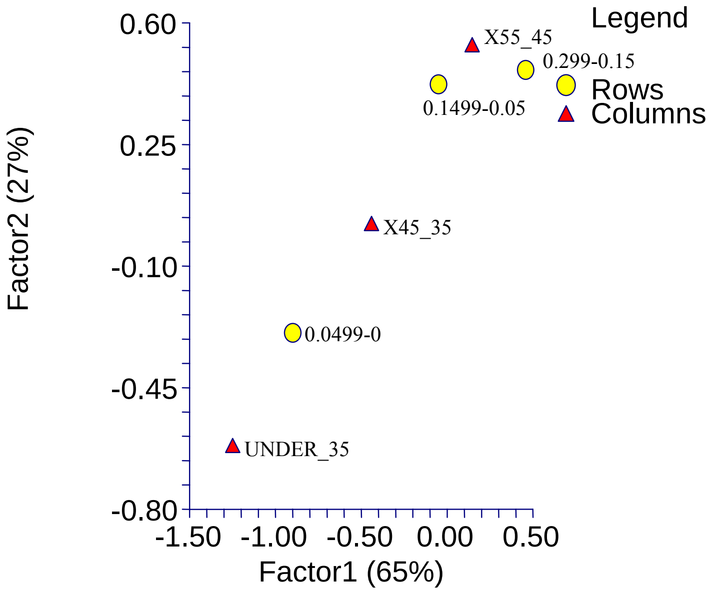


**Figure 57. Correspondence plot of CSW consumption classes per capita (PC) based on the Northern latitude class of the country. Results of two factors of correspondence analysis.**

### 4.4.2 Discussion

As a result, it is likely that a country's geographical location – here, latitude – has a significant meaning for CSW consumption. Northern countries use more CSW. Nevertheless, the analysis leaves out the highest per capita class because of that class' concentration to Northern latitude class. This underlines the meaning of local wood raw material for the large CSW consumption.

What does such an evident result mean for promoting the use of sawnwood? It can be seen as a fact that the country's tradition of sawnwood use is linked with local raw materials. Use of local materials often creates competitiveness for the local construction and industry (e.g. Tiittanen 1986 and Relander 1986). Construction has always been the main use of sawnwood. Between local traditions in countries, there are large differences in both construction methods and industrial structure. Therefore sawnwood use between countries will likely remain different.

Measured per capita of population, the consumption of CSW has traditionally been high in the Nordic countries and in North America (Key to Finnish Forest Industries 2000). In the countries of the borealic coniferous wood zone and in the mountain regions like Alps area in Central Europe, where large amounts of CSW have been available in the local forests, CSW is also used much. Contrastingly, in countries where little CSW has been available, such as South Europe and Northern Africa, it is little used when measured per capita.

Where is it worthwhile to direct the major campaigns promoting sawnwood, if the campaign results are measured with per capita consumption? Perhaps the primary target areas should be evaluated with two criteria: (1) tradition, (2) growth of construction and economy. Tradition often brings volume whereas growth gives opportunities for change.

The regions where the traditions for sawnwood use already exist are likely more willing to use more sawnwood. These are areas like the Northern parts of Europe, Alps and other mountain region areas. This often requires that users have already got good results with sawnwood. Specifically, when sawnwood is recommended to be used with a new target it should always give a measurable added value to the users.

A significant growth of construction and economy often opens opportunities for sawnwood and other material to be used in larger volumes. Local construction and industrial processes may be more willing to try Nordic sawnwood instead of previous material when there is a significant growth in economy. When trying a new product, users always require more added value, e.g. better quality or/and cost savings. To increase sawnwood use, this added value must be clearly proved to the users by e.g. research results, user tests and business analyses.

One critical view on the significance of latitude for sawnwood use can be found by viewing the issue from the perspective of regional use of sawnwood. Considering Japan and Northern Italy, they can be observed to have a long tradition of wood and CSW use. In these regions, coniferous timber has been available as raw material for centuries and it has also been used. On the other hand, both of these regions are in the South.

## *4.5 Coniferous sawnwood consumption periods in Finland*

### 4.5.1 Aim and results

Coniferous sawnwood consumption in Finland has traditionally had its ups and downs. Sawmilling people may say that during the last 30 years there have been more poor years than good ones. The purpose of this section of the thesis is to find out whether there is anything in the time period to indicate a structural change in sawnwood consumption. The reasons behind consumption are reviewed separately in the discussion section instead of the analysis.

The proposition to be tested in this section was the following: Changes in sawnwood consumption can be found in Finland during the time periods between 1961 and 2002. It is possible that the CSW consumption in Finland in 1961–1996 was significantly different from the CSW consumption in the years 1997–2002 and 1961–2002.

The research data chosen were the consumption of CSW in Finland in the time period 1961–2002 (Figure 58). The data were divided into three, partially overlapping time periods: 1) 1961–2002, 2) 1961–1996, 3) 1997–2002. The year 1996 is assumed to be a year of turning point, because after it, during the years from 1997 to 2002, the consumption of CSW has significantly increased onto a new level (Figure 58).

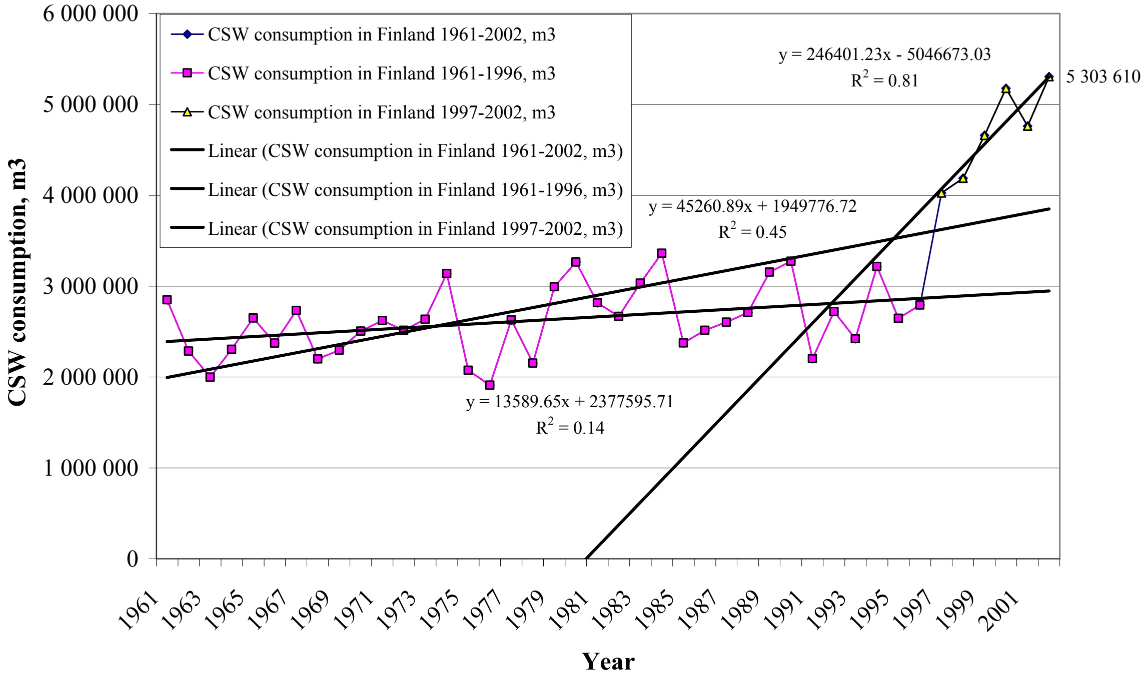


**Figure 58. CSW consumption in Finland 1961–2002. Data source: FAOSTAT data (2004).**

The method chosen was linear regression analysis. The measure indicating a structural change in the consumption of sawnwood was selected to be the coefficient of the time series. Thus, an indication of a structural change is proven if the coefficient of linear regression for time period does not fit to (1) the time period or (2) the confidence limits of the coefficient. Similarly, an indication of structural change is proven if the coefficient of linear regression for time period 2) does not fit the confidence limits of the coefficient of time period.

Table 30 shows that the coefficient of the time period 1961–2002 does not fit the confidence limits of the time period 1961–1996. At the same time, it can be observed that the coefficient of 1961–1996 does not fit the confidence limits of 1961–2002.

**Table 30. Confidence limits (Lower 95% and Upper 95%) of linear regression coefficient B.**

| Periods | B | Lower 95% | Upper 95% | *p*-value for B |
|---|---|---|---|---|
| **1961–2002** | 45260.89 | 29257.77 | 61264 | 1.18E–06 |
| **1961–1996** | 13589.65 | 1966.29 | 25213 | 0.023277 |
| **1997–2002** | 246401.23 | 80450.41 | 412352 | 0.014584 |

The tested proposition was proved with linear regression analysis. Thus there were sawnwood consumption changes that could be found in Finland between 1961 and 2002. The CSW consumption in the periods of 1961–1996 and 1997–2002 in Finland was significantly different from the CSW consumption in the years 1961–2002 and as shown in Table 30. On the basis of this result, there is a proven indication of a structural change in consumption, because the consumption of CSW in Finland has changed significantly from the time period of 1961–1996 to the period of 1997–2002. Otherwise, the result does not explain the reasons for the structural change.

Despite the fact that the tested proposition was proved with linear regression analysis there was a need to test the statistical significance with t-test. There were a few observations of the period of 1997–2002 which may impact on results. Therefore statistical testing of sawnwood consumption changes in Finland between the time periods of 1961–1996 and 1997–2002 was made as shown in Table 31. The tested proposition was proved with t-tests, too. Thus there were sawnwood consumption changes that could be found in Finland between the time periods of 1961–1996 and 1997–2002.

**Table 31. Statistical testing of sawnwood consumption changes in Finland between the time periods of 1961–1996 and 1997–2002.**

| F-Test Two-Sample for Variances | | | t-Test: Two-Sample Assuming Equal Variances | | |
|---|---|---|---|---|---|
| **Indicator** | **CSW consumption in Finland 1961–1996, m3** | **CSW consumption in Finland 1997–2002, m3** | **Indicator** | **CSW consumption in Finland 1961–1996, m3** | **CSW consumption in Finland 1997–2002, m3** |
| **Mean** | 2629004.167 | 4686175.5 | **Mean** | 2629004.167 | 4686175.5 |
| **Variance** | 1.440E+11 | 2.625E+11 | **Variance** | 1.440E+11 | 2.625E+11 |
| **Observations** | 36 | 6 | **Observations** | 36 | 6 |
| **df** | 35 | 5 | **df** | 40 | |
| **F** | 0.548 | | **t Stat** | –11.708 | |
| ***p* (F≤f) one-tail** | 0.134 | | ***p* (T≥t) one-tail** | 8.468E–15 | |
| **F Critical one-tail** | 0.402 | | **t Critical one-tail** | 1.689 | |
| | | | ***p* (T≤t) two-tail** | 1.694E–14 | |
| | | | **t Critical two-tail** | 2.021 | |

## 4.5.2 Discussion

The results show that a change in sawnwood consumption in Finland between periods of 1961–1996, 1961–2002 and 1997–2002 can be observed. The change can be assumed to be structural. Even so, this cannot be stated with certainty, because these results do not explain the factors behind the change in consumption and their effect on sawnwood consumption. Nevertheless, it can be observed that during the years 1997–2002, the consumption for CSW has stayed at a level noticeably higher than previously. Another point of interest is that the R2 statistics. This statistical indicator for the time periods of 1961–2002 (R2 = 0.45) and 1997–2002 (R2 = 0.81) is significantly higher than that of time period 1961–1996 (R2 = 0.14).

What does the result of the structural change of CSW consumption mean for promoting the sales of sawnwood? Regarding the CSW consumption in Finland, it is possible that the structural change of CSW consumption is a result of successful promotion of sawnwood. The promotion may have lead to a change of attitudes towards CSW use in construction and other CSW uses. Nevertheless, the structural change of CSW consumption in Finland may not only come from the successful sales promotion in construction.

A factor in the structural change of CSW consumption that cannot be excluded is the way the Finnish industrial end-users of CSW have expanded their production and started to export their products. It is likely that there has been a change of strategy in the Finnish sawmilling industry. Consequently, refining of sawnwood has increased significantly in Finland between 1996 and 2002. Still, this cannot be proved. Moreover, it needs to be taken into account that the change of CSW consumption is also a result of other demand sources. For further research, this raises the question of what exactly would explain the observed structural change in sawnwood consumption in Finland.

# 5 CONIFEROUS SAWNWOOD (CSW) SUPPLY AND PRODUCTION

All data leading to the results of this chapter are based on the Wood Product Database (WPDB).

## 5.1 *Dimension approach*

### 5.1.1 Number of CSW dimensions produced in Finland

The aim of this part of the thesis is to answer to the following questions: (1) What is the number of CSW dimensions produced in Finland? (2) What is the difference between species (in $m^3$) when compared by the number of dimensions? Furthermore, there was a need to see the average volume ($m^3$) of one dimension.

The number of CSW dimensions produced in Finland was 890 in the sample within the period of time 1995 and 2000. The number of shared dimensions, i.e. dimensions for both pine and spruce, was 216 (Table 32).

**Table 32. Number of CSW dimensions produced in Finland between 1995 and 2000.**

| **Indicator** | **Spruce** | **Pine** | **All** | **Shared** |
|---|---|---|---|---|
| **Number of dimensions** | 615 | 491 | 890 | 216 |
| **Sample, $m^3$** | 9,350,194 | 9,872,083 | 19,222,277 | |
| **Average, $m^3$** | 15,204 | 20,106 | 21,598 | |
| **Average,% of sample ($m^3/m^3$)** | 0.16% | 0.20% | 0.11% | |

### 5.1.2 The most common sawnwood dimensions in Finland

The aim of this part of the thesis is to find the most common sawnwood dimensions in Finland. The aim is linked to the broader scope of determining the overall picture of sawnwood supply and demand. The aim was restricted to twenty sawnwood dimensions, with studs and boards analysed together.

It is possible to see a strong standardised volume product character for sawnwood in the dimension distribution for 20 the most common CSW dimensions produced in Finland (Table 33). According to Table 33, the sawmilling industry in Finland has focused on producing few dimensions in large numbers to meet the demand on global market.

Regarding pine, Finland is a production country of three studs and two boards (studs – 50 x 100, 50 x 150 and 50 x 125 mm; boards – 25 x 100 and 19 x 100 mm). Every dimension covers at least 5% of the whole pine CSW production in Finland (Table 33).

As for spruce, the leading dimension is 22 x 100 mm, whose production volume accounts for over 12% of the total volume of spruce CSW production in Finland. For spruce CSW studs, the most important dimensions are 50 x 125 and 44 x 100 mm. There is a large difference between dimension distributions of pine and spruce. Spruce dimension fractions decrease fast (Table 33).

It is interesting in the results that both wood species had similar form but the form is not simultaneous (see Table 33 and Figure 59). The 20 most common CSW dimensions produced in Finland covered 79.2% of pine dimensions and 61.3% of spruce dimensions. Thus the supply of pine seems to be clearly more clustered than the supply of spruce. On the other hand, the most common dimension for spruce, 22 x 100, is typical only for spruce. Furthermore, the spruce dimension 22 x 100 had more volume (12.2% of all spruce volume) than any pine dimension (Table 33).

**Table 33. The most common CSW dimension produced in Finland ($m^3/m^3$) in 1995–2000.**

| Order | Pine | | | Spruce | | |
|---|---|---|---|---|---|---|
| | mm | Share | Cumulative | mm | Share | Cumulative |
| 1 | 50 x 100 | 9.10% | 9.10% | 22 x 100 | 12.20% | 12.20% |
| 2 | 25 x 100 | 9.10% | 18.20% | 50 x 125 | 5.40% | 17.60% |
| 3 | 19 x 100 | 8.90% | 27.10% | 44 x 100 | 5.00% | 22.60% |
| 4 | 50 x 150 | 8.10% | 35.20% | 63 x 150 | 4.20% | 26.80% |
| 5 | 50 x 125 | 7.30% | 42.50% | 50 x 150 | 3.70% | 30.50% |
| 6 | 38 x 150 | 4.70% | 47.20% | 22 x 125 | 3.30% | 33.80% |
| 7 | 75 x 150 | 3.60% | 50.80% | 50 x 100 | 3.30% | 37.10% |
| 8 | 50 x 200 | 3.20% | 54.00% | 25 x 100 | 2.90% | 40.00% |
| 9 | 25 x 125 | 3.00% | 57.00% | 22 x 150 | 2.60% | 42.60% |
| 10 | 25 x 150 | 2.90% | 59.90% | 32 x 150 | 2.50% | 45.10% |
| 11 | 50 x 225 | 2.80% | 62.70% | 63 x 200 | 2.20% | 47.30% |
| 12 | 63 x 150 | 2.50% | 65.20% | 44 x 125 | 2.20% | 49.50% |
| 13 | 63 x 200 | 2.40% | 67.60% | 44 x 150 | 2.10% | 51.60% |
| 14 | 75 x 200 | 2.00% | 69.60% | 32 x 200 | 1.90% | 53.50% |
| 15 | 75 x 225 | 1.90% | 71.50% | 50 x 200 | 1.60% | 55.10% |
| 16 | 38 x 100 | 1.70% | 73.20% | 19 x 100 | 1.30% | 56.40% |
| 17 | 25 x 175 | 1.60% | 74.80% | 75 x 225 | 1.30% | 57.70% |
| 18 | 50 x 175 | 1.50% | 76.30% | 75 x 200 | 1.20% | 58.90% |
| 19 | 19 x 125 | 1.50% | 77.80% | 47 x 200 | 1.20% | 60.10% |
| 20 | 63 x 175 | 1.40% | 79.20% | 38 x 150 | 1.20% | 61.30% |
| Sample size, $m^3$ | | 9,872,083 | | | 9,350,194 | |

### 5.1.3 CSW dimensions and the Pareto principle assumption

The proposition to be tested in this section was the following: In 2000, sawnwood trade was concentrated on main dimensions in Finland. Simultaneously, the number of dimensions was large. The Pareto principle assumption and its 20–80 rule applied to sawnwood dimensions.

The results of the distribution of the most common coniferous sawnwood dimensions (Section 5.1.2) raise a question. Could the Pareto principle assumption be used more widely than just for pine and spruce dimensions and their volume distribution in 1995-2000 (Table 33)? The Pareto principle assumption has been explained in Section 3.6.3. Two goals for this part of the thesis were set: (1) does the Pareto principle assumption work for both volume ($m^3$) and value (€) distributions for pine and spruce, (2) can it be said that there is a statistically significant difference between volume and value distributions of both pine and spruce. The research was restricted to (1) the year 2000, (2) those transactions in the year 2000 that had accurate price and volume information in the database (Table 34). The Kolmogorov–Smirnov method could be applied for comparisons because distributions were continuous.

**Table 34. Sample information of value and amount dimension comparison.**

| Sample information | Spruce | Pine |
|---|---|---|
| Number of dimensions | 202 | 150 |
| Total value, M€ | 135.195 | 167.292 |
| Amount, $m^3$ | 887,067 | 990,673 |
| Price average, €/$m^3$ | 152 | 169 |

For pine, 20% of the number of dimensions results in 91% of volume and 90% of value. For spruce, 20% of the dimensions cause 82% of volume and 83% of value (Figure 59). The Pareto principle assumption seems to apply to CSW dimension distribution on both amount ($m^3$) and value (€) basis.

The sawnwood supply consists mainly of a limited number standard products. The results (Figure 59) suggest that pine CSW has a standard product character. This means, in this case, that there is a relatively small amount of dimensions that produce a large portion of volume. However, this raises the question why there is a need to produce such a large number of other dimensions in small amounts.

According to the results, pine is more strongly distributed into few volume dimensions than spruce. The Pareto principle assumption still applies to both species.

The comparison of the statistical significance of distributions was started by constructing four distribution pairs and then comparing their differences through statistical methods. The distribution pairs were pine-spruce value, pine-spruce quantity, pine value-quantity and spruce value-quantity.

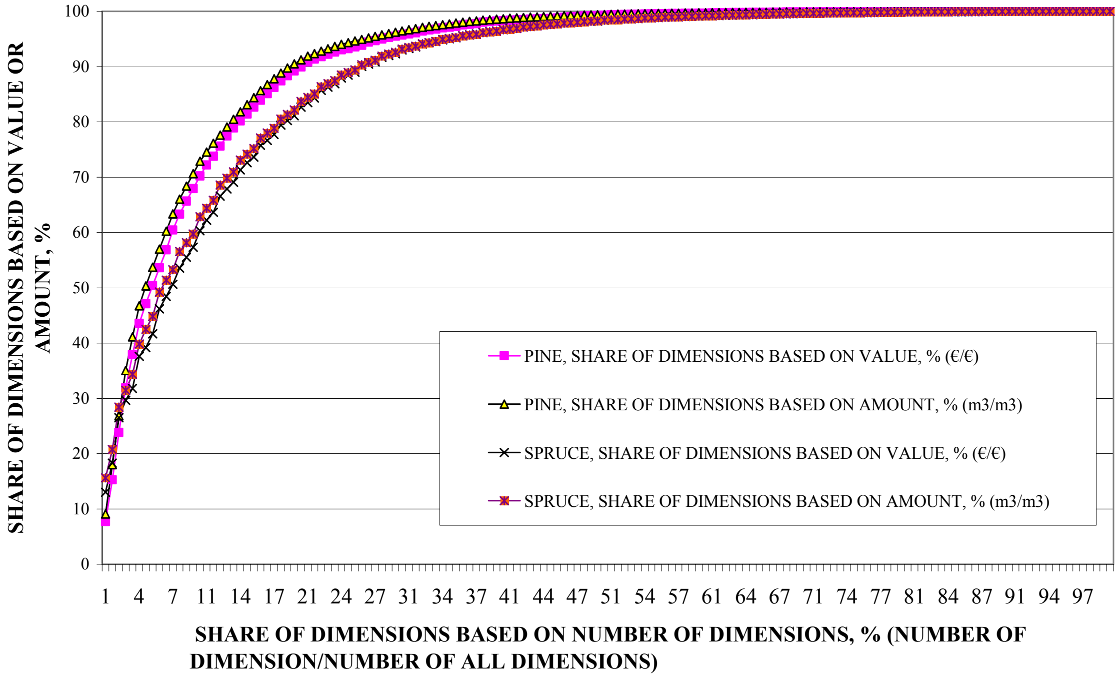


**Figure 59. The cumulative dimension distribution of pine and spruce.**

The differences between distributions are not statistically significant except in the pine and spruce comparison of amounts (Table 35). Otherwise, it has to be noted that also the value distribution comparison for pine and spruce is close to the limit for statistical significance 0.05 (Probability Level 0.0507). On the other hand, there is no noticeable statistically significant difference between the value-quantity distributions of the same species.

**Table 35. Kolmogorov–Smirnov test for dimension distributions comparisons. All distributions consist of per cent values.**

| Distribution comparison | Alternative hypothesis | Alternative criterion value | Reject Ho if greater than | Test alpha level | Decision (Test alpha) | Probability level | Signficantly different |
|---|---|---|---|---|---|---|---|
| Pine-spruce value | D(1)<>D(2) | 0.143564 | 0.1466 | 0.05 | Accept Ho | 0.0507 | |
| | D(1)<D(2) | 0.143564 | 0.1466 | 0.025 | Accept Ho | | |
| | D(1)>D(2) | 0.003432 | 0.1466 | 0.025 | Accept Ho | | |
| Pine-spruce amount | D(1)<>D(2) | 0.16033 | 0.1466 | 0.05 | Reject Ho | 0.0207 | x |
| | D(1)<D(2) | 0.16033 | 0.1466 | 0.025 | Reject Ho | | x |
| | D(1)>D(2) | 0.006667 | 0.1466 | 0.025 | Accept Ho | | |
| Spruce amound and value | D(1)<>D(2) | 0.024752 | 0.1353 | 0.05 | Accept Ho | 1 | |
| | D(1)<D(2) | 0.009901 | 0.1353 | 0.025 | Accept Ho | | |
| | D(1)>D(2) | 0.024752 | 0.1353 | 0.025 | Accept Ho | | |
| Pine amound and value | D(1)<>D(2) | 0.046667 | 0.157 | 0.05 | Accept Ho | 0.9969 | |
| | D(1)<D(2) | 0.046667 | 0.157 | 0.025 | Accept Ho | | |
| | D(1)>D(2) | 0.02 | 0.157 | 0.025 | Accept Ho | | |

### 5.1.4 Difference between volume and value based dimension distributions

CSW dimension distribution can be approached on amount or value basis. The aim of this part of the thesis is to answer to the following questions: (1) is it possible to find differences between volume and value based dimension distributions of coniferous sawnwood? If it is possible, (2) how big is the difference?

There are several restrictions in this part of the thesis. In this context, quantity means the volume of the transactions ($m^3$) and not the number of the transactions. This part of the research was restricted to (1) the year 2000, (2) those transactions in the year 2000 that have accurate price and volume information in the WPDB database (Table 34). The research procedure was arranging the data by volume ($m^3$) and then comparing if the value of sales (€) follows the volume of sales ($m^3$).

The difference between volume ($m^3$) and value (€) based dimension distributions was not more than 4%. The sample here, as in Table 35, covered only those CSW sales that have both value and amount information Figure 60).

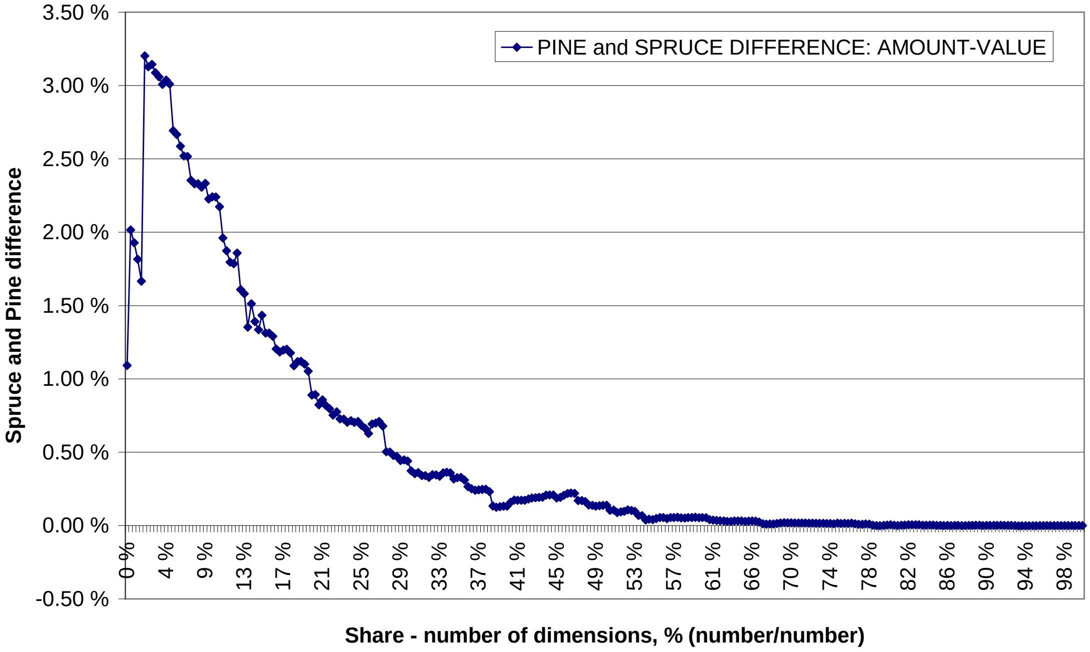


**Figure 60. The cumulative dimension distribution difference between amount and value for pine and spruce.**

These results indicate that some 20% of CSW dimensions stand out with an amount-value difference higher than 1% (Figure 60). The observed difference between volume and value based dimension distributions can be seen as a small difference. The result emphasises the observation that coniferous sawnwood had a standard product character in 2000.

### 5.1.5 Development of dimension size distribution between 1995 and 2000

The aim of this part of the thesis is to answer to the following questions: (1) What was the wood species specific dimension distribution between 1995–2000? (2) Was the change statistically significant in 1995–2000? Significance of difference in the shares of thicknesses in 1995–2000 is measured by using linear regression so that the limit for significant change is $p = 0.05$.

On the other hand, the development of dimension size distribution between 1995 and 2000 can give an answer to the following question: Has increased CSW refining in the Finnish sawmilling industry between 1995 and 2000 caused a change in thickness distribution?

Pine CSW thicknesses had significant production changes between 1995 and 2000 (Table 36). The significant growth trend in pine CSW thickness shares were thicknesses 10–19 mm, 40–49 mm, 90–99 mm and 100– mm. However, significant decline can be found in thicknesses 50–59 mm and 60–69 mm. Thus there can be seen two opposite trends, (1) towards smaller dimensions and (2) towards large thicknesses (≥ 90 mm).

**Table 36. Pine CSW thickness development in Finland 1995–2000.**

| **PINE CSW** | **YEAR** | | | | | | | **LINREG** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **THICKNESS (T), MM** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **Grand Total** | **R-squared** | **Year *p*-value** | **Significant change** |
| **T10–19** | 9.25% | 10.21% | 11.17% | 12.06% | 12.88% | 12.55% | 11.81% | 0.919 | 0.003 | Yes |
| **T20–29** | 19.58% | 17.99% | 18.83% | 18.55% | 18.64% | 18.27% | 18.56% | 0.229 | 0.337 | No |
| **T30–39** | 14.06% | 14.81% | 13.62% | 13.86% | 13.47% | 14.64% | 14.03% | 0.007 | 0.871 | No |
| **T40–49** | 0.72% | 0.82% | 0.78% | 1.43% | 1.48% | 1.34% | 1.20% | 0.738 | 0.028 | Yes |
| **T50–59** | 36.99% | 36.15% | 35.71% | 35.01% | 33.99% | 32.91% | 34.67% | 0.981 | 0.000 | Yes |
| **T60–69** | 10.51% | 9.55% | 9.16% | 8.82% | 8.79% | 8.95% | 9.10% | 0.718 | 0.033 | Yes |
| **T70–79** | 8.73% | 9.97% | 9.61% | 9.29% | 9.51% | 9.95% | 9.57% | 0.258 | 0.304 | No |
| **T80–89** | 0.01% | 0.05% | 0.06% | 0.05% | 0.02% | 0.04% | 0.04% | 0.019 | 0.795 | No |
| **T90–99** | 0.00% | 0.00% | 0.07% | 0.06% | 0.07% | 0.09% | 0.06% | 0.807 | 0.015 | Yes |
| **T100–** | 0.15% | 0.44% | 0.99% | 0.88% | 1.15% | 1.28% | 0.95% | 0.888 | 0.005 | Yes |
| **TOTAL** | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | | | |
| **SAMPLE, m$^3$** | 760,714 | 1,040,388 | 1,408,887 | 2,096,996 | 2,174,732 | 2,255,805 | 9,737,520 | | | |

From the volume (m$^3$) perspective, pine CSW thickness distribution results show that in thickness class T10–19, there was a significant volume, 13% in 2000. The most significant pine thickness class is T50–59, 33% in 2000. The following pine thickness classes had volumes (m$^3$) less than 2%: T40–49 and all thickness classes of 80 mm or more (see Table 36).

Spruce CSW thicknesses remained quite stable within the period of 1995 to 2000. There were no spruce thickness classes with a significant change in the 1995–2000 period (see Table 37). The share of thicknesses of class T70–79 decreased one per cent (Table 37).

**Table 37. Spruce CSW thickness development in Finland 1995–2000.**

| **SPRUCE CSW** | **YEAR** | | | | | | | **LINREG** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **THICKNESS (T), MM** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **Grand Total** | **R-squared** | **Year *p*-value** | **Significant change** |
| **T10–19** | 1.55% | 1.32% | 1.85% | 1.52% | 1.30% | 1.91% | 1.58% | 0.086 | 0.574 | No |
| **T20–29** | 25.48% | 26.22% | 27.59% | 26.74% | 26.35% | 28.30% | 26.89% | 0.515 | 0.108 | No |
| **T30–39** | 18.04% | 16.23% | 14.46% | 17.67% | 18.21% | 17.02% | 17.09% | 0.023 | 0.772 | No |
| **T40–49** | 21.33% | 21.57% | 22.82% | 18.73% | 20.57% | 19.82% | 20.53% | 0.299 | 0.262 | No |
| **T50–59** | 17.27% | 17.64% | 17.86% | 17.60% | 17.92% | 17.11% | 17.58% | 0.001 | 0.945 | No |
| **T60–69** | 10.08% | 9.88% | 9.89% | 11.32% | 10.47% | 10.83% | 10.54% | 0.414 | 0.168 | No |
| **T70–79** | 5.56% | 6.47% | 4.96% | 5.86% | 4.46% | 4.45% | 5.18% | 0.495 | 0.119 | No |
| **T80–89** | 0.06% | 0.00% | 0.00% | 0.01% | 0.05% | 0.00% | 0.02% | 0.074 | 0.603 | No |
| **T90–99** | 0.08% | 0.02% | 0.00% | 0.00% | 0.00% | 0.01% | 0.01% | 0.492 | 0.121 | No |
| **T100–** | 0.56% | 0.65% | 0.57% | 0.54% | 0.67% | 0.55% | 0.59% | 0.0004 | 0.971 | No |
| **TOTAL** | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | | | |
| **SAMPLE, m$^3$** | 1,023,669 | 992,421 | 1,288,083 | 1,988,123 | 2,016,273 | 1,833,337 | 9,141,905 | | | |

Based on thickness analysis, sawnwood product assortment looked stable for spruce, but for pine, there were significant trends towards smaller and large dimensions.

From the volume (m$^3$) perspective, spruce CSW thickness distribution results show that in the volume of the thickness class T40–49 was significant, 20% in 2000, contrary to the results of pine thickness distribution. The most significant spruce thickness class was T20–29, 28% in 2000. The following spruce thickness classes had volumes (m$^3$) less than 2%: T10–19 and all thickness classes of 80 mm or more (Table 37).

### 5.1.6 Dimension by volumes in selected ten countries

The proposition to be tested in this section was the following: For sawnwood delivered from Finland, dimensions had big differences specific to country and species of sawnwood between 1995 and 2000. The dimensions of pine and spruce differed by country.

The aim of this part of the thesis is to answer to the following questions: (1) How dimension distribution has clustered country-specifically? (2) Which export countries for the Finnish CSW are pine or spruce countries from the perspective of supply from Finnish sawmills?

The sample of ten countries gives a picture of CSW exports from Finland (Table 38). Based on Table 38, the major pine export countries are Norway, Denmark, UK, Austria and Italy. However, CSW export to Austria and Norway from Finland is relatively small. Sweden is also a country of larger pine exports than spruce exports.

The major spruce CSW export countries from Finland are Germany, France and the Netherlands. Finland itself uses relatively large amounts of both pine and spruce.

**Table 38. The three largest volumes of Finnish CSW dimensions by country. The shares of export volume apply to all the three dimensions. N = 10 countries.**

| **Country** | **Three pine dimensions, mm** | **Share of export volume, %** | **Sample size, $m^3$** | **Three spruce dimensions, mm** | **Share of export volume, %** | **Sample size, $m^3$** |
|---|---|---|---|---|---|---|
| **Finland** | 50 x 100, 19 x 100, 50 x 125 | 49% | 1,481,978 | 22 x 100, 25 x 100, 50 x 100 | 37% | 1,515,593 |
| **Sweden** | 50 x 125, 25 x 100, 50 x 100 | 80% | 90,167 | 25 x 100, 50 x 150, 50 x 125 | 94% | 54,864 |
| **Norway** | 19 x 100, 25 x 100, 50 x 150 | 43% | 27,062 | 75 x 100, 16 x 125, 25 x 125 | 69% | 720 |
| **Denmark** | 19 x 100, 50 x 125, 50 x 100 | 54% | 933,717 | 22 x 100, 19 x 125, 22 x 125 | 52% | 14,508 |
| **Germany** | 25 x 100, 50 x 125, 50 x 150 | 31% | 117,526 | 50 x 125, 44 x 100, 63 x 150 | 56% | 1,283,946 |
| **UK** | 50 x 150, 50 x 100, 50 x 125 | 31% | 1,728,541 | 22 x 100, 36 x 75, 22 x 125 | 31% | 542,920 |
| **France** | 50 x 150, 50 x 200, 38 x 150 | 28% | 119,292 | 63 x 150, 50 x 150, 32 x 200 | 22% | 1,454,298 |
| **the Netherlands** | 19 x 100, 50 x 115, 25 x 100 | 53% | 123,612 | 22 x 100, 32 x 150, 22 x 125 | 32% | 1,446,591 |
| **Austria** | 36 x 127, 36 x 112, 36 x 125 | 53% | 11,510 | 50 x 150, 50 x 100, 38 x 135 | 56% | 720 |
| **Italy** | 63 x 200, 75 x 200, 50 x 200 | 33% | 375,256 | 63 x 200, 50 x 200, 75 x 200 | 30% | 91,941 |

It should be noticed that the results are limited to CSW exports from Finland to a destination country. The results do not necessarily show all the dimensions or species used in a country but only the Finnish exports to the destination countries. However, it is possible to make the following observations on the Finland CSW export to destination countries from the perspective of Table 38:

- Finland: the most common dimensions for pine are 50 x 100 and 19 x 100, and for spruce 22 x 100 and 25 x 100. Both for pine and spruce, the sum of these dimensions exceeds 30% of the total volume. This may indicate a stable supply situation.
- Sweden: The most common pine dimensions are 50 x 125, 25 x 100 and 50 x 100. For spruce, the most common dimension is 25 x 100. The number of dimensions is relatively small, as is the sample size compared to other export countries in the sample.
- Norway: The most common dimensions for pine are 19 x 100, 25 x 100 and 50 x 150. For spruce, the most common are 75 x 100 and 16 x 125. The export amount is relatively small compared to other countries.
- Denmark: The most common dimensions for pine are 19 x 100, 50 x 125 and 50 x 100. For spruce, the most common dimensions are 22 x 100, 19 x 125 and 22 x 125. Denmark can be seen as a pine country from Finland's perspective.
- Germany: Spruce country. Very focused on three spruce dimensions. Pine volume is large but more distributed among several dimensions.
- UK: Pine country. Dimension distributions are not concentrated to only a few dimensions.
- France: Spruce country. Large dimension distributions.
- the Netherlands: Spruce country. Still, Finland exports also some pine with only a few dimensions.
- Austria: small volume, not a special CSW export country for Finland. More pine than spruce.
- Italy: Pine country, large dimension distribution. Nevertheless, it should be noticed that Italy uses much spruce but imports more pine from Finland.

The thesis result of dimension clusters (Table 38) strengthens the picture of CSW supply clustering to few volume dimensions (e.g. Table 33).

## 5.1.7 Case UK and large pine CSW dimensions - Pine thickness distribution development of CSW exports from Finland to UK between 1995 and 2000

The aim of this section is to answer the following question: Has there been a significant change of dimension sizes in Finnish exports of sawnwood to UK markets between 1995 and 2000? One of the more specific questions was: Is it possible to find any sings that the larger dimensions of Finnish pine CSW export market in UK have transferred to smaller dimensions? The approach selected was thickness (mm). The significance of difference in the share of thicknesses in 1995–2000 was measured with the help of linear regression, so that the limit for significance, i.e. significant change, was set at (value) $p = 0.05$.

The proposition to be tested in this section was: the importance of large pine dimensions, as concerns sawnwood exported from Finland, decreased in the UK markets due to thickness approach between 1995 and 2000.

Finland CSW exports to UK markets have mostly focused on seven standard thicknesses (19, 25, 32, 38, 50, 63 and 75 mm) between 1995 and 2000. Other thicknesses were included in the category "Other". CSW is divided into thickness classes irregularly. Approximately 40% of the CSW exports from Finland to UK markets consisted of the thickness 50 mm. There are signs that the large pine CSW thicknesses have lost their market share in UK to some smaller thicknesses (see Appendix 7).

In pine CSW, the sales distribution of the thicknesses of 32 mm and the class "Other" has grown between 1995 and 2000. Simultaneously, the thicknesses of 63 mm and 75 mm have lost their significance on the market (Figure 61).

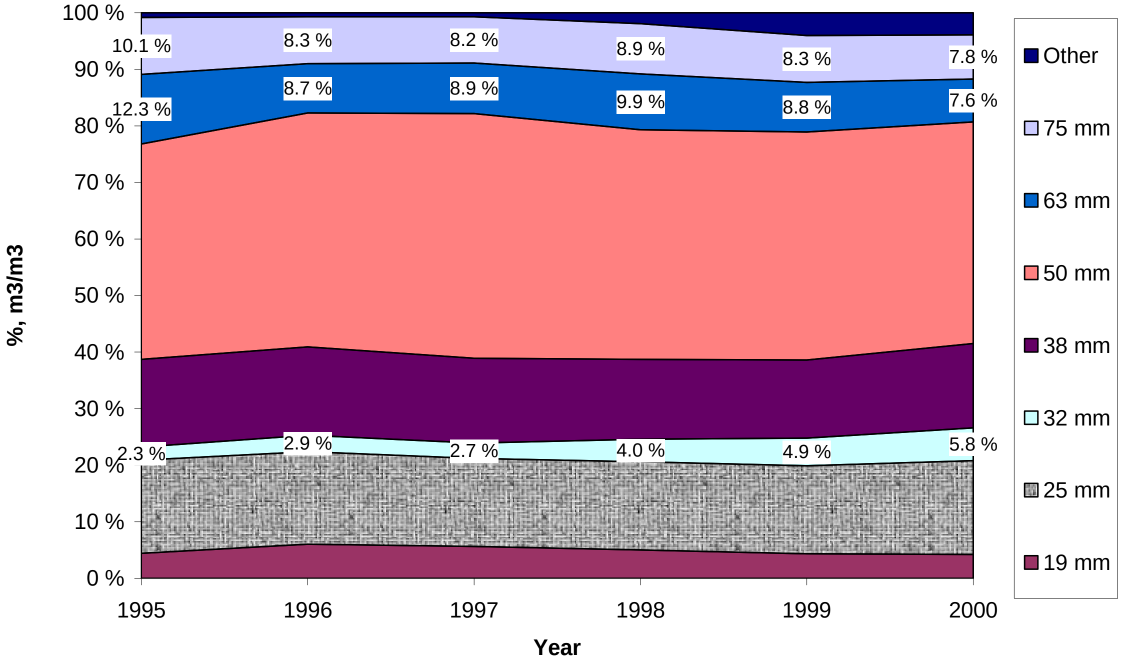


**Figure 61. Thickness distribution of pine in the sample of timber exported to UK in 1995–2000.**

The share of dimensions of large thicknesses (63, 75 mm) has decreased but the change is not statistically significant. Nevertheless, the growth of dimensions of thickness 32 mm was statistically significant (See Appendix 7). It is interesting to observe that statistically significant changes (32 mm, Other) took place in the thickness classes whose share (%) was on a relatively low level.

### 5.1.8 Discussion

The number of dimensions produced, 890, can be considered high because sawnwood is mainly a standard product (see the Section 5.1.1). It is also interesting to observe that there is a significantly larger number of spruce dimensions (615) than pine dimensions (491) according to the results. Reasons for this can be sought from the differences between end-use applications and markets.

The sawnwood supply consists mainly of a limited number standard products. The results show that sawnwood supply and demand from Finnish sawmills was limited to only a few volume dimensions. These were for pine 19, 25 and 50 x 100 mm. For spruce the most important dimension was 22 x 100 mm (see Table 33). It may be typical for the mature or declining phase of business to have high volumes and to cut down costs. This can be seen in the sawmilling industry in three areas: 1) reduction of the number of products, 2) emphasis of the importance of some products 3) high volumes of some products.

It is interesting that the most common CSW dimensions in Finland include boards, too (Table 33). There may have been a traditional way of thinking in the Finnish sawmills where studs and other thick dimensions are produced but the boards just fall as a part of the production. The same way of thinking included a focus on centre yield (see Figure 8). The side yield was left with less importance in research by optimising sawing pattern to maximise value yield. There can be found signs of research focusing more on centre yield in, for instance, Usenius and Viitaniemi (1976), Usenius et al. (1983), Virtanen et al. (1997), Vuorilehto (2001).

If the sawing pattern changes because of altered CSW supply, it may lead to smaller dimensions of centre yield. This leads to larger volumes of side yield, i.e. boards. This leads to the question how much of supply originates from the demand of CSW end-users, and how much originates from the falling supply. The fact is that there is a share of CSW dimensions that normally falls in the sawing without known customers at the moment of sawing.

It is possible that the operation of Finnish sawmills was largely based on the standard product strategy and not on customer or value adding strategy between 1995 and 2000. Nevertheless, the purpose of sawing is to maximise the total sawing value (€/m$^3$) and not just maximise the value of centre yield.

The short period of time, six years between 1995 and 2000, may not give a solid basis to draw drastic conclusions. There were often small differences in annual variation like in Figure 61. These differences can be due to different quantities of sales between years (see e.g. Table 36 and Table 37) or even cyclical factors in supply. On the other hand, the year 2000 was cyclical peak in Finnish wood product industry as can be seen in the Figure 62. This could have an effect on all changes during 1995–2000.

Wood product industry output in Finland as described in Figure 62 remained on a high level from 2001 to 2003. The output reached its new peak, 5725 M€, in 2003. Figure 62 shows that development of output of Finnish wood product industry was closely linked with intermediate consumption but not with added value. In brief, intermediate consumption of Finnish wood product industry is the cost of raw materials (largely logs) and other inputs which are used in the production processes. This indicates that output of Finnish wood industry is mostly a channel to sellers of raw material (logs and other), not an indicator of value added in wood product industry.

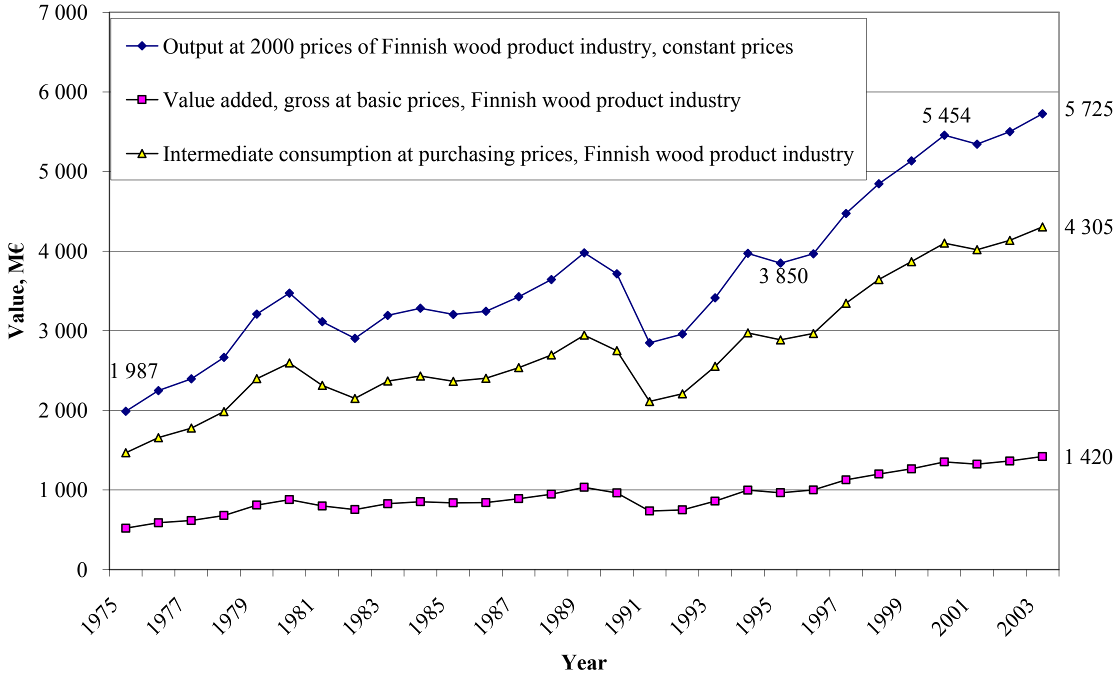


**Figure 62. Output, value added and intermediate consumption are given at 2000 prices for Finnish wood product industry from 1975 to 2003. Finnish wood product industry covers all wood product industries in Finland, not just the sawmilling industry. Source of data: STAT 2005.**

According to the results, sawnwood trade was concentrated on main dimensions in Finland in 2000. Simultaneously, the number of dimensions was large. The Pareto principle assumption and its 20–80 rule applied to sawnwood dimensions. Nevertheless, in the light of the results, it can be asked why a large number of different qualities are still produced in the Finnish sawmilling industry.

The results show that the largest share of volume ($m^3$) was produced by a limited amount of dimensions. Therefore it is justified to ask if the system to produce a large number of CSW dimensions has been proved profitable for the Finnish sawmilling industry. In the background of this observation there may be the desire of sawmills to apply key customer strategy and serve particular customers better. Otherwise, this strategy seems to lead to a great number of dimensions. There may be a situation where all the costs directed at a specific dimension may not be known in the Finnish sawmilling industry or this kind of activity-based costing is not considered important.

In the Sections 5.1.3 and 0, where dimension quantity ($m^3$) and value distributions (€) are compared, the results show the standard product character of sawnwood. According to the research results, dimensions with a large volume ($m^3$) had smaller price average (€/$m^3$). On the other hand, the results show that there was a relatively small difference between quantity and value distributions.

The development of dimension distributions from 1995 to 2000 seems to vary between species. Pine had a two-way change in distribution where the supply was focused more on smaller dimensions and, on the other hand, on large dimensions. The situation of spruce dimension distribution development can be considered stable within the period from 1995 to 2000 (see the Section 5.1.5). The reasons for differences in both dimension distributions and dimension development between 1995 and 2000 can possibly be found in the differences in end-user segments and markets.

The supply of Finnish sawnwood can be divided into different markets based on wood species (see the Section 5.1.6). It is possible to name pine and spruce countries on the basis of the sawnwood distribution of the Finnish sawmilling industry, as has been done for 10 countries. The export share of CSW distribution is often focused only on certain dimensions and qualities. It should be noticed that the results are limited to CSW exports from Finland to a destination country. The results do not necessarily show all the dimensions or species used in a country but only the Finnish exports to the destination countries. A country's profile based on wood species may be a consequence linked to the tradition of wood use in the country.

It can be assumed that the local climate affects the tradition of wood use. For example, naming the Netherlands as a spruce country for the Finnish sawmilling industry can be a consequence of both the sea climate and tradition. Sawn timber users in the Netherlands may have an idea that the spruce sawnwood used in the Netherlands withstands moisture better than pine. Naming UK as a pine country agrees with the fact that the UK climate can be seen slightly comparable with the Netherlands, but it is in contradiction with the view that spruce sawnwood could withstand moisture better than pine in those moisture conditions. It has to be noticed that the comparisons of both moisture properties and differences between species cannot be proved within the limits of the thesis. On the other hand, the concentration of CSW supply mainly on only a few dimensions strengthens the picture of standard product nature of CSW.

The development of thickness dimensions in the UK market can be generally considered as quite stable between 1995 and 2000 (see the Section 5.1.7). Nevertheless there have been signs in the market indicating that supply would become more focused on thinner dimensions. In addition to this, there will be other thicknesses among the standard thicknesses in the UK market. This can be seen as an increase in the share of the class "Other" (see Appendix 7). It is perhaps surprising to observe that there is a slow change in thicknesses in the UK market between 1995 and 2000. The supply picture of CSW from the Finnish sawmilling industry in the UK market is quite stable in terms of thicknesses.

It must be said that no universal conclusions can be drawn from the presented analyses because:

1. Data from databases were limited to sales information from Finnish sawmills from 1995 to 2000 in WPDB.
2. WPDB is a fragmented database covering much sales dimension and quality class information but lacking relatively much e.g. sales price information.
3. The short period of time, six years between 1995 and 2000, may not give a solid basis to draw drastic conclusions
4. Cyclical factors and peaks cannot be excluded in supply analysis.

## *5.2 Length approach – CSW length distribution in Finland*

### 5.2.1 Aim and results

Length approach was chosen as a part of the thesis and supply analysis because there is no published information on CSW length distributions. The aim of this part of the thesis is to find out (1) what is the Finnish CSW length distribution for pine and spruce and for both side boards (i.e. side yield, see Figure 8) and centre boards (i.e. centre yield, studs and other thick dimensions), and (2) if there are statistically significant changes between distributions for pine-spruce and side boards – centre boards.

The proposition to be tested in this section was the following: Differences of length between pine and spruce sawnwood delivered from Finland were relatively small in 2000.

A large sample, 478,853 m$^3$, was collected from the sawmilling industry for research purposes in 2000. This sample was divided into side and centre boards as well as pine and spruce (See Appendix 7). The sample is based on the indicators of sawmills themselves. Control measurements for lengths were not made. The length distributions were built with the same

30 cm division that the sawmills use. Because of this, there were 15 distribution points for length distributions.

Length distributions for side and centre boards as well as pine and spruce look similar (Figure 63). Distribution peaks are located in the length classes of 420 cm or 450 cm. Still, pine seems to have most kurtosis.

From the statistical data analysis perspective, the length distribution data are categorical and classified. Based on this categorical data, the discrete distribution was formed (See Appendix 7). Therefore methods which require continuous distributions – like the Kolmogorov–Smirnov test for comparing continuous distributions – cannot be used to analyse the data. Thus there was a need to find an appropriate method and solution for comparative analysis of the length distribution data.

For the length distribution comparative analysis, class average values were selected to be the object of comparison, and the method of comparison was selected to be t-test, which is suitable for comparisons of individual distribution points. Nevertheless, to analyse data in a reliable way, t-tests require that the sample is (1) distributed according to normal distribution or can be justifiably assumed to be distributed in that way and (2) a continuous distribution. Neither of these requirements is fulfilled, which must be taken into account when the reliability of the results is evaluated. Nevertheless, the t-test gives a picture of sample comparison although the use of the t-test contains these methodological problems.

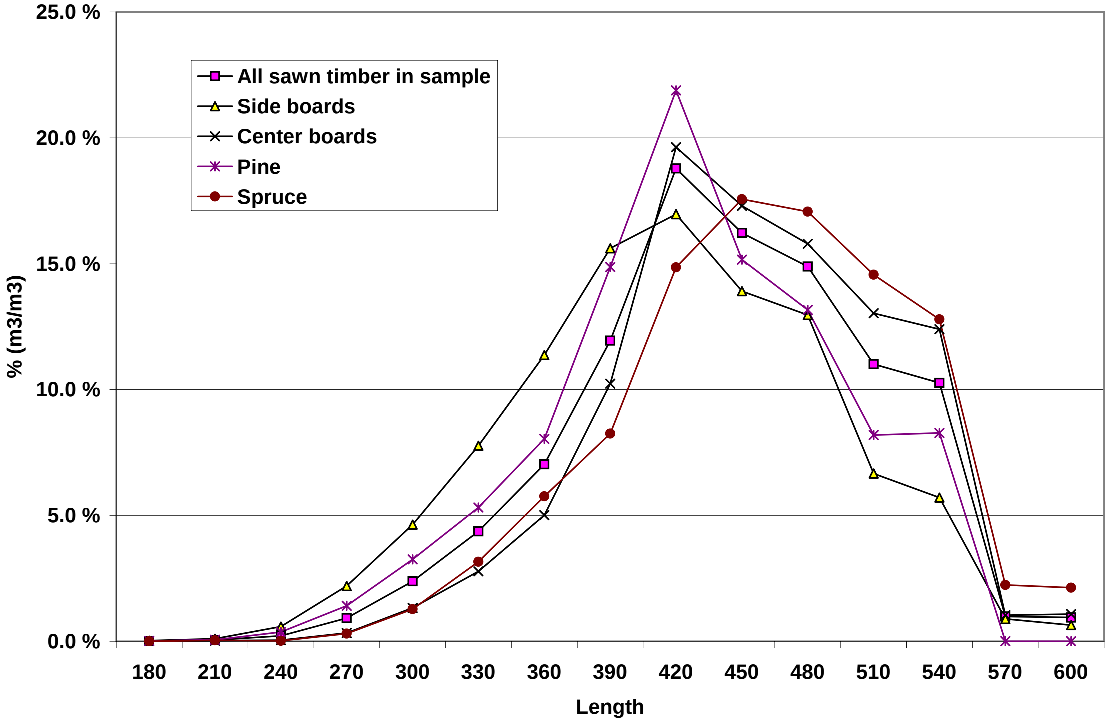


**Figure 63. The CSW length (cm) distribution. The sample consists of 478,853 m$^3$ sawnwood from the Finnish sawmilling industry in 2000.**

The length distributions (Figure 63) are tilted to the right. In other words, there is more volume (m$^3$) of length classes between 400 cm and 600 cm than in length classes under 400 cm. All the length distributions described have one peak, rise slowly and fall sharply at the end. In the last length class from 570 to 600 cm, the distributions are steady. The distribution of pine has a strong peak at the length of 420 cm, but the distribution of spruce is fairly steady and reaches its peak at the length of 450 cm.

Length distribution comparison (Table 39 and Table 40) shows that there is no statistical difference between pine and spruce. On the other hand, there is a statistical difference between Side boards and Centre boards with one tail ($p = 0.046$). The result is expected, since the side boards are typically shorter than the centre boards due to the conic form of logs. It is interesting to see that the variances in the sample are enormous. This is possibly the reason why the distributions are not statistically different, even though there seems to be a difference between their average values.

**Table 39. The results of the length distribution comparison.**

| **F-Test Two-Sample for Variances** | | | | |
|---|---|---|---|---|
| **Indicator** | **Side boards, $m^3$** | **Centre boards, $m^3$** | **Pine, $m^3$** | **Spruce, $m^3$** |
| **Mean** | 10139.88 | 21783.63 | 17812.99 | 14110.53 |
| **Variance** | 86044557 | 5.58E+08 | 3.46E+08 | 2.09E+08 |
| **Observations** | 15 | 15 | 15 | 15 |
| **Kurtosis** | –1.34518 | –1.30665 | –0.22689 | –1.49249 |
| **Skewness** | 0.446666 | 0.637647 | 0.823084 | 0.563977 |
| **Range** | 25778.09 | 64132.04 | 58494.51 | 37186.8 |
| **Minimum** | 34.82 | 1.41 | 0 | 0.05 |
| **Maximum** | 25812.91 | 64133.45 | 58494.51 | 37186.85 |
| **df** | 14 | 14 | 14 | 14 |
| **F** | 0.15411 | | 1.656366 | |
| ***p*(F≤f) one-tail** | 0.000619 | | 0.178104 | |
| **F Critical one-tail** | 0.402621 | | 2.483723 | |

It should be noticed that results of length analysis (Table 40) are valid only for (1) named length classes with 30 cm allocation (180, 210 etc.), (2) for lengths between 180 cm 600 cm.

**Table 40. The selected t-tests according to the results of the length distribution comparison.**

| **Selected test** | **t-Test: Two-Sample Assuming Unequal Variances** | | **t-Test: Two-Sample Assuming Equal Variances** | |
|---|---|---|---|---|
| **Indicator** | **Side boards, $m^3$** | **Centre boards, $m^3$** | **Pine, $m^3$** | **Spruce, $m^3$** |
| **Mean** | 10139.88 | 21783.63 | 17812.99 | 14110.53 |
| **Variance** | 86044557 | 5.58E+08 | 3.46E+08 | 2.09E+08 |
| **Observations** | 15 | 15 | 15 | 15 |
| **df** | 18 | | 28 | |
| **t Stat** | –1.77652 | | 0.609087 | |
| ***p*(T≤t) one-tail** | 0.046277 | | 0.273689 | |
| **t Critical one-tail** | 1.734063 | | 1.70113 | |
| ***p*(T≤t) two-tail** | 0.092553 | | 0.547378 | |
| **t Critical two-tail** | 2.100924 | | 2.048409 | |

The aim of the t-tests was to compare the distributions of two related variables with severe cautions. In addition to t-tests, the Wilcoxon signed-rank test was chosen because the distributions are not required to be normally distributed. Nevertheless, the Wilcoxon signed-rank test requires data to be continuous, but the test data are categorical. Therefore there is a need to be cautious with the results in Table 41.

**Table 41. The Wilcoxon signed-rank test for length distribution comparison of side boards-centre boards and pine-spruce. The Z-value for Side boards-Centre boards is based on negative ranks while Pine-Spruce value is based on positive ranks.**

| **Indicator** | **Side boards - Centre boards** | **Pine - Spruce** |
|---|---|---|
| **Z** | –1.533 | –1.193 |
| **Asymp. Sig. (2-tailed)** | 0.125 | 0.233 |

The Wilcoxon signed-rank test considers information about both the sign of the differences and the magnitude of the differences between pairs. The Wilcoxon signed-rank test results show that there is no statistical difference between distributions of either side boards - centre boards or pine - spruce. Otherwise, the value of significance (2-tailed) for side boards - centre boards, 0.125, is close to the limit of 0.05, which may indicate a slight difference between side boards and centre boards. Furthermore, with the Wilcoxon signed-rank test, it may be reasonable to use the significance limit 0.1 instead of 0.05, because the results are based on simplified and categorical distributions. The length comparison can perhaps be construed so that there is a comparison of length medians, which indicates the sample coarsely. Therefore there is a reason to stress the challenges to see the differences of significance between the length distributions.

### 5.2.2 Discussion

No statistically significant difference was detected between pine and spruce. This may indicate two things: (1) the similarity of the lengths of raw material, (2) closeness of user segments, prices and other supply factors to each other. The reason for a slight difference between pine and spruce might also be the differences in the method of bucking of species. From a traditional Finnish sawmilling perspective for pine, bucking and length optimisation is focused on improvements in quality distribution. For spruce, bucking is focused on certain lengths that the customers are willing to pay more.

A slight difference between the lengths of centre and side yield (see Figure 8) can be considered supply derived because of conicality of logs. Lengths of side yield are naturally shorter but it may be surprising that the difference is statistically significant only on the other side of the distribution. The distribution for the length of side yield rises faster than other distributions (Figure 63) and it is the most flat of all distributions (Table 39), which may indicate that the distribution of side yields is more even than other distributions. Nevertheless, there is more kurtosis in the spruce distribution than in side yield distributions.

From the statistical point of view, length distributions of sawnwood can be considered an occurrence of deviation from statistical conventionality due to the shape of distribution. A significant share of distributions for technical, natural or business events can be seen as one of these two: (1) normally distributed and even almost symmetrical (2) asymmetrical so that they rise quickly and decline slowly, e.g. typical distributions for time or Poisson distribution. However, it is typical for the length distribution of sawnwood that there is a heavy decline from a length 540 cm to 570 cm and a subsequent gentle decline to the length of 600 cm. The reason for this may be that the maximum length of logs in the most Finnish sawmills is 550 cm. On the other hand, it may seem that sawmills would not like to use short log lengths but, based on the results, there seems to be a small group of 180 cm lengths.

It is also interesting to note that every distribution (pine, spruce, centre boards, side boards) has a small minimum (Table 39). This may indicate that at least one length class from both ends of distribution can be seen as some kind of reserve class. Nevertheless, little sawnwood supply and demand is focused on these two classes at the both ends of the distribution.

Length distributions (Figure 63) lean towards right (maximum) which can be considered an anticipated phenomenon. In the Finnish sawmilling industry, the economic optimisation of end-user segments, logs as raw material, transportation and bucking typically leads to lengths between 390 cm and 480 cm. There can be two reasons for this: 1) quality and better profits are sought in sawing through shorter lengths, 2) the commonly used height of apartments, h = 250 cm, leads sawmills to seek lengths of sawn logs near 2 x h because sawnwood is used mostly in the construction segment. Usenius (1980) introduces (p. 46) two length distributions for logs in two different log classes of a sawmill. The shapes of these distributions resemble the length distribution of sawnwood in Figure 63. However, the top of length distributions of Usenius (1980) is in the length classes of 450 and 480 cm. As a result, this matches Figure 63. Concurrently, the result indicates that the difference between log and sawnwood lengths would be at the most 30 cm. The tops of the length distributions of sawnwood in Figure 63 are in the length classes 420 and 450 cm, which is 30 cm less than shown by Usenius (1980). Sandberg (1996) shows results of sawnwood length from three Finnish sawmills. According to Sandberg (1996), excess length in log ranged from 5 cm to 19 cm for a 90% yield in the production of high quality sawnwood. The log excess length depends of the log grade, felling season, harvesting accuracy and sawmill machinery.

On the other hand, it must be said that no universal conclusions can be drawn from the presented analyses from the similar reasons listed in Section 5.1.8.

## 5.3 End moisture content approach – MC distribution by segments and countries

Three goals were set for this part of the thesis: to determine (1) the development of end moisture content distribution of the supply in the Finnish sawmilling industry, (2) the subdivision of end moisture content in terms of segments used by the Finnish sawmilling industry and (3) the distribution of end moisture content in accordance with important target countries of Finnish coniferous sawnwood exports.

The proposition to be tested in this section was the following: The development of end moisture content distribution remained rather stable for both pine and spruce in the years 1995–2000.

### 5.3.1 End moisture content development

The development of end moisture content distribution from 1995 to 2000 can be seen in Table 42. Most of the sawnwood was still dried into the end moisture content of 16–18% which contained the biggest moisture class, 18%. The share of special kiln drying (6–14%) in the production of sawnwood industry increased but it was still only 4% of the production in 2000.

**Table 42. Development of the end moisture content (MC) in Finnish sawmills. The MC classes are formed by the following classification: [6,14]; ]14,16]; ]16,18]; ]18,20]; ]20,22]; ]Green–]. Green includes all end MC above 22% but not 22%. The class ”No information” includes all the sawnwood sales that lack end MC information (WPDB).**

| MC % | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | Total | Sample, $m^3$ |
|---|---|---|---|---|---|---|---|---|
| **6–14%** | 0% | 1% | 1% | 1% | 1% | 4% | 2% | 289,706 |
| **14–16%** | 1% | 1% | 1% | 1% | 0% | 1% | 1% | 142,300 |
| **16–18%** | 91% | 85% | 62% | 42% | 41% | 44% | 54% | 10,457,800 |
| **18–20%** | 0% | 0% | 0% | 0% | 0% | 38% | 9% | 1,639,568 |
| **20–22%** | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 11,099 |
| **Green** | 1% | 1% | 1% | 1% | 1% | 2% | 1% | 186,933 |
| **No information** | 7% | 12% | 35% | 56% | 57% | 10% | 34% | 6,494,871 |
| **Total** | 100% | 100% | 100% | 100% | 100% | 100% | 100% | 19,222,277 |
| **Sample, $m^3$** | 1,784,382 | 2,032,809 | 2,696,969 | 4,147,642 | 4,285,671 | 4,274,803 | 19,222,277 | |

As the results are reviewed it should be noted that the material includes a large number of sawnwood sales with no end moisture content information. For the years 1998 and 1999, these sales formed over a half of the material. Despite this, the relationship between end moisture content classes gives a good overview of the end moisture content distribution of the Finnish sawmilling industry.

An interesting point for the results is the decrease of end moisture content class 16–18% from over 90% to about 40% of sawnwood production between the years 1995 and 1998. From 1998 to 2000, the proportion of end moisture content class 16–18% became stable at a little over 40% of sawnwood production. Based on the changes in end moisture content distribution, a radical distribution change from moisture content MC 18% is unlikely towards lower end moisture contents.

The rise of the share of end moisture content 18–20% to 38% in 2000 is interesting. The reason for the change of end moisture content 20% is not known, but it is possible that there was a change in the classification systems of end moisture content classes. The share of green sawnwood remained 1–2% of production in the period from 1995 to 2000.

### 5.3.2 Connection between end moisture contents and user segments

The distribution of end moisture contents into user segments was examined so that the species were separated and there were two segment analyses (pine and spruce). In these analyses, data from 1995–2000 were divided into two parts based on the available information on end moisture content and user segments. The first part of the data (see Appendix 7, MC total) consists of those sawnwood sales which had information of end moisture content. Thus the moisture content sample data for this study were formed with the following subset: spruce 6,252,780 $m^3$ and pine 6,474,790 $m^3$. The second part of the data (see Appendix 7, Total with segment and MC information) consist of those sawnwood sales which had information for both end moisture content and segment. Thus the segment and moisture content sample data for this study were formed with the following subset: spruce 862,187 $m^3$ and pine 1,089,864 $m^3$.

CSW supply was between 1995 and 2000 much focused to MC 18% (see Appendix 7). Thus, over 90% of both pine and spruce supply is sold in moisture content 18%. There are slight differences between wood species. In addition to moisture content 18%, the supply of pine is focused to moisture content 20% whereas the supply of spruce is focused to moisture contents 20%, 16% and 14%.

The connection between end moisture contents and product segments shows that the end moisture content class indicates the user segment, particularly in lower moisture content classes (8–12%). The distribution segment, on the other hand, can be seen to include different user segments because the segment is present in most moisture content classes.

In all pine end-user segments, the relative volumes by MC classes are targeted to MC 18%. However, in the distribution segment, which is the biggest segment for pine, there is a relatively large number of MC 20% CSW (Figure 64 and see Appendix 7).

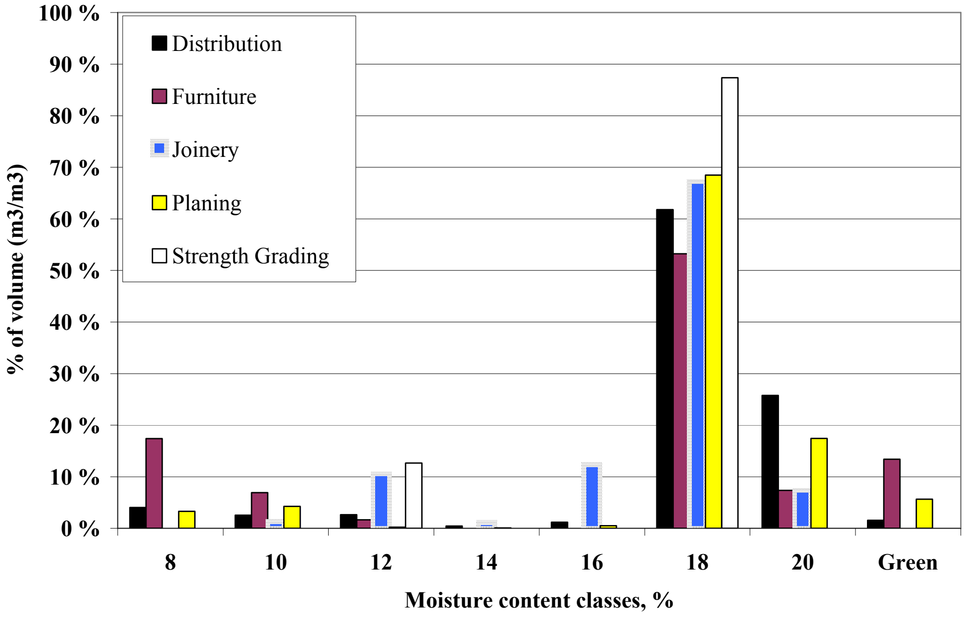


**Figure 64. The pine end-user segment relative volumes (%, $m^3/m^3$) by moisture content (MC) classes.**

It is interesting to see (Figure 64 and Appendix 7) that the largest relative CSW volumes of the furniture and joinery segments of pine are in MC18. This indicates that CSW for furniture and joinery segments will be dried again later in a kiln because these segments normally use moisture contents of less than 14%.

In most spruce segments, MC 18% or 20% is predominant. Nevertheless, in the furniture segment, MC 20% and green have the majority of the volume. It must be mentioned that the spruce volume for furniture segment is small (Figure 65 and see Appendix 7).

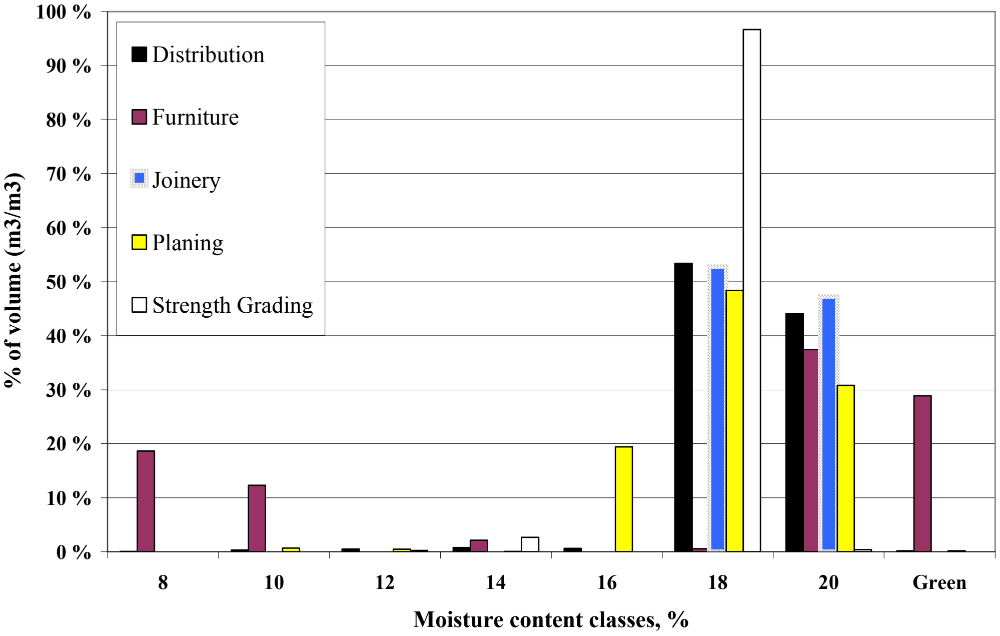


**Figure 65. The spruce end-user segment relative volumes (%, $m^3/m^3$) by moisture content (MC, %) classes.**

There are some differences between species. Pine CSW is delivered more in MC Green (not kilned) and spruce more in MC 20% (see Appendix 7). This is interesting because usually all CSW delivered as MC Green (not kilned) will be dried again. Pine has more volume in furniture and joinery segments, whereas spruce has more volume in planning and strength grading. If the distribution segment is excluded, MC 8% has the most volume in the furniture segment, MC 10% in furniture and planing, MC 12% in pine joinery, MC 14% in spruce strength grading and MC 16% in the pine joinery as well as the spruce planing segments.

### 5.3.3 Connection between end moisture contents and destination country

In analysing the supply distribution of end moisture contents for some of the most important target countries for CSW export, the countries studied were limited to the seven countries with the largest volume ($m^3$) in each MC class. Thus, the analysis included the following countries, each in at least one MC class: Finland (FI), Japan (JP), Denmark (DK), Germany (DE), Italy (IT), UK (GB), the Netherlands (NL), Spain (ES), France (FR), Egypt (EG), Algeria (DZ), Austria (AT), Sweden (SE) and Switzerland (CH). The only country included in all the analysed MC classes was Finland. The title Other was used for the countries where a certain MC class is exported but which are below the seven largest countries. The basis for this selection was to include those countries in the data where the largest possible volume of sawnwood by MC class was exported in 1995–2000.

Pine and spruce were not separated in the target country analysis. Moreover, the analysis was simplified to have only five MC classes: 14% and the moisture contents below it, 14–16%, 16–18%, 18–20% and Green.

The end moisture content class of 6–14% has a fairly large volume (289,705 $m^3$), as it consists of all the end moisture contents up to 14%. In the end moisture contents between 6–14%, the most predominant countries were Finland, Japan and Denmark. A significant point is that for special kiln drying (6–14%), the exports into Japan (32.50%) were almost as important as the amount of special kiln dried sawnwood remaining in Finland (33.05%). In addition to Japan and Denmark, the most important export countries for special kiln dried sawnwood (6–14%) were Germany, Italy, UK and the Netherlands. Still, the significance of the last four countries is clearly smaller than that of Finland, Japan and Denmark (Table 43).

**Table 43. Moisture content (MC) class volumes by destination country. See abbreviations for the country codes. The sample sizes are marked in the title row above the figures of country share. Sample sizes are listed above country shares. The MC classes are: [6,14]; ]14,16];] 16,18]; ]18,20]; Green–]30,unlimited].**

| **6–14%** | **$m^3$** | **14–16%** | **$m^3$** | **16–18%** | **$m^3$** | **18–20%** | **$m^3$** | **Green** | **$m^3$** |
|---|---|---|---|---|---|---|---|---|---|
| **Country** | **289,705** | **Country** | **142,302** | **Country** | **10,457,799** | **Country** | **1,639,569** | **Country** | **186,933** |
| **FI** | 33.05% | **DE** | 83.05% | **GB** | 14.00% | **FI** | 28.31% | **FI** | 81.36% |
| **JP** | 32.50% | **NL** | 6.18% | **FI** | 13.17% | **GB** | 10.68% | **DK** | 18.18% |
| **DK** | 17.28% | **FI** | 4.25% | **NL** | 10.76% | **FR** | 9.40% | **FR** | 0.21% |
| **DE** | 4.02% | **ES** | 2.09% | **FR** | 8.95% | **EG** | 7.75% | **AT** | 0.08% |
| **IT** | 2.82% | **DK** | 1.26% | **JP** | 8.07% | **NL** | 6.31% | **SE** | 0.07% |
| **GB** | 2.62% | **IT** | 1.16% | **DE** | 7.59% | **DK** | 6.10% | **DE** | 0.06% |
| **NL** | 2.37% | **FR** | 0.58% | **EG** | 6.95% | **DZ** | 5.91% | **CH** | 0.05% |
| **Other** | 5.34% | **Other** | 1.43% | **Other** | 30.51% | **Other** | 25.54% | **Other** | 0.00% |

The end moisture content class of 14–16% is the smallest class in the analysis, only 142,302 $m^3$. In this end moisture content class MC 14–16%, Germany played a significant role because more than 83% of CSW in this sample was exported to Germany. The sample does not explain reasons why Germany had such a large share of sawnwood volume ($m^3$) in this class. However, it can be assumed that the reason was the large share of planing segment in MC 14–16% spruce export from Finland to Germany between 1995 and 2000 (Figure 65 and Table 38).

The end moisture content class of 16–18% has the largest volume in the analysis, because it includes the export kiln dried (MC 18%) sawnwood. For MC 16–18%, UK, Finland and the Netherlands have the largest volumes. Other important export countries for MC 16–18% sawnwood are France, Japan, Germany and Egypt.

The end moisture content class of 18–20% has the second largest volume ($m^3$) in the analysis. The largest share (28%) of the supply for this MC class is from Finland. Other significant countries include UK, France and Egypt. The end moisture content class green has the second smallest volume and is demanded mainly in Finland and Denmark.

## 5.3.4 Discussion

The dominance of the end moisture content class of MC 18% – over 90% of the distribution of end moisture contents – supports the standard product character of sawnwood that was observed earlier (e.g. see Appendix 7), also when the product character is evaluated through end moisture content. Another supporting observation is that there are not many differences between pine and spruce when compared based on MC classes. These differences come because species are delivered to different user segments and the segments have different user needs. The results emphasise the significance of spruce as construction material and also highlight the supply of pine in visual segments, such as joinery and furniture. In construction, the end moisture content of sawnwood may often be 16–20%, whereas in the indoor usages of joinery and furniture segments, the end moisture content is often 8–12%.

The analysis of the supply distribution of end moisture contents by the most important export countries for CSW gives rise to two issues:

1. Finland has a central role in the supply distribution of end moisture contents. The reason for this may be the high capacity of domestic refining of CSW.
2. The other countries have widely varying supply profiles in the distribution of end moisture contents.

In all the MC classes analysed, the domestic deliveries of Finnish sawmills belonged to the top three of the countries with the largest volumes. Some countries were only profiled in a few MC classes. For example, the MC classes typical for Japan were 6–14% and 16–18%; for Denmark 6–14%, 18–20% and Green; for UK 16–18% and 18–20%; and for Germany 14–16% and 16–18%. This kind of connection between destination countries and end moisture content classes may indicate market segmentation. However, it must be said that no universal conclusions can be drawn from the presented analyses from the similar reasons listed in Section 5.1.8.

## *5.4 Quality approach – CSW quality class distributions*

### 5.4.1 Main quality class distribution development 1995–2000

The purpose of this section in the thesis is to determine how main quality class distribution developed in the period from 1995 to 2000.

The proposition to be tested in this section was the following: The development of quality distribution remained rather stable for both pine and spruce in the years 1995–2000.

The analysis of main quality class distribution development was done in the following way. The qualities of U/S, V, VI, SF and Other were selected to be the main qualities. The main qualities were formed so that all quality classes with the name and contents that were close to the main quality were merged into the main quality. For instance, quality VI was formed by merging quality QVI with all the subqualities like QVIE, QVIEJ, QVIJ, QVIM and QVIW. In addition to main quality VI, the same process was done with the qualities U/S, V and SF. All the other qualities were merged and named as quality “Other”. The changes of quality class shares in the distribution from 1995 to 2000 were measured with a linear regression analysis so that the limit of significant change was set to be under the value $p = 0.05$.

Pine CSW quality class development shows that the amount of U/S quality remained quite stable between 1995 and 2000 while the shares of V and VI qualities decreased (see Figure 66). Simultaneously, the share of SF and other qualities increased.

For pine in the Finnish sawmilling industry, main qualities by volume ($m^3$) were V and VI. More than half of the coniferous sawnwood was graded to these two quality classes based on sawnwood volume ($m^3$). Pine changes of U/S, V and VI are statistically significant (see Appendix 7).

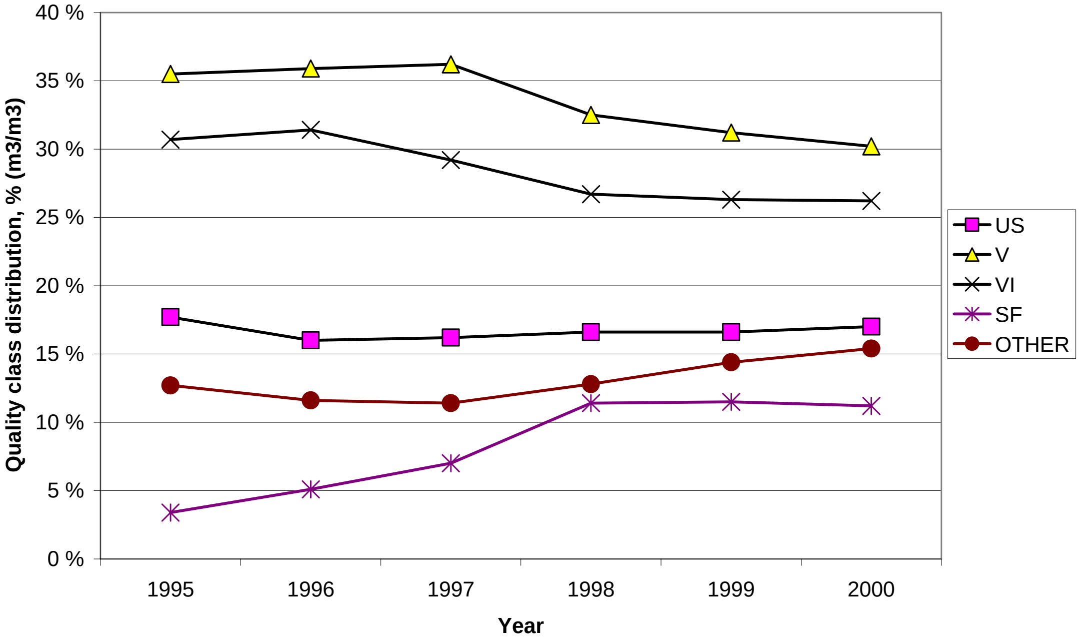


**Figure 66. The pine CSW quality class development 1995–2000. The WPDB has similar quality classes.**

The quality class distribution of spruce CSW shows the significance of SF quality for spruce (Figure 67). Almost half of spruce volume was sold as SF or as its modification. On the other hand, the result shows that the significance of U/S and V qualities was about 10% ($m^3/m^3$) in the grading of spruce CSW. The share of the other qualities in the sawnwood distribution increased during the analysis period 1995–2000 from 12% to 19%. All other but SF changes were statistically significant (see Appendix 7).

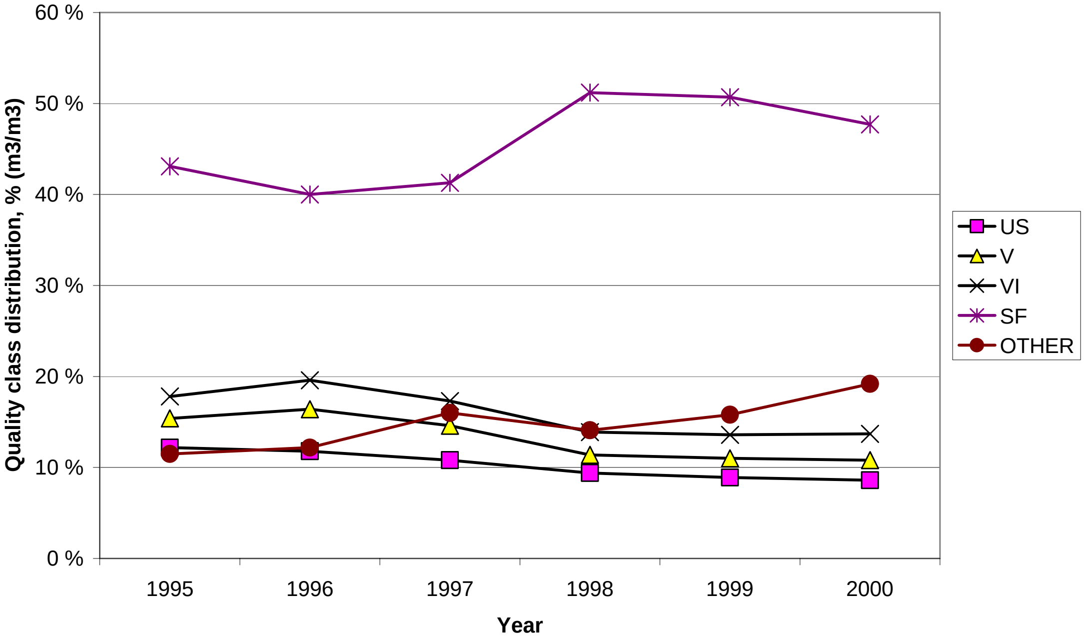


**Figure 67. The spruce CSW quality class development 1995–2000. The WPDB has similar quality classes.**

The change of the trend in the distribution of quality classes was statistically significant for most quality classes (see Appendix 7). For the quality classes of pine, a statistically significant change in 1995–2000 occurred for the quality classes V, VI and SF, whereas the quality classes of spruce that have a statistically significant change are the qualities U/S, V, VI and Other. However, it must be stated that a large, radical change, such as the disappearance of a quality class or a rise into the largest class, did not occur in the data.

The development of quality distribution showed a stable quality situation. There were few major changes of CSW quality distributions, which indicates the standard quality nature of Finnish sawmills.

### 5.4.2 Importance of modified special qualities

The purpose of this section is to determine whether the supply for modified special qualities increased in the Finnish sawmilling industry between the years 1995 and 2000. Here, modified special qualities refer to qualities that have been categorised by modifying the grading instructions of the main quality classes (U/S, V, VI, SF). The significance of the change in modified special qualities is measured with a linear regression analysis where $p$ = 0.05 is used as the limit of significance.

It can be assumed that CSW quality distribution shows standardised main qualities (like U/S or V) as well as modified special qualities (including customer qualities) based on these standardised qualities. This kind of customer quality orientation has been one of the events seen in the Finnish sawmilling industry during the last 10 years.

For pine CSW, the assumption applies better for better qualities and their modifications. In U/S standard quality, the U/S share dropped from 99% to 84% while the number of modified qualities increased (Table 44). For other main qualities, the importance of modified subqualities did not change when the significant change was measured statistically. Regarding quality class VI, the change in quality class VI from modified subqualities to the standard quality VI was close to being seen as statistically important ($p$ = 0.053).

**Table 44. The pine CSW quality comparison of standard and modified qualities. The linear regression approach, which indicates significant changes, is applied here.**

| **Quality class** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **Grand Total** | **R-squared** | ***p*-value** | **Significant change** | **Direction of change** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **U/S-STANDARD** | 99% | 99% | 99% | 94% | 95% | 84% | 94% | 0.711 | 0.035 | Yes | - |
| **U/S-MODIFIED** | 1% | 1% | 1% | 6% | 5% | 16% | 6% | | | | + |
| **Sample, U/S, m$^3$** | 134,711 | 166,361 | 227,720 | 353,369 | 370,510 | 391,925 | 1,644,596 | | | | |
| **V-STANDARD** | 82% | 77% | 78% | 75% | 75% | 77% | 77% | 0.495 | 0.119 | No | - |
| **V-MODIFIED** | 18% | 23% | 22% | 25% | 25% | 23% | 23% | | | | + |
| **Sample: V, m$^3$** | 270,400 | 373,632 | 509,348 | 690,802 | 694,818 | 696,789 | 3,235,788 | | | | |
| **VI-STANDARD** | 0% | 0% | 16% | 33% | 37% | 22% | 22% | 0.648 | 0.053 | No | + |
| **VI-MODIFIED** | 100% | 100% | 84% | 67% | 63% | 78% | 78% | | | | - |
| **Sample: VI, m$^3$** | 233,411 | 326,837 | 411,654 | 569,024 | 585,727 | 603,730 | 2,730,383 | | | | |
| **SF-STANDARD** | 12% | 10% | 15% | 19% | 15% | 35% | 21% | 0.630 | 0.060 | No | + |
| **SF-MODIFIED** | 88% | 90% | 85% | 81% | 85% | 65% | 79% | | | | - |
| **Sample: SF, m$^3$** | 29,188 | 58,230 | 113,845 | 288,745 | 294,421 | 351,111 | 1,135,539 | | | | |

For spruce coniferous sawnwood, the quality comparison between standard and modified qualities looks different when compared with pine (Table 45). Amounts of U/S and V standard qualities remained quite stable. For VI and SF qualities, there was a majority of modified qualities. The relative amount of modified VI and SF qualities decreased between 1995 and 2000. The only statistically important change in the quality class distribution was that the share of VI standard qualities increased and the share of VI modified qualities decreased. Regarding spruce sawfalling quality (SF), the importance of standard sawfalling (SF) quality increased within the period from 1995 to 2000 but the result of change indicated that the change was almost significant (Table 45). From the statistical point, the quality class SF change was not significant ($p$ = 0.053).

**Table 45. The spruce CSW quality comparison of standard and modified qualities. The linear regression approach, which indicates significant changes, is applied here.**

| Quality class | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | Grand Total | R-squared | *p*-value | Significant change | Direction of change |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **U/S-STANDARD** | 92% | 96% | 99% | 94% | 94% | 94% | 95% | 0.0005 | 0.97 | No | + |
| **U/S-MODIFIED** | 8% | 4% | 1% | 6% | 6% | 6% | 5% | | | | - |
| **Sample: U/S, m$^3$** | 124,551 | 116,938 | 138,791 | 189,318 | 182,729 | 169,762 | 922,088 | | | | |
| **V-STANDARD** | 99% | 100% | 100% | 98% | 98% | 98% | 99% | 0.4995 | 0.116 | No | - |
| **V-MODIFIED** | 1% | 0% | 0% | 2% | 2% | 2% | 1% | | | | + |
| **Sample: V, m$^3$** | 157,577 | 163,041 | 187,725 | 231,165 | 227,081 | 213,264 | 1,179,852 | | | | |
| **VI-STANDARD** | 0% | 0% | 8% | 27% | 28% | 27% | 17% | 0.8464 | 0.009 | Yes | + |
| **VI-MODIFIED** | 100% | 100% | 92% | 73% | 72% | 73% | 83% | | | | - |
| **Sample: VI, m$^3$** | 182,314 | 194,276 | 222,812 | 280,735 | 280,650 | 269,140 | 1,429,928 | | | | |
| **SF-STANDARD** | 7% | 12% | 13% | 14% | 13% | 31% | 16% | 0.6499 | 0.053 | No | + |
| **SF-MODIFIED** | 93% | 88% | 87% | 86% | 87% | 69% | 84% | | | | - |
| **Sample: SF, m$^3$** | 441,250 | 397,062 | 532,153 | 1,033,347 | 1,043,001 | 939,101 | 4,385,916 | | | | |

The results for both species showing a growth in the importance of modified (Table 44 and Table 45) are likely to indicate a trend from standard products to special products. On the other hand, the results indicate a significant growth in product segmentation.

### 5.4.3 Annual changes in number of quality classes

There was a significant annual increase in the number of quality classes (Table 46). Regarding both pine and spruce, the number of quality classes increased statistically significantly in the sample in the period from 1995 to 2000. Significance of change was measured in the sample by linear regression so that the limit of significant change is $p = 0.05$.

In 2000, there were 126 quality classes of pine sawnwood in the Finnish sawmilling industry and 71 quality classes of spruce.

**Table 46. Change in the number of quality classes 1995–2000. Quality classes = number of quality classes in the sample. The linear regression approach (LINREG), which indicates significant changes, is applied here.**

| PINE | | | | | | | LINREG | | |
|---|---|---|---|---|---|---|---|---|---|
| **Year** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **R-squared** | **Year *p*-value** | **Significant change** |
| **Sample, m$^3$** | 760,713.9 | 1,040,388 | 1,408,887 | 2,128,101 | 2,227,353 | 2,306,641 | | | |
| **Quality classes** | 36 | 45 | 61 | 77 | 87 | 126 | 0.941 | 0.006 | Yes |
| **Mean, m$^3$** | 4,845 | 6,627 | 8,974 | 13,555 | 14,187 | | | | |
| SPRUCE | | | | | | | LINREG | | |
| **Year** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **R-squared** | **Year *p*-value** | **Significant change** |
| **Sample, m$^3$** | 1,023,668.5 | 992,421 | 1,288,082.6 | 2,019,541.4 | 2,058,318.2 | 1,968,162.2 | | | |
| **Quality classes** | 34 | 41 | 51 | 51 | 52 | 71 | 0.780 | 0.047 | Yes |
| **Mean, m$^3$** | 9,843 | 9,542.5 | 12,385.4 | 19,418.7 | 19,791.5 | 18,924.6 | | | |

### 5.4.4 Discussion

Regarding the development of pine and spruce main quality classes, the results emphasise that the Finnish sawmilling industry has limited means to control their business environment through qualities. Sawmills can combine quality classes, develop new qualities or refine their qualities to better meet the needs of the customers. However, sawmills can control their raw material quality only in limited scale because the log quality is directly linked with sawnwood quality. The volume of U/S and other higher qualities increases and the share of the weaker qualities decreases when log diameter grows (Heiskanen and Asikainen 1969). On the other hand, Uusvaara (1985) states that large log sizes can cause a CSW quality class to decrease, for large logs often come from stems that have grown quicker than the average and thus are of poorer quality.

The sawmills still used in the year 2000 the same principles of grading systems and the same names of main quality classes that Siimes (1945) presented. The share of qualities has decreased from the level that Siimes (1945) presented to the level of table in Appendix 7. According to Siimes (1945), there were 45–75% of U/S quality, 15–45% of V quality and 5–10% of VI quality. Reasons for the remarkable change in quality class distribution can be found in changes of both raw material quality and grading systems.

The development of pine main quality classes in 1995–2000 points to an economical optimisation of quality distribution. The aim is to keep the most valuable of the main quality classes, U/S, stabilised so that its share of the quality distribution will not decrease. The results of quality class distribution are similar to previous results, e.g. Table 47.

**Table 47. The CSW pine quality class distribution comparison.**

| Quality class | U/S | V | VI | SF | OTHER |
|---|---|---|---|---|---|
| **1994 from Tikka (1997)** | 21% | 37% | 21% | 10% | 11% |
| **2000 results** | 17% | 30% | 26% | 11% | 15% |

The growing proportion of sawfalling quality class (SF) and the simultaneous decrease of the V and VI quality classes may suggest an emphasis on fresh knot quality classes and better flexibility. At many sawmills, the quality class requirements of sawfalling quality are less stringent than for the V and VI quality classes. On the other hand, every sawmill tries to avoid delivering VI and to increase the proportion of more valuable quality classes. The large proportion of V and VI quality classes indicate the need for value added production. The pine sawmills need to find more value added for pine sawnwood through the flexibility provided by sawfalling quality class (SF). The observations on the interconnected dynamics of quality classes V, VI and SF are supported by the result that the change in all these quality classes was statistically significant in the years 1995–2000. A good signal can be seen in the volume reduction of V and VI quality classes, whereas there have been signals of growth for these quality classes in history (e.g. Leppänen 1993).

The results of the thesis concerning the development of spruce main qualities place the emphasis on the great significance of sawfalling quality class (SF). Nevertheless, it must be noted that the change of all the other quality classes expect for SF was statistically significant. Between 1995 and 2000 the proportions of quality classes U/S, V and VI decreased whereas the proportion of the quality class Other, comprising of several special qualities, increased with statistical significance. Most probably the result indicates that spruce sawmills are seeking to improve profitability through spruce special grading. It is interesting to see that quality class U/S was allowed to decrease from 12% to 9%. This is likely to suggest that the profitability of spruce U/S quality class was lesser than that of special qualities (Other).

In the relationship between standard and modified qualities, a two-way movement can be seen. The importance of modified special qualities will grow, if customers will get more value of them and thus are willing to pay more for them. Simultaneously, the importance of standard qualities will grow if more cost advantage can be achieved through standardisation of qualities. The observed importance of modified qualities supports the results by Usenius (1980). Usenius (1980) suggests that sawmills have got their own, fairly stable grading rules that have been formed during the centuries due to local raw material and stable relationships with customers. Therefore, sawnwood quality and quality distributions are often sawmill specific. On the other hand, Virtanen (1995) shows that Nordic timber (1994) quality classes are divided into several product-based qualities.

For pine, the relative share of standard U/S quality diminishes at the same time as the share of special quality classes increases. This can be a consequence of both the change of supply into more precise qualities and the rapid development of quality sorting processes during the time period. The systems using machine vision allow sorting to be done according to the customer specifications and it is likely that some customers are willing to pay enough for special sorting based on the U/S quality. For other standard quality classes, the situation remains the same, which may reflect the need for cost-efficient processes for these classes.

For spruce, the importance of standard classes is strong for U/S and V, but for SF and VI, most of the quality classes are modified special qualities. The only statistically significant trend was the change away from VI modified special classes towards VI standard classes. This is logical, since for VI, profitability is probably sought through quality standardisation and large volumes, even if specialisation is still strong. Furthermore, it must be noticed that no Finnish sawmill aims at producing low price and quality VI quality.

A similar tendency towards VI, which is almost significant, can be seen for SF. Quality class SF has typically been modified special quality classes, but the direction seems to be such that a certain part , possibly some 15 – 30%, of SF is made into a standard class. The change from standard sawnwood to special and customer sawnwood and further to product components can be described as in Table 48.

**Table 48. Classification of sawnwood product and quality requirements.**

| **Product** | **Product quality definition** | **Product standards** |
|---|---|---|
| **Standard sawnwood** | Standard quality | Regional or national product standards, e.g. Nordic timber (1994) or SFS 5878 (2000) |
| **Special and customer sawnwood** | Special and customer qualities | Quality agreements: product agreements between sawmill and customer |
| **Product components** | Product component quality requirements | Product component standards |

The increase of the number of quality classes is supported by Puun mekaanisen jalostuksen teknologiaohjelma (1997) (see Figure 28). The result is related to two things: (1) more specific quality requirements by customers and (2) more accurate automatic grading systems. These automatic sawnwood grading systems based on machine vision have gained lots of ground in sawnwood grading in the sawmills since the 1980s. The became more common solutions in the period from 1995 to 2000, too. It is interesting that the annual increase in the number of quality classes was more significant for pine than for spruce. This may point to a situation where there were more customer qualities for pine than for spruce. However, the reasons behind this development cannot be proved in the thesis.

As the results are reviewed it should be noted that the research materials were not standardised for the same number of sawmills during the reviewed period from 1995 to 2000. It is probable that part of the growth in modified special qualities and the increase of the number of quality classes can be explained by the increase in the amount of research materials. In addition to this, it must be said that no universal conclusions can be drawn from the presented analyses from the similar reasons listed in Section 5.1.8.

## 5.5 CSW batch size approach

The aim of this part of the thesis is to answer the following questions: (1) What were the CSW batch sizes between 1995 and 2000? (2) What was the development in batch sizes? There was a particular interest to see if there was a sawnwood market trend towards smaller batch sizes between 1995 and 2000. The volume ($m^3$) change of CSW batch sizes between 1995 and 2000 was measured by linear regression analysis in a way that the significant change was observed when $p$ is less than the limit $p = 0.05$.

The proposition to be tested in this section was the following: There was a market trend towards smaller batch sizes in sawnwood delivered from Finland between 1995 and 2000.

The average CSW batch size decreased from 456 $m^3$ to 242 $m^3$ between 1995 and 2000. Simultaneously, there was a statistically significant sawnwood market trend towards smaller batch sizes in CSW trade (Table 49).

**Table 49. The CSW batch size approach. The linear regression approach (LINREG), which indicates significant changes, was applied here.**

| | Year | | | | | | LINREG | | |
|---|---|---|---|---|---|---|---|---|---|
| **Indicator** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **R-squared** | **Year *p*-value** | **Significant change** |
| **Mean** | 455.8 | 401.7 | 415.8 | 293.6 | 259.5 | 241.9 | 0.91 | 0.0031 | Yes |
| **Standard Error** | 17.9 | 16.1 | 14.5 | 7.6 | 6.4 | 5.8 | | | |
| **Median** | 104.93 | 78.46 | 80.02 | 66.1 | 60.83 | 55.7 | | | |
| **Mode** | 5 | 3 | 4 | 50 | 50 | 4 | | | |
| **Standard Deviation** | 1,118.5 | 1,144.6 | 1,163.9 | 906.2 | 819.6 | 774.4 | | | |
| **Sample Variance** | 1,250,986 | 1,310,119 | 1,354,666 | 821,227 | 671,715 | 599,638 | | | |
| **Kurtosis** | 91.5 | 121.5 | 111.3 | 230.0 | 279.1 | 296.7 | | | |
| **Skewness** | 7.6 | 8.8 | 8.4 | 11.6 | 13.0 | 13.5 | | | |
| **Range** | 19,776.1 | 25,236.4 | 27,097.7 | 29,153.1 | 28,630.3 | 26,732.4 | | | |
| **Minimum** | 0.06 | 0.01 | 0.02 | 0.04 | 0.05 | 0 | | | |
| **Maximum** | 19,776.13 | 25,236.38 | 27,097.76 | 29,153.14 | 28,630.38 | 26,732.44 | | | |
| **Sum** | 1,784,382 | 2,032,809 | 2,696,970 | 4,147,642 | 4,285,671 | 4,274,803 | | | |
| **Count** | 3,915 | 5,060 | 6,486 | 14,126 | 16,516 | 17,671 | | | |

The decrease in the average size of sales can be a consequence of many simultaneous and coherent tendencies. Sawmills and their customers want to have a faster return on equity, because the owners and investors require improved return on investment. On the other hand, machine sorting allows smaller and yet profitable sorting batches. Possibly in addition to these, the increase of truck transportation and other prompt transportation methods directly to destination may decrease the average size of sales.

## 5.6 Price approach

The aim of this part of the thesis is to answer the following questions: (1) Is there a logical sawnwood price system that can be found for a set of sawnwood dimensions and species? If there is such a price system, how does the system work? (2) What kind of comparisons can be found from price species comparisons in the market area of Finland? (3) What kind of comparisons can be found from quality price comparisons in the market area of Finland? (4) What kind of price behaviour and distributions can be found by number of sales for sawnwood main qualities U/S, V and VI?

The proposition to be tested in this section was the following: A logical sawnwood price system can be found for a set of sawnwood dimensions and species in Finland in 2000. In this system, a specific pine dimension of 50 x 150 mm (or close to this) set a basis price, and the prices of other dimensions could be derived from the basis price. Both pine and spruce pricing used the basis price system but it was more dominant with pine.

The aim for basis price method is to give an estimation tool for analysing prices for different qualities and their relations when one of the qualities is known. The basis price method was still in use in 2000 in the Finnish sawmilling industry.

### 5.6.1 Basis price

The basis pricing tests shown here are based on a sample of CSW sales in 2000: pine and spruce – 3830 sales, pine 2126 sales and spruce 1704 sales.

#### 5.6.1.1 Basis price method

To be able to find a logical sawnwood price system for dimensions and species, at first there must an idea what kind of pricing system is sought from the sample. After this it may be possible to see how the pricing system works.

In the thesis it is assumed that there is a pricing method for coniferous sawnwood which is called basis price. In the thesis, the method is assumed to comprise of several variations but simplified to the following stages:

1. Basis species selection. Traditionally this has been pine in the Finnish sawmilling industry.
2. Basis dimension and quality selection. It is common that the basis dimension is 50 x 150 mm U/S pine or other similar dimension (like 50 x 175 mm). The basis price is fixed for this.
3. Added price for a) thickness less than this dimension b) widths more than this dimension.

### 5.6.1.2 Basis price example – exports from Finland

Pine sample for Finnish markets demonstrates that there are signs of a basis pricing method. The index has been set for pine 50 x 150 mm = 100. See Figure 68 where both thickness and width show basis price trend, with the slope growing for thicknesses from 50 mm to smaller thicknesses and for widths from 150 mm to 250 mm (Table 50).

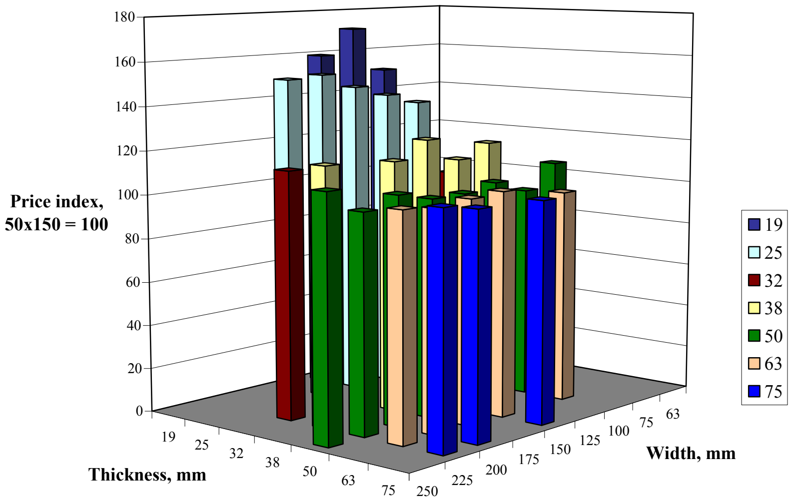


**Figure 68. An example of U/S basis prices. The indices are based on basis price hypothesis: pine U/S 50 x 150 = 100. The sample consists of pine of quality U/S from 2000. Destination country: Finland. The colours indicate thickness (mm). For figure values see Table 50.**

Figure 68, which is based on Table 50, shows an idea of a basis price system where the price is a function of thickness and width. The price decreases drastically from the most thin U/S dimension (19 mm) to the dimension of 50 mm. From 50 mm CSW to thicknesses of 75 mm, the price remains on the same level with all widths (150, 200, 225 mm) (see Table 50). For more information on basis table see Appendix 1.

**Table 50. Relative prices (€/m$^3$) for U/S and its derivates are marked on the table. The market area is Finland. An example of basis price indices of pine: price for pine of U/S 50 x 150 mm = 100.**

| | | **Width, mm** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **Thickness, mm** | **63** | **75** | **100** | **125** | **150** | **175** | **200** | **225** | **250** | **Grand Total** |
| **Q-US** | **19** | | | 150 | 171 | 159 | | | | | 160 |
| | **25** | | | 135 | 140 | 145 | 152 | 151 | | | 141 |
| | **32** | | | 102 | | | | | 113 | | 106 |
| | **38** | | | 118 | 112 | 123 | 115 | | 117 | | 117 |
| | **50** | | 108 | 97 | 103 | **100** | 100 | 104 | 99 | 110 | 102 |
| | **63** | | | 98 | | 103 | 102 | 100 | 102 | | 102 |
| | **75** | | | | | 101 | | 102 | 105 | | 104 |
| **Q-US Total** | | | 108 | 137 | 144 | 125 | 109 | 108 | 105 | 110 | 128 |
| **Q-US13** | **38** | | | | | 139 | | 0 | | | 139 |
| **Q-USSP** | **25** | | | | | | 98 | 98 | | | 98 |
| | **38** | 147 | | | | | | | | | 147 |
| | **50** | | 113 | | 113 | | | | | | 113 |
| **Q-USCCA** | **19** | | | 218 | 216 | | | | | | 217 |
| | **38** | | | | | 187 | | | | | 187 |
| **Q-USSQ** | **50** | | | 158 | | | | | | | 158 |

### 5.6.1.3 Basis prices results from 50 x 150 U/S pine

The aim of this section was to see if the basis price test works for a sample starting from 50 x 150 pine. The average price of the dimension 50 x 150 of pine U/S was given a relative value 100. All the other average values for other dimensions, pine and spruce, were calculated vis-à-vis price for 50 x 150 mm pine (Table 51).

**Table 51. The basis price test for 2000. The dimension 50 x 150 pine of U/S was given relative price value 100. All CSW was exported from Finland.**

| **Thickness** | | | |
|---|---|---|---|
| **Country** | **Species** | **Linear** | **R2 statistics** |
| **Denmark** | Pine | y = –1.9443x + 189.41 | R2 = 0.89 |
| **Germany** | Pine | y = –1.9871x + 198.59 | R2 = 0.99 |
| **Germany** | Spruce | y = –0.1493x + 91.658 | R2 = 0.36 |
| **UK** | Pine | y = –1.7004x + 179.37 | R2 = 0.92 |
| **France** | Pine | y = –1.7268x + 181.1 | R2 = 0.86 |
| **France** | Spruce | y = –0.248x + 104.49 | R2 = 0.99 |
| **NL a)** | Spruce | y = –0.0673x + 90.048 | R2 = 0.15 |
| **Italy** | Pine | y = –1.7682x + 187.4 | R2 = 0.97 |
| **Italy** | Spruce | y = –0.2814x + 95.95 | R2 = 0.69 |
| **Width** | **Species** | **Linear** | **R2 statistics** |
| **Denmark** | Pine | y = 0.256x + 57.5 | R2 = 0.71 |
| **Germany b)** | Pine | y = 0.1x + 85 | R2 = 1 |
| **Germany** | Spruce | y = –0.0676x + 94.45 | R2 = 0.11 |
| **UK** | Pine | y = 0.148x + 75.6 | R2 = 0.86 |
| **France** | Pine | y = 0.272x + 55.5 | R2 = 0.83 |
| **France** | Spruce | y = 0.0064x + 91.4 | R2 = 0.08 |
| **NL a)** | Spruce | y = 0.004x + 85 | R2 = 0.02 |
| **Italy** | Pine | y = 0.124x + 78.6 | R2 = 0.81 |
| **Italy** | Spruce | y = –0.0743x + 92.571 | R2 = 0.86 |

Notes for the table: a) Not enough data in the sample for pine. b) Only two points.

The previous table shows that both pine thicknesses and widths follow the basis price method. Spruce thicknesses also follow the basis price method but the slope is much lower than the one of pine. There is an example in Figure 69 from Denmark of the idea of the basis price method based on 50 x 150 mm pine U/S.

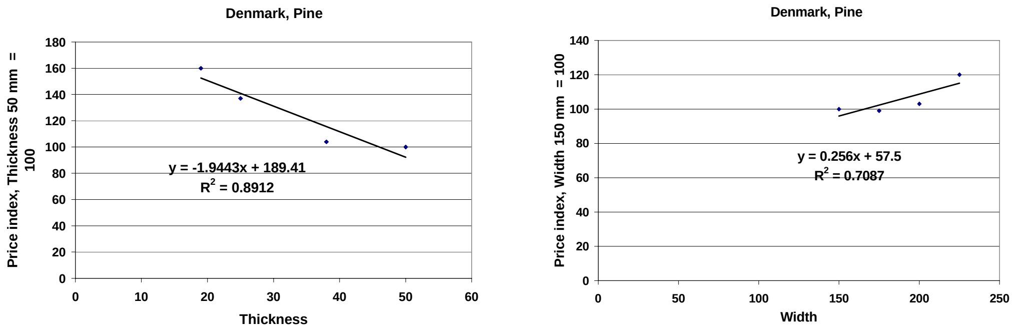


**Figure 69. An example of the basis price system. Thickness and width in the basis price system approach for pine of 50 x 150 mm from Finland to Denmark Price of 100 = thickness of 50 mm, price of 100 = width of 150 mm. See Appendix 1 for more information.**

## 5.6.2 Species price comparison - Finnish markets

The aim of this part of the thesis is to answer to the following question: what kind of comparisons can be found from price species comparisons in the market area of Finland?

The aim of this part was restricted by area, quality and dimension to a sample of CSW sales in Finland in 2000, and further restricted to three main qualities which were U/S, V and VI domestic quality. Dimensionwise, the restriction was made to include five common dimensions, which were 19 x 100, 22 x 100, 25 x 100, 50 x 100, 50 x 150 and 50 x 200 mm. The price index was set so that pine U/S 50 x 100 mm was given an price value index of 100.

According to the results, pine has higher prices than spruce except in two cases (25 x 100 quality VI and 50 x 150 quality V). The price difference between species is the largest for U/S quality (Figure 70). In pine and spruce comparison, spruce U/S was given a price value index in 2000, if pine U/S receives the value 100. However, it must be seen that in the comparison, U/S spruce had prices only for the following dimensions: 50 x 100, 50 x 125 and 50 x 150 mm.

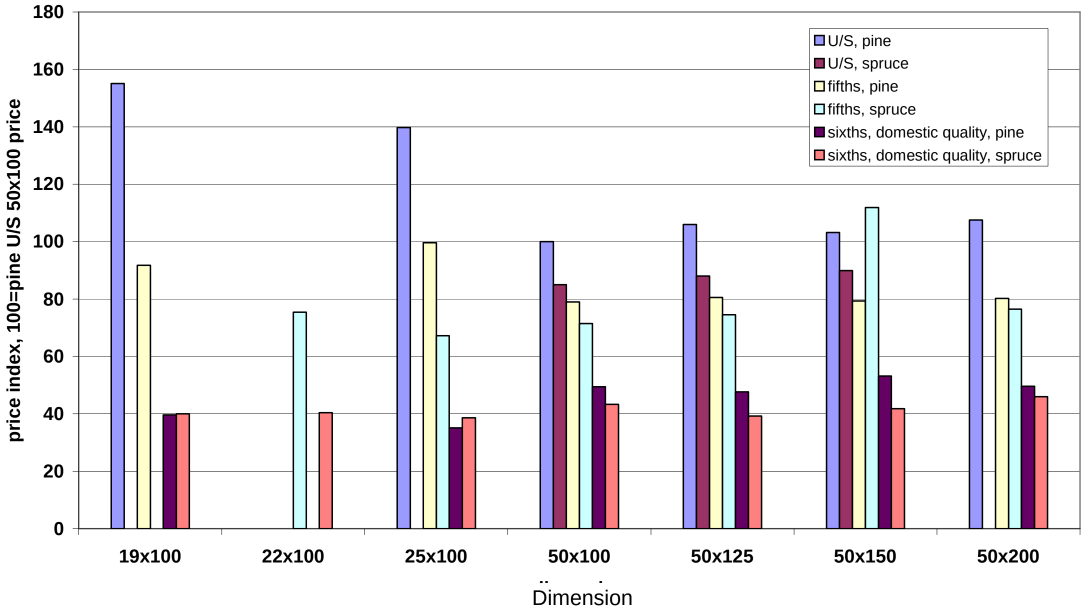


**Figure 70. The price/species comparison in Finland in 2000. The comparison consists of seven dimensions, three qualities. Pine of U/S 50 x 100 price = 100 (price €/m$^3$).**

Price species comparison is hindered by a small number of pine-spruce pairs of the same quality. For dimension 19 x 100, there is no price information of spruce qualities U/S and V as well as of pine quality VI domestic. Dimension 22 x 100 has price information for only the spruce qualities V and VI domestic.

The results support the picture of large CSW price differences between some board qualities. Moreover, the results show that there are relatively small price differences between species of the same quality in most pairs of comparison. Pine has generally higher prices than spruce but spruce can obtain a higher price than pine in some cases (e.g. 50 x 150 quality V). However, it cannot be said if this is a temporary or enduring phenomenon. Nevertheless, the results show that sawnwood price formation based on quality-dimension connection does not follow the basis price system in all cases. For more information and price relationships see Appendix 1.

### 5.6.3 Quality-price comparison – 50 x 100 pine

The aim of this part of the thesis is to answer to the following question: what kind of comparisons can be found from quality price comparisons in the market area of Finland?

There was a need to make the quality price comparison as homogenous as possible according to species, dimension and market area. For the species, it was decided to restrict comparison only to pine because pine has more qualities than spruce (Table 46). For the dimension, it was decided to select 50 x 100 because it is a common dimension and it is graded and refined to many purposes. For the market area, comparison was restricted only to Finland because the volume of sales from the Finnish sawmilling industry for Finnish markets is relatively stable and large. Moreover, there are many CSW qualities that are sold to Finnish markets. Therefore, the quality price comparison was done with a sample of 50 x 100 pine for Finnish domestic markets. The relative price was pine U/S 50 x 150 price = 100 (Figure 71).

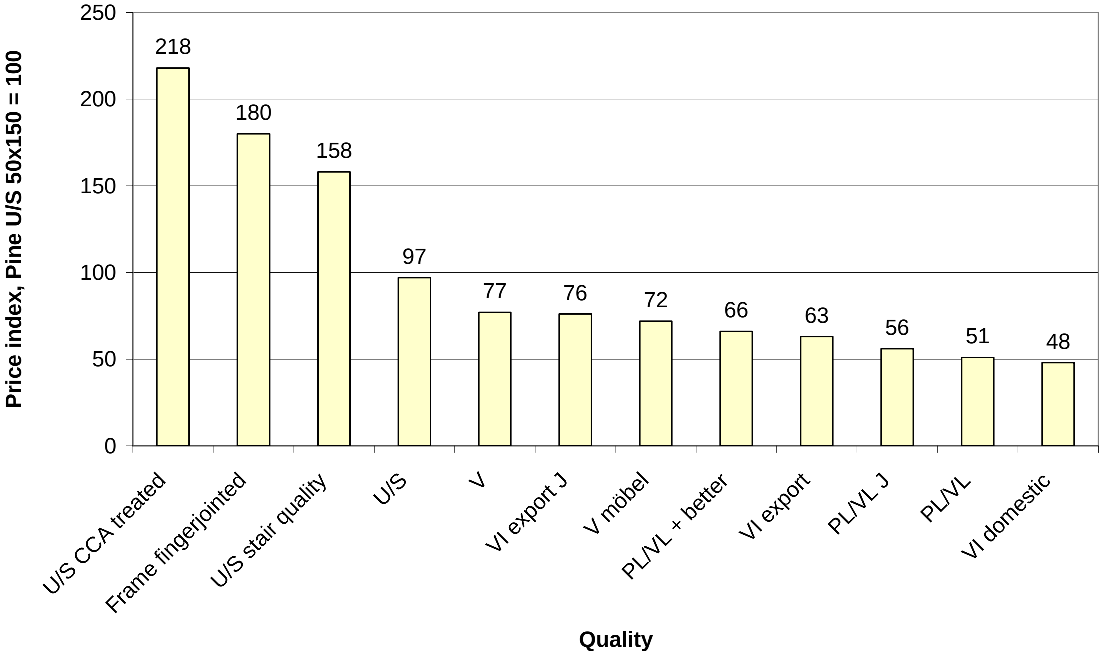


**Figure 71. Relative prices of pine 50 x 100 quality when pine of U/S 50 x 150 price = 100. The sample is Finland, year 2000.**

With the restrictions (pine, 50 x 100, sales to Finland), there were 12 qualities included in the sample. The results show that the price differences are relatively large. Refined CSW products like fingerjointed or CCA treated CSW obtain a price index of 180–218, when the standard 50 x 100 U/S receives only 97. On the other hand, there are large price differences from U/S quality to lower prices.

The results raise a question of value added to prices from refining of sawnwood. On the other hand, the results lead to ask if it is profitable to produce lower qualities like QPLVL1 or VI domestic, if their value is from 50% to 60% of the price of U/S-quality. For more information and price relationships see Appendix 1.

### 5.6.4 Price behaviour by number of sales

The aim of this part of the thesis is to answer to the following question: What kind of price behaviour and distributions can be found by the number of sales for sawnwood main qualities U/S, V and VI? Behind this aim, there is an observation that in statistics and time series, prices are often expressed as averages. However, behind an average there is normally a distribution.

The proposition to be tested in this section was the following: In the predominant quality classes (U/S, V, VI), a small number of special lots was priced differently in Finland in 2000, with a few lower and higher price classes.

In Figure 72, price formation is described according to number of sales, qualities and species. It can be observed in Figure 72 that all qualities act in a similar way. It is interesting to observe that price distributions within a quality are large. In other words, the same quality is sold with an affordable and a high price. As a consequence of this, the prices of U/S, V and VI qualities overlap to each other in part. Simultaneously, it can be observed that the sample covers some sales of U/S, V and VI qualities that are sold with the same price.

Every quality class seems to have a small sample of high price products. The Pareto principle assumption seems to apply in this context, too. Some 20% of the products make a better price class than the other 80%. Moreover, the phenomenon in Figure 72 can be described and analysed with an exponent function due to the form of the price curve.

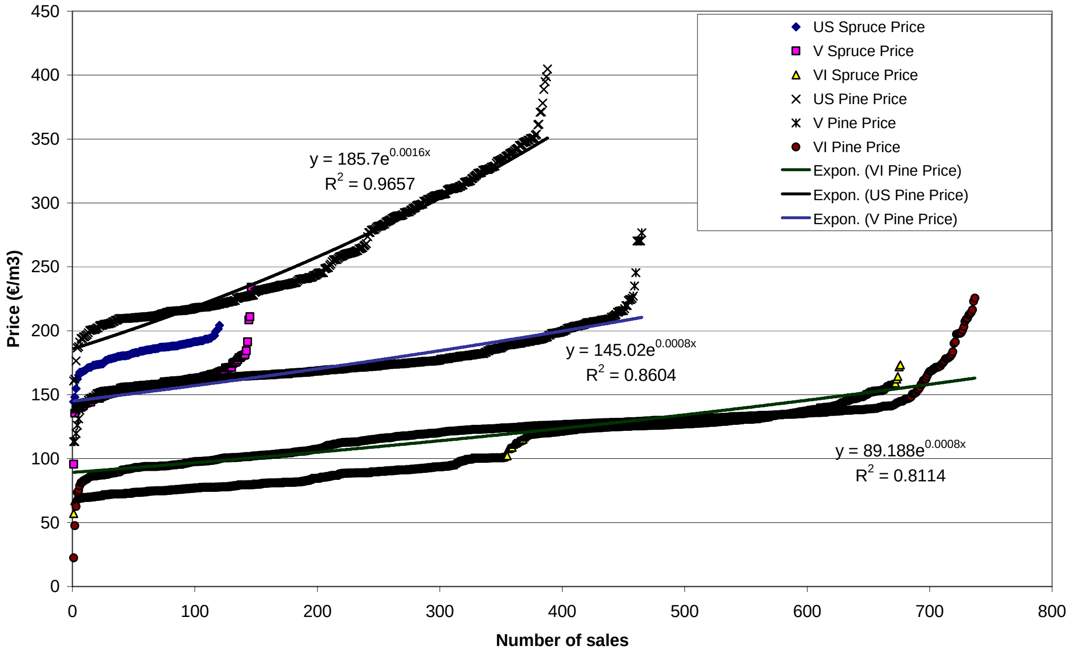


**Figure 72. Pine and spruce prices by number of sales in 2000. Data source: WPDB.**

### 5.6.5 Discussion

According to the sample, the basis price system was used in the Finnish sawmilling industry in 2000 (see Section 5.6.1) in the way Savolainen (1971) described. In the observed basis price system, sawnwood price was affected by production costs, raw material size and quality limits through dimension. The basis price system was used more for pine sawnwood pricing than for spruce. The result that sawmills operated with a basis price system still in 2000 can be considered interesting from at least two reasons. First, the result supports the picture of the stable character of operation methods in the Finnish sawmilling industry when the same pricing system was used in the 1960s and in the 2000s (see example of Table 52). Second, there has been little information available related to pricing systems in the sawmilling industries so far.

**Table 52. Example of Kemi sawmill pricing for CSW pine, year 1979, from Kemi (1979). For Ex-log, see Figure 8. The currency is FIM in 1979 values.**

| Kemi sawmill, pine | Ex-log | FIM |
|---|---|---|
| **Planks and studs** | | 1,020 |
| **38/32 mm boards** | 2 ex-log | 1,080 |
| | 4 ex-log | 1,350 |
| **25 mm side boards** | | 1,500 |
| **19 mm side boards** | | 1,610 |

There is nothing new in the result that pine has higher prices than spruce (see Sections 5.6.2 and 5.6.4), but there has not been much similar information of pine and spruce price comparison based on their qualities. Furthermore, there were some interesting and illogical exceptions to the basis price system as, for instance, a single price of spruce V quality (see Figure 71). Sawnwood prices for species are perhaps influenced by supply derived factors, such as construction cycles in some market areas. Moreover, sawnwood prices are influenced by the price relationship between pine and spruce logs as well as the value relationships for log quality and size (see Figure 73).

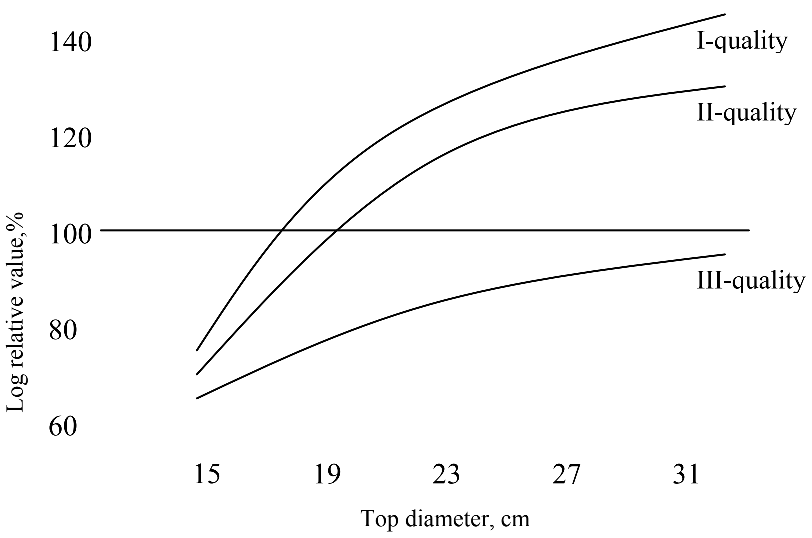


**Figure 73. The value relationships for pine log quality and size. Log with top diameter 19 cm and II-quality = 100 (Pelkonen 1986 and Paajanen 1997).**

The result of large price differences between quality classes cannot be seen as a new result (Section 5.6.3). However, there has not been much information available on the prices of other qualities than traditional U/S, V and VI. The results show good reasons to improve sawnwood selling price by refining. Nevertheless, sawnwood refining requires recognition of user needs, user segmentation and information of quantity and quality variables of supply.

The price distributions of pine and spruce (Section 5.6.4) for main qualities U/S, V and VI describe price differences between the main qualities and, on the other hand, overlap of prices between the main qualities. The idea that pine U/S quality has a higher price than pine VI quality is probable but not absolutely sure because the distributions overlapped. The result that quality class price curves are similar to exponential curves in the higher prices of a quality class can be seen interesting. On the other hand, the average export prices and amounts ($m^3$) have remained fairly stable (Figure 74).

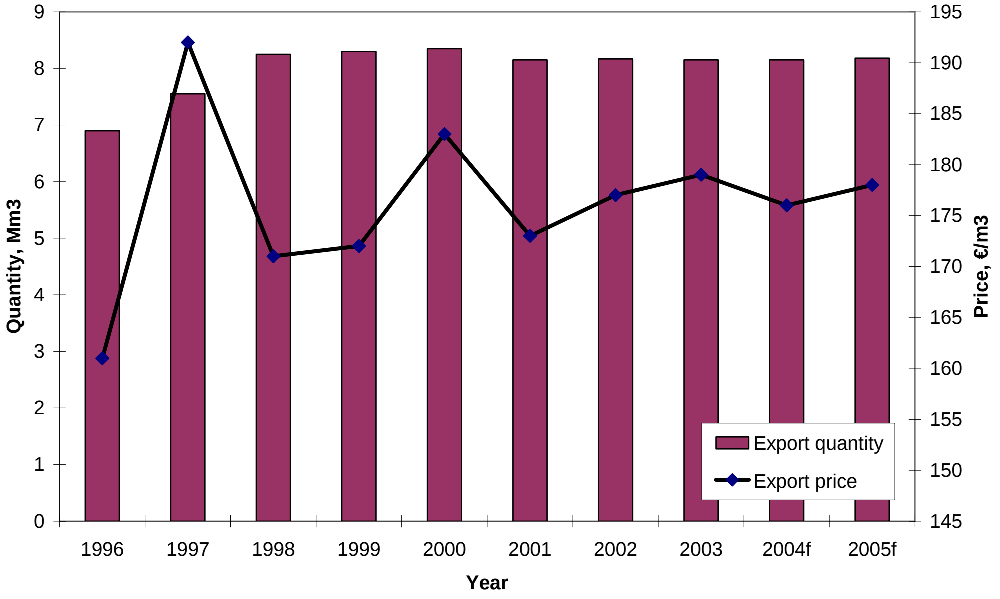


**Figure 74. Export quantity (Mm3) and price (€/m3) of sawnwood from Finland. Source information and estimations for 2004 and 2005 by Pellervo economic research institute PTT (PTT 2004).**

However, it must be said that no universal conclusions can be drawn from the presented analyses from the similar reasons listed in Section 5.1.8.

## 5.7 *Segment approach*

### 5.7.1 Aim and results

The aim of this part of the thesis is to answer the following question: How does the product segmentation work between the Finnish sawmills and the markets that the sawmills find important? Behind this aim, there is an assumption that the sawmills would like to move from an obscure distribution segment that can be seen as it is named, product segment, to more specific product segments like furniture, joinery, planing and strength grading. These four – furniture, joinery, planing and strength grading – can be seen as product segments.

The proposition to be tested in this section was the following: Sawmills had not completed their user segmenting strategies in Finland in the years 1998–2000. They used a user segment system in their sales but still divided most of their production into the distribution segment as a general segment instead of more specified joinery, furniture, planing and strength grading segments.

This part of thesis was restricted to the following seven countries: Finland, Denmark, Germany, UK, France, NL and Italy. The most important criteria for the selection of these countries was their importance to the Finnish sawmilling industry. The time period was selected between 1998 and 2000, because there was more information on these segments in WPDB. Denmark was an exception among the selected countries because there was enough segment information on Denmark only for pine sales in the year 2000.

Product segments for CSW exported from Finland into some countries show that the distribution segment is still a dominant segment in most combinations of country and species (Table 53). Distribution seemed to be the largest product segment in Finland (Table 53), UK and the Netherlands for both species in 1998–2000.

According to the results (see Table 53), the furniture segment is a small pine product segment in the seven countries in the study. The Finnish sawmilling industry used furniture segment in their product segmentation of pine sales proportionally the most in the Netherlands (31%) and Denmark (14%). Furniture segment was not used or was used little in the sales to the following countries: Germany, UK, France, Italy. From species perspective, furniture seems to be a product segment which is used for the user segmentation of pine. In spruce user segmentation, the Furniture segment is used little.

**Table 53. CSW product segments in seven European countries. All CSW has been exported from Finland. No blank segment information has been included in samples.**

| | | **Product segments** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Country** | **Species** | **Distribution** | **Furniture** | **Joinery** | **Planing** | **Strength Grading** | **Total** | **Sample, m$^3$** | **Years** |
| **Finland** | **Pine** | 80% | 6% | 1% | 12% | 1% | 100% | 661,199 | 1998–2000 |
| | **Spruce** | 75% | 1% | 0% | 21% | 3% | 100% | 692,757 | 1998–2000 |
| **Denmark** | **Pine** | 76% | 14% | 9% | 0% | 0% | 100% | 144,126 | 2000 |
| | **Spruce** | | | | | | | a) | |
| **Germany** | **Pine** | 25% | 1% | 52% | 23% | | 100% | 68,150 | 1998–2000 |
| | **Spruce** | 7% | 2% | 0% | 91% | 0% | 100% | 253,865 | 1998–2000 |
| **UK** | **Pine** | 94% | 0% | 6% | | 0% | 100% | 349,110 | 1998–2000 |
| | **Spruce** | 47% | 0% | 1% | | 52% | 100% | 159,452 | 1998–2000 |
| **France** | **Pine** | 26% | | 17% | 11% | 46% | 100% | 71,078 | 1998–2000 |
| | **Spruce** | 49% | | 3% | 17% | 31% | 100% | 387,753 | 1998–2000 |
| **NL** | **Pine** | 69% | 31% | | | | 100% | 51,045 | 1998–2000 |
| | **Spruce** | 99% | 0% | | | 1% | 100% | 243,113 | 1998–2000 |
| **Italy** | **Pine** | 44% | 0% | 49% | 7% | | 100% | 78,879 | 1998–2000 |
| | **Spruce** | 40% | | 57% | 3% | | 100% | 8,859 | 1998–2000 |

a) no relevant segment information.

Joinery was the largest segment in Italy for both species and in Germany for pine. For the joinery product segment, UK and France were countries where this segment was used only in a limited scale. When joinery segment was used, it was often used for pine user segmentation. It is interesting to observe that there was no use for joinery segmentation in sales to the Netherlands. Moreover, joinery segmentation was used little in sales to Finland. Joinery segment was used in a limited scale in spruce segmentation, except in Italy, where it was used relatively much (57%). However, the volume ($m^3$) of spruce sales to Italy was low (8859 $m^3$) in the sample.

Planing was the largest segment for spruce CSW to Germany. Planing was used as a product segment in Finland, Germany, France and Italy. In the sales of the Finnish sawmilling industry to Denmark, UK and to the Netherlands, planing was used little as a product segment.

Strength grading was the largest product segment for UK spruce and France pine. From species perspective, both of these country and segment combinations (UK spruce and France pine) had smaller sales volumes ($m^3$) than the other species to their destination country. In sawnwood sales in the UK, pine is the dominant species and in France, the volume of sawnwood sales ($m^3$) consists mostly of spruce.

There was lots of variation in the development of product segments between the selected seven (7) countries from 1998 to 2000. Big changes of sales from a product segment to another segment took place for instance in the sales to UK and France (see Table 54). Nevertheless, in Finland the coniferous sawnwood segmentation remained fairly stable in product segmentation in the period from 1998 to 2000 (see Table 54).

**Table 54. CSW segment development 1998–2000 from Finnish sawmills. Data source: WPDB. Countries: Germany (DE), Finland (FI), France (FR), United Kingdom (UK).**

| Country | Segment | 1998 | 1999 | 2000 | Total |
|---|---|---|---|---|---|
| **DE** | **Distribution** | 2% | 3% | 5% | 2% |
| | **Furniture** | 1% | 1% | 1% | 1% |
| | **Joinery** | 2% | 4% | 4% | 3% |
| | **Planing** | 19% | 29% | 21% | 18% |
| | **Srength Grading** | 0% | 0% | 0% | 0% |
| | **No segment information** | 76% | 63% | 69% | 77% |
| | **Total, %** | 100% | 100% | 100% | 100% |
| | **Sample, $m^3$** | 365,167 | 379,202 | 327,756 | 1,401,472 |
| **FI** | **Distribution** | 41% | 52% | 52% | 38% |
| | **Furniture** | 2% | 2% | 2% | 2% |
| | **Joinery** | 1% | 0% | 0% | 0% |
| | **Planing** | 9% | 12% | 9% | 8% |
| | **Srength Grading** | 2% | 1% | 2% | 1% |
| | **No segment information** | 45% | 33% | 35% | 51% |
| | **Total, %** | 100% | 100% | 100% | 100% |
| | **Sample, $m^3$** | 574,033 | 862,934 | 867,974 | 2,997,570 |
| **FR** | **Distribution** | 16% | 11% | 35% | 14% |
| | **Joinery** | 1% | 1% | 5% | 2% |
| | **Planing** | 6% | 7% | 8% | 5% |
| | **Srength Grading** | 16% | 26% | 0% | 10% |
| | **No segment information** | 61% | 54% | 52% | 70% |
| | **Total, %** | 100% | 100% | 100% | 100% |
| | **Sample, $m^3$** | 341,130 | 378,209 | 354,768 | 1,573,590 |
| **UK** | **Distribution** | 22% | 31% | 30% | 19% |
| | **Furniture** | 0% | 0% | 0% | 0% |
| | **Joinery** | 3% | 1% | 1% | 1% |
| | **Srength Grading** | 11% | 13% | 12% | 8% |
| | **No segment information** | 64% | 55% | 57% | 72% |
| | **Total, %** | 100% | 100% | 100% | 100% |
| | **Sample, $m^3$** | 464,464 | 544,359 | 499,060 | 2,271,461 |

### 5.7.2 Discussion

The research result of segmentation, the emphasis on the distribution segment, indicates a situation where sawmills do not like to link or are not able to link sales information with more specific user or product segment. When evaluating the segmentation results, it must be said that the distribution segment is, as it is named, a distribution segment, and the four other segments are product or user segments. Moreover, in this context there is not assumed to be a difference between product and user segments.

In the seven countries of the segmentation study, product segmentation was more developed in the sales of the Finnish sawmilling industry to the markets of Germany. Moreover, product segmentation was fairly developed in the sales to France and Italy. Generally, the results indicate that product and user segmentation in the Finnish sawmilling industry was not yet developed according to products and users in destination countries in 2000.

When the segmentation of sales result is compared with the connection presented by Juslin and Hansen (2002) (see Table 55), the markets in Germany seemed to be in the stage Special products – Few specified segments in 2000. The markets of France and Italy seemed to move to this direction but are still behind the product segmentation situation in the sales to Germany. Still, it must be said for other markets that they were probably at least partially in the stage Commodity products – As many as possible.

**Table 55. Connection between product and customer strategies by Juslin and Hansen (2002, p. 304).**

| PRODUCTS | CUSTOMERS | | |
|---|---|---|---|
| | As many as possible | Few specified segments | Known end-users |
| Commodity | ○○○ | ○○ | ○ |
| Special | ○ | ○○○ | ○○ |
| Custom-made | ○ | ○ | ○○○ |

○○○ Optimal, ○○ Possible, ○ Illogical

Regarding the distribution segment, the results of segmentation approach raise the question why the product segment with the largest volume, construction segment, was apparently considered a part of the distribution segment between 1998 and 2000. It is probable that if the construction segment could have been separated from the distribution segment as one construction segment or as a set of smaller segments, the segmentation and market planning processes in the Finnish sawmilling industry could be much more accurate. There is lots of information available on wood and sawnwood use in construction, segmentation, products and quality requirements in these seven and many other user countries of coniferous sawnwood (e.g. Germany in Forest 1998, and North America in Williamson (ed.) 2002 and Wood 1999).

On the other hand, it must be said that no universal conclusions can be drawn from the presented analyses from the similar reasons listed in Section 5.1.8.

## 5.8 Examples of analysing factors affecting coniferous sawnwood supply distributions

Three examples to analysing factors affecting sawnwood supply distributions are applied in this section. These three examples are (1) end moisture content, (2) batch size, and (3) price. All data leading to the results of this section are based on Wood Product Database WPDB.

The propositions to be tested in this section were the following:

1. Sawnwood supply distributions consisted primarily of the supply of standardised sawnwood in Finland in 2000. The number of special products was still small. Sawnwood supply can be estimated with both logistic and linear regression analyses.
2. Sawnwood supply can be analysed by end moisture contents as well as batch sizes and prices. It is possible to create logistic and linear regression analyses for sawnwood supply distributions with the database approach.

## 5.8.1 Factors affecting CSW end moisture content

### 5.8.1.1 Why end moisture content?

Correct moisture content is among the qualities that buyers appreciate increasingly. The reason for this lies in the fact that if timber is delivered at a moisture content that is far from the end moisture content, the change in moisture content will cause deformations and other defects.

The dryness and drying quality is determined by several factors such as the end moisture content after drying, moisture gradient and drying defects (e.g. Forsén and Tarvainen 2003). Sawnwood drying is a complicated process in which optimisation, sawnwood quality and process technology are closely linked (e.g. Salin (1990, 2000 and 2001), Morén (1993), Rosenkilde 2002). Sawmills give their customers information of CSW end moisture content after drying in connection with every sale. Therefore, the end moisture content (MC) was chosen as the classifying variable by which CSW dryness was measured.

The dependence of end moisture content on other classified variables of sales was analysed. The aim was to explain factors affecting CSW sales with a specific end moisture content (MC) class. All the sales in the sample were made with a specific MC class. Moisture content classes in the models were MC8, MC10, MC12, MC14, MC18, where the number indicates moisture content in % (mass of water/mass of CSW). The moisture content is the final average moisture content of the batch.

### 5.8.1.2 Results

The results for factors affecting CSW end moisture content in 2000 can be seen in Table 56. Positive coefficients (COEF) indicate that these variables have a positive correlation between a variable and end moisture content class. Negative coefficients indicate that the variables reject supply for specific moisture content.

Results can also be expressed so that there is a relationship between response variable (y, in this section MC class of the sales in the sample) and explanatory variables (x, other variables) to the direction addressed by the sign of a coefficient. If the sign of a coefficient of an explanatory variable is positive, an explanatory variable expresses the strengthening effect on MC class by an external factor.

**Table 56. Factors affecting CSW end moisture content in 2000. Five end moisture content supply models with database approach, y = MC class of the sales. Sample: 14,469 CSW sales. Year: 2000. Method: Binary Logistic Regression, forward selection. B = regression coefficient. Stepping method criteria: use probability of F, PIN: 0.01, POUT: 0.02.**

| Variable No | MC8 | B | MC10 | B | MC12 | B | MC14 | B | MC18 | B |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | C-DE | 2.689 | C-DE | 2.340 | C-DE | 0.971 | C-DE | 3.052 | C-DK | –0.653 |
| **2** | C-DK | 2.691 | C-DK | 2.409 | C-DK | 1.484 | C-FI | 2.046 | C-ES | –0.880 |
| **3** | C-FI | 2.887 | C-FI | 1.988 | C-FI | 0.888 | C-NL | 3.685 | C-FI | –0.348 |
| **4** | C-IE | 2.374 | C-JP | 2.227 | C-GB | –1.048 | SOUTH | –2.701 | C-GB | –0.740 |
| **5** | PINE | 2.341 | PINE | 1.881 | C-IT | 1.265 | S-DIST | 1.624 | C-IE | –0.891 |
| **6** | Q-SF | 1.505 | Q-SF | 1.233 | C-JP | 1.423 | S-STGR | 3.605 | C-NL | –0.322 |
| **7** | SOUTH | 2.303 | Q-US | 0.648 | EAST | –1.909 | T-47 | 2.319 | EAST | –7.684 |
| **8** | S-DIST | 1.143 | S-DIST | 1.628 | PINE | 2.401 | T-50 | 1.232 | PINE | 0.341 |
| **9** | S-FUR | 1.403 | S-FUR | 2.637 | Q-SF | 0.972 | T-63 | 2.011 | Q-SIDE | –0.413 |
| **10** | T-50 | 2.396 | S-PLAN | 1.299 | Q-US | 1.182 | T-75 | 1.869 | Q-STGR | 5.368 |
| **11** | T-63 | 0.996 | T-19 | –1.195 | S-DIST | 0.571 | Constant | –9.158 | Q-VI | 0.333 |
| **12** | WEST | 1.614 | T-50 | 0.426 | S-JOI | 1.635 | | | SOUTH | –3.562 |
| **13** | W-200 | –2.325 | WEST | –1.014 | T-19 | –2.528 | | | S-DIST | 1.152 |
| **14** | Constant | –9.419 | W-175 | –2.275 | T-25 | –1.697 | | | S-FUR | –0.633 |
| **15** | | | W-200 | –2.558 | T-32 | –2.023 | | | S-JOI | 0.563 |
| **16** | | | W-225 | –1.470 | T-63 | 1.058 | | | S-PLAN | 1.288 |
| **17** | | | Constant | –1.758 | T-75 | 0.835 | | | S-STGR | 3.594 |
| **18** | | | | | W-100 | –1.113 | | | T-19 | 0.387 |
| **19** | | | | | W-125 | –1.068 | | | T-22 | 0.518 |
| **20** | | | | | W-150 | –2.291 | | | T-25 | 0.326 |
| **21** | | | | | W-175 | –1.624 | | | T-44 | 0.464 |
| **22** | | | | | W-200 | –2.132 | | | T-63 | –0.234 |
| **23** | | | | | W-225 | –2.916 | | | WEST | –6.168 |
| **24** | | | | | Constant | 11.861 | | | W-100 | 0.807 |
| **25** | | | | | | | | | W-125 | 0.750 |
| **26** | | | | | | | | | W-150 | 0.726 |
| **27** | | | | | | | | | W-175 | 0.772 |
| **28** | | | | | | | | | W-200 | 0.625 |
| **29** | | | | | | | | | W-225 | 0.418 |
| **30** | | | | | | | | | Constant | –0.188 |

With Stepwise regression, all MC class models require at least 10 steps. MC18, the biggest MC class model measured in the amount of data, requires 29 steps and ends with a constant term and 29 statistically significant variables. The sample sizes of MC class models vary widely. MC14, the smallest of the models, is composed of only 59 sales with the MC 14% whereas MC18 is composed of 7113 sales.

Validation and reliability for end moisture content class models are shown in Table 57.

**Table 57. Validation and reliability for five end moisture content models. Method: Binary Logistic Regression, forward selection. Forward (Wald). Maximum Iterations 100. Stepping method criteria: use probability of F, PIN: 0.01, POUT: 0.02. Contrast: Indicator. Reference Category: First. Degrees of freedom (Hosmer and Lemeshow): 8. All are categorical variables except quantity and constant. For more information see Appendix 3.**

| Indicator | MC8 | MC10 | MC12 | MC14 | MC18 |
|---|---|---|---|---|---|
| Number of steps | 13 | 16 | 25 | 10 | 29 |
| Number of observations | 182 | 211 | 281 | 59 | 7,113 |
| Cox & Snell  R2 | 0.046 | 0.038 | 0.064 | 0.014 | 0.355 |
| Nagelkerke R2 | 0.366 | 0.266 | 0.366 | 0.269 | 0.473 |
| Hosmer and Lemeshow goodness-of-fit | 23.594 | 7.353 | 23.837 | 7.061 | 107.633 |
| *p*-value of goodness-of-fit (Hosmer and Lemeshow) | 0.003 | 0.499 | 0.002 | 0.530 | 0.000 |

### 5.8.1.3 Interpretation of empirical results

General

According to Cox & Snell and Nagelkerke R-squared values (see Table 57), results for MC18 analysis are fairly good. Likewise, the results for MC8 and MC12 models are good according to Nagelkerke R2 statistics (MC8 – R2 0.366). According to Hosmer and Lemeshow goodness-of-fit (HaL gof), the results show that models for MC10, MC14 and MC16 are good (*p* of gof (HaL) over 0.05) but that the other MC models are poor. This indicates a poor fit for MC8, MC12, MC18 and MC20 according to this indicator.

End moisture content 8%

The results in Table 56 show that sawnwood of the moisture content class MC8 is likely to be pine (B 2.341). At the same time, it can be observed that the end uses in Germany, Finland, Denmark and Ireland value this low moisture content class the most (Table 58). These countries have traditionally been important users of Finnish pine timber in the furniture and planing segments. This picture of the supply is also supported by the result (see Table 56) according to which the furniture, distribution and planing are those end uses in which low moisture content is appreciated the most. The MC8 sales in 2000 were likely to be thickness dimensions of 50 or 63 mm but not the width of 200 mm. The MC8 CSW in 2000 likely came from sawmills of south or west parts of Finland (South 2.303, West 1.614).

The result is also logical from the point of view of supply because wide or only 25 mm thick timber with MC8 is not profitable because of its tendency of deformation, shakes and other drying defects. On the other hand, it is profitable to produce timber with MC8 for the markets of Germany, Denmark, Ireland and Finland, mainly from pine with quality class SF. The segments favouring MC8 are furniture and distribution. Thickness is typically 50 or 63 mm, but the width can vary.

To illustrate the effect of one per cent change of several variables to MC8 supply in the Finnish sawmilling industry, there is an example of interpretation of empirical results in Table 58. According to the example in Table 58, the supply of MC8 sawnwood in the Finnish sawmilling industry is sensitive to changes in four countries (Germany, Finland, Denmark and Ireland). Nevertheless, a combination of changes may cause a direct and significant effect to sawnwood supply. If it is assumed that there is a simultaneous one per cent (1%) increase or decrease of sales, the effect to MC8 sawnwood supply from the Finnish sawmilling industry may be even 10% as shown in Table 58. For example, if there would be one per cent more quality SF sawnwood demanded, this would cause some 1.5% increase of MC8 sawnwood sales in Finnish sawmills.

**Table 58. Effect of one per cent change of several variables to MC8 supply in the Finnish sawmilling industry. Example of interpretation of empirical results.**

|  |  | Species effect | Quality effect | Segment effect | Thickness effect |
|---|---|---|---|---|---|
| Country indicator | Country effect | Pine | Q-SF | S-DIST | T-50 |
| C-DE | 2.689 | 2.341 | 1.505 | 1.143 | 2.396 |
| C-DK | 2.691 | 2.341 | 1.505 | 1.143 | 2.396 |
| C-FI | 2.887 | 2.341 | 1.505 | 1.143 | 2.396 |
| C-IE | 2.374 | 2.341 | 1.505 | 1.143 | 2.396 |

Of course there are severe reservations of the approach in Table 58:

- The future is assumed to be similar than in year 2000 when the sample of sawnwood sales was taken, and it is clear that there is no similar future than history.
- There are probably more variables that have significant effect to the research object.
- The effect of one per cent change is limited only to (1) given variables (2) MC8 supply and (3) the Finnish sawmilling industry.
- Correlations between variables cannot be eliminated.

### End moisture content 10%

The sawnwood with MC10 is likely to be pine (B 1.881). At the same time, it can be observed that the markets of Germany, Denmark, Finland and Japan appreciate end moisture content MC10 the most. The user segments are likely to be furniture (B 2.637), planing (B 1.299) and distribution (B 1.628).

MC10 sales did not likely include thickness of 19 mm nor widths of 175, 200 and 225 mm. The MC10 CSW in 2000 was either not likely to be produced in sawmills of West part of Finland (West –1.014).

The results of the MC10 supply correspond to the general opinion. Sawnwood of MC10 is often produced for indoor use with special dimensions and qualities. The species is likely to be pine and destinations Denmark, Germany or Finland. Furniture, planing and distribution segments are the typical users.

### End moisture content 12%

MC12is likely to be pine (B 2.401). Furthermore, MC12 is appreciated by CSW users in Germany, Denmark, Finland, Italy and Japan. These countries have traditionally been important users of Finnish pine timber in joinery and distribution segments. Statistically the most important segment for MC12 is the joinery segment (B 1.635).

The MC12 sales in 2000 were likely to be standard U/S (B 1.182) or SF (0.972) qualities. However, MC12 sales were not likely to be thickness dimensions of 19, 25 or 32, rather the likely thicknesses were 63 or 75 mm. Moreover, MC12 sales were not standard widths of 100, 125, 150, 175, 200 or 225 mm. Thus it can be said that MC12 is likely to be an end moisture class of special widths.

The results are logical, since MC 12% is produced for special indoor uses and often with special widths. Typical uses are windows, doors and stairs. The fact that the likely species in this moisture content class is pine is a long tradition in the joinery branch, which is traditionally country and segment specifically specialised to a certain species.

### End moisture content 14%

The sawnwood of MC14 can be of pine or spruce. The supply of MC14 follows the changes in supply of markets in Germany, the Netherlands, Finland and Japan. Statistically the most important country for MC14 in 2000 was the Netherlands (B 3.685). End-user segments were likely to be distribution and strength grading. MC14 sales were likely to be of thickness dimensions of 47, 50, 63 or 75 mm.

### End moisture content 18%

The supply of MC18 is the largest of the sample. MC18 CSW is more likely to be pine than spruce (B 0.341).

Timber of MC18 is sold to many countries. Nevertheless, according to the results the following countries are not typical destination countries of MC18: Denmark, Spain, Finland, UK, Ireland and the Netherlands. Thus, these countries bought something else than MC18 sawnwood in 2000.

In the MC18 sales in 2000 there were likely to be strength graded qualities. The MC18 sales were likely to have standard thickness dimensions of 19, 22, 25 and 44 mm but not thickness of 63 mm. The MC18 were likely to have standard widths of 100, 125, 150, 175, 200 and 225 mm.

The result which indicates that MC18 was not likely to be produced in the East, the West or the South suggests that sales without location information produce CSW with MC18. Results give evidence that MC18 supply likely comes from distribution (B 1.152), joinery (B 0.563), planing (B 1.288) and strength grading segments (B 3.594) but not from furniture segment (B –0.633). This supports the result that MC18 supply is linked to standard dimensions and qualities.

#### 5.8.1.4 Discussion

The thesis results emphasise the dependency of the supply of coniferous sawnwood moisture content classes on certain factors such as countries, dimensions and segments. In general it can be stated that the results strengthen the picture that supply of moisture classes is fragmented. This is due to variability between the classes. Standard thicknesses, widths and qualities are linked to moisture classes that have large volumes ($m^3$, e.g. moisture class of MC18). This strengthens the picture that there is a difference between the supply profile of coniferous standard and special products.

It is interesting to note that the analysis for MC18, which have plenty of data for the models), have poor goodness-of-fit measures. Causes for this could not be found. However, in order to create better models it might be useful to aim at defining more accurate moisture content classes of MC18.

Still, it must be said that no universal conclusions can be drawn from the presented analyses from the similar reasons listed in Section 5.1.8. In addition to this, the problems and dangers of stepwise procedures as well as data mining should be taken into account as listed in 3.6.5.3.

#### 5.8.1.5 Testing logistic regression models

##### *5.8.1.5.1 Testing results*

The logistic regression models were tested by comparing observed and predicted values. The results can be seen in classification Table 59. Percentage correct indicates ability of a model to both recognize (no) and explain variables (yes). Overall percentage indicates overall goodness of the model.

The main objective was not to classify sales by the probability of moisture content, quality class or user segment. Rather the goal was to quantify each factor affecting CSW supply on a ceteris paribus, i.e. all other things being equal, basis, and therefore the commonly preferred cut value point of 0.5 was chosen (Table 59).

**Table 59. A classification table. The cut value is 0.500. Step indicates the step where the model requirements were met.**

| Step | Observed | | Predicted | | Percentage Correct | Overall Percentage |
|---|---|---|---|---|---|---|
| | | | No | Yes | | |
| 13 | MC8 | No | 14,279 | 8 | 99.9 | 98.7 |
| | | Yes | 178 | 4 | 2.2 | |
| 16 | MC10 | No | 14,249 | 9 | 99.9 | 98.5 |
| | | Yes | 210 | 1 | 0.47 | |
| 25 | MC12 | No | 14,177 | 11 | 99.92 | 98.4 |
| | | Yes | 220 | 61 | 21.7 | |
| 10 | MC14 | No | 14,409 | 1 | 99.99 | 99.6 |
| | | Yes | 59 | 0 | 0 | |
| 29 | MC18 | No | 5,740 | 1,616 | 78.0 | 75.8 |
| | | Yes | 1,891 | 5,222 | 73.4 | |

The overall rate of correct classification of variables was estimated to be varying between 75.8 and 99.6%, being the lowest with the largest subset MC18 and the highest with the smallest subset MC14. Nevertheless, the percentage correct to explain variables for small subsets was generally low but for a large subset of MC18 fairly good (73%).

The classification accuracy with percentage correct to recognize the variables of the model (no column) is generally good. However, the ability of the analysis to explain variables (yes column) ranges from poor (e.g. MC8) to good (e.g. MC18). Overall percentage indicates the overall goodness of the model.

#### *5.8.1.5.2 Discussion*

The classification results in Table 59 indicate good results for models to observe correct sales cases. Still, the models have some problems in explaining sales cases. The situation is similar to Figure 75 where model 1 gives good results in identification but poor results in explanation. Consequently, there is a need for model 2 to explain the results.

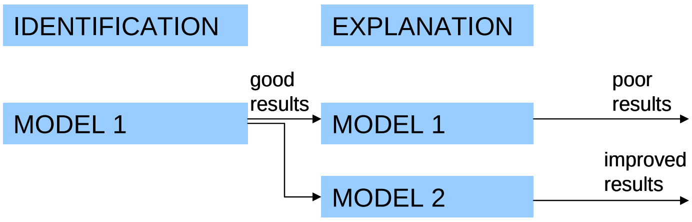


**Figure 75. Model classification results. Model 1 means that the model is good for identification but poor for explanation. Model 2 is needed for improving the explanation.**

The results may be affected by classification sensitivity to group sizes. Pindyck and Rubinfeld (1998) point out that classification is sensitive to the relative size of the two component groups and will always favour classification into the larger groups. In addition to this, the problems and dangers of stepwise procedures as well as data mining should be taken into account as listed in Section 3.6.5.3.

## 5.8.2 Factors affecting CSW batch size

### 5.8.2.1 Aim and execution

The aim was to create three batch size supply models that would explain factors affecting CSW batch sizes in 2000. The sample consisted of 14,469 CSW sales in 2000. The method applied here was stepwise multiple regression with maximum iterations of 100.

### 5.8.2.2 Results

The results of models can be seen in Table 60. The models are based on batch size ($m^3$) data of sawnwood sales.

**Table 60. CSW supply batch size models. The method used for the models was stepwise multiple regression, forward selection. Stepping method criteria: use probability of F, PIN: 0.01, POUT: 0.02. Unit for y (batch size) is $m^3$. No = Number of variable, B = regression coefficient.**

| | PINE AND SPRUCE | | PINE | | SPRUCE | |
|---|---|---|---|---|---|---|
| **Variables, No** | | **B** | | **B** | | **B** |
| **1** | (Constant) | 183.278 | (Constant) | –81.829 | (Constant) | 124.293 |
| **2** | C-DZ | 259.413 | C-DZ | 714.183 | C-DE | 1221.038 |
| **3** | C-EG | 123.021 | C-EG | 235.609 | C-FR | 373.864 |
| **4** | C-ES | –65.395 | C-GB | 654.203 | C-JP | 513.474 |
| **5** | C-FI | –93.844 | C-MA | 1534.632 | C-NL | 407.276 |
| **6** | C-IL | 83.897 | C-SA | 559.492 | MC16 | –1033.144 |
| **7** | MC16 | 94.715 | C-TN | 524.797 | Q-LAMA | 1060.251 |
| **8** | MC20 | –33.292 | Q-LAMA | 1570.094 | Q-PLVL1 | 2648.279 |
| **9** | MC8 | 90.385 | Q-PLVL1 | 1657.112 | Q-SF15 | 791.977 |
| **10** | PINE | –45.589 | Q-SFMB | 768.249 | | |
| **11** | Q-SF | 85.219 | Q-V | 315.334 | | |
| **12** | Q-SIDE | 250.180 | Q-VA | 640.523 | | |
| **13** | Q-STGR | 290.829 | Q-VIE | 310.102 | | |
| **14** | Q-V | 48.369 | T-50 | 344.423 | | |
| **15** | S-FUR | 101.290 | W-100 | 400.793 | | |
| **16** | S-STGR | 155.981 | W-150 | 205.896 | | |
| **17** | T-22 | 95.346 | | | | |
| **18** | T-32 | –33.174 | | | | |
| **19** | T-50 | 54.246 | | | | |
| **20** | W-100 | 74.261 | | | | |
| **21** | W-175 | –56.085 | | | | |
| **22** | W-200 | –38.750 | | | | |
| **23** | W-225 | –41.539 | | | | |
| **24** | WEST | –39.928 | | | | |

Validation and reliability for batch size models are shown in Table 61.

**Table 61. Validation and reliability of batch size models. For more information see Appendix 5.**

| Indicator | PINE AND SPRUCE | PINE | SPRUCE |
|---|---|---|---|
| **Number of steps** | 23 | 15 | 8 |
| **R** | 0.287 | 0.342 | 0.370 |
| **R-squared** | 0.082 | 0.117 | 0.137 |
| **Adjusted R-squared** | 0.081 | 0.111 | 0.133 |
| **R-squared Change 1)** | 0.000 | 0.003 | 0.006 |
| **F Change** | 7.369 | 7.269 | 11.644 |
| **df1** | 1 | 1 | 1 |
| **df2** | 14,445 | 2,110 | 1,695 |
| **Significant F Change** | 0.007 | 0.007 | 0.001 |

1) The change in the R2 statistic that is produced by adding or deleting an independent variable. If the R2 change associated with a variable is large, that means that the variable is a good predictor of the dependent variable. Source: SPSS® 2003.

#### 5.8.2.3 Discussion

Models explaining batch sizes are poor according to results (R2 0.082–0.137). This means that it is not possible to construct a good model that would explain the reasons behind a batch size ($m^3$) with the present data. Thus, a batch size ($m^3$) will not indicate in which country, segment or quality the purchase is targeted or what the thickness or width dimensions of the purchase are reliably. The result may indicate that there are no large group of customers behind the batch size information ($m^3$) that could be identified significantly different – e.g. much more large or smaller batch size – from statistical or database perspective.

The result is logical in the standard product sense that sawnwood trade sales of the same size are made of many different qualities for several countries. Nevertheless, it is interesting that some variables that explain sizes of sales can be found from the large database. On the other hand, it must be said that no universal conclusions can be drawn from the presented analyses from the similar reasons listed in Section 5.1.8.

### 5.8.3 Factors affecting CSW price

#### 5.8.3.1 Aim and execution

The price models aim at creating price estimates for species, export countries, moisture contents and dimensions in three cases: i) pine and spruce, ii) pine, iii) spruce. Price models were given the variables in Table 62 for variable selection in linear regression with stepwise method. Table 62. Available variables for price models are shown in Table 63.

**Table 63. Available variables for price models. Sample size: 3,830 sales from 2000.**

| Variable class | Variables |
|---|---|
| **Countries** | C-AT, C-AU, C-BE, C-CN, C-CY, C-DE, C-DK, C-DZ, C-EG, C-ES, C-FI, C-FR, C-GB, C-GR, C-HK, C-HU, C-IE, C-IL, C-IT, C-JP, C-MA, C-MY, C-NL, C-NO, C-SA, C-SE, C-TH, C-TN, C-TW, C-VN |
| **End moisture content classes** | MC10, MC12, MC14, MC16, MC18 |
| **Quality classes** | Q-FRA, Q-GLUE, Q-HVS1, Q-HVS2, Q-KNOT, Q-LAMA, Q-LAMB, Q-OTH1, Q-OTH2, Q-PLKL, Q-PLVL, Q-SF15, Q-SF15B, Q-SF16, Q-SF56, Q-SFLQ, Q-SFMB, Q-SFSG, Q-SFSP, Q-SFUSV, Q-TY, Q-US, Q-USSP, Q-V, Q-VA, Q-VIB, Q-VIC, Q-VID, Q-VIE, Q-VIEJ, Q-VIJ, Q-VIM, Q-VIW, Q-VM |
| **Thickness** | T-16, T-19, T-22, T-25, T-26, T-28, T-29, T-30, T-32, T-33, T-34, T-35, T-36, T-37, T-38, T-40, T-41, T-42, T-44, T-46, T-47, T-48, T-50, T-53, T-55, T-56, T-60, T-63, T-75, T-100 |
| **Widths** | W-50, W-63, W-75, W-90, W-100, W-110, W-111, W-112, W-115, W-125, W-127, W-128, W-130, W-145, W-150, W-153, W-155, W-160, W-165, W-175, W-180, W-185, W-190, W-200, W-220, W-225, W-250 |
| **Other** | PINE[1], PRICE |

[1] indicates species

#### 5.8.3.2 Results

The price model results are shown in Table 64. The models are based on price data (€/$m^3$) of sawnwood sales from 2000.

**Table 64. CSW supply price models for a) pine and spruce, b) pine, c) spruce. The method used for the models was stepwise multiple regression, forward selection. Stepping method criteria: use probability of F, PIN: 0.01, POUT: 0.02. Unit for y (price) is €/m$^3$. The models are based on price data of sawnwood sales from 2000. No = Number of variable, B = regression coefficient.**

| PINE AND SPRUCE | | | | | | PINE | | | SPRUCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **No** | **Variable** | **B** | **No** | **Variable** | **B** | **No** | **Variable** | **B** | **No** | **Variable** | **B** |
| **1** | (Constant) | 165.425 | **45** | Q-VIJ | -74.579 | **1** | (Constant) | 195.908 | **1** | (Constant) | 158.606 |
| **2** | C-AU | 84.936 | **46** | Q-VIM | -60.702 | **2** | C-AU | 72.773 | **2** | C-CN | 21.631 |
| **3** | C-CN | 27.048 | **47** | Q-VIW | -75.727 | **3** | C-DK | 10.886 | **3** | C-EG | -25.653 |
| **4** | C-DK | 13.604 | **48** | Q-VM | -19.633 | **4** | C-GB | 18.673 | **4** | C-FI | -7.861 |
| **5** | C-EG | -16.256 | **49** | T-100 | 17.437 | **5** | C-JP | 42.106 | **5** | C-FR | -4.144 |
| **6** | C-GB | 18.750 | **50** | T-16 | -21.446 | **6** | C-MY | 27.045 | **6** | C-GB | 5.021 |
| **7** | C-HK | 27.431 | **51** | T-19 | 15.286 | **7** | C-NO | 37.918 | **7** | C-HK | 22.178 |
| **8** | C-HU | 25.541 | **52** | T-25 | 11.963 | **8** | Q-FRA | 210.160 | **8** | C-IE | -9.884 |
| **9** | C-JP | 50.068 | **53** | T-63 | -5.532 | **9** | Q-GLUE | 232.530 | **9** | C-IT | -8.006 |
| **10** | C-MY | 22.570 | **54** | T-75 | -6.774 | **10** | Q-LAMA | -34.549 | **10** | C-JP | 44.081 |
| **11** | C-NO | 36.881 | **55** | W-100 | -5.087 | **11** | Q-OTH1 | -144.952 | **11** | C-MY | 20.859 |
| **12** | C-TW | 17.275 | **56** | W-50 | 32.756 | **12** | Q-OTH2 | -140.954 | **12** | C-SE | -42.942 |
| **13** | MC10 | 25.799 | **57** | W-63 | 55.275 | **13** | Q-PL | -88.732 | **13** | C-TH | 17.200 |
| **14** | MC12 | 29.628 | **58** | W-75 | 13.966 | **14** | Q-PLKL | 81.859 | **14** | C-TN | -11.549 |
| **15** | MC16 | 24.193 | **59** | W-90 | 42.398 | **15** | Q-PLVL1 | -110.711 | **15** | C-TW | 13.011 |
| **16** | MC18 | 17.454 | | | | **16** | Q-SF15 | -30.423 | **16** | C-VN | 11.762 |
| **17** | PINE | 13.522 | | | | **17** | Q-SF16 | -45.402 | **17** | Q-KNO | 21.193 |
| **18** | Q-FRA | 217.035 | | | | **18** | Q-SF56 | -43.908 | **18** | Q-LAMB | -63.618 |
| **19** | Q-GLUE | 246.709 | | | | **19** | Q-SFLQ | -50.109 | **19** | Q-OTH1 | -37.141 |
| **20** | Q-HVS2 | 32.820 | | | | **20** | Q-SFMB | -36.351 | **20** | Q-OTH2 | -24.048 |
| **21** | Q-LAMA | -25.868 | | | | **21** | Q-US | 51.333 | **21** | Q-PLVL1 | -54.838 |
| **22** | Q-LAMB | -90.590 | | | | **22** | Q-USSP | 69.087 | **22** | Q-PLVL2 | -59.599 |
| **23** | Q-OTH1 | -104.204 | | | | **23** | Q-V | -31.407 | **23** | Q-SF15 | 4.327 |
| **24** | Q-OTH2 | -121.332 | | | | **24** | Q-VA | -44.201 | **24** | Q-SF56 | -11.001 |
| **25** | Q-PL | -80.513 | | | | **25** | Q-VIB | -110.999 | **25** | Q-US | 27.670 |
| **26** | Q-PLKL | 93.302 | | | | **26** | Q-VIC | -84.530 | **26** | Q-VID | -60.582 |
| **27** | Q-PLVL1 | -93.488 | | | | **27** | Q-VID | -103.317 | **27** | Q-VIE | -32.979 |
| **28** | Q-PLVL2 | -88.907 | | | | **28** | Q-VIE | -77.344 | **28** | Q-VIJ | -37.282 |
| **29** | Q-SF15 | -24.578 | | | | **29** | Q-VIEJ | -52.763 | **29** | T-19 | -9.553 |
| **30** | Q-SF15B | -31.136 | | | | **30** | Q-VIJ | -87.095 | **30** | T-22 | -5.025 |
| **31** | Q-SF16 | -31.140 | | | | **31** | Q-VIM | -60.209 | **31** | T-48 | 42.386 |
| **32** | Q-SF56 | -38.992 | | | | **32** | Q-VIW | -94.166 | | | |
| **33** | Q-SFLQ | -47.086 | | | | **33** | Q-VM | -19.735 | | | |
| **34** | Q-SFMB | -29.645 | | | | **34** | T-100 | 26.168 | | | |
| **35** | Q-SFSG | -39.193 | | | | **35** | T-19 | 21.390 | | | |
| **36** | Q-US | 42.275 | | | | **36** | T-25 | 22.166 | | | |
| **37** | Q-USSP | 73.783 | | | | **37** | T-56 | 60.225 | | | |
| **38** | Q-V | -27.539 | | | | **38** | W-50 | 37.084 | | | |
| **39** | Q-VA | -38.485 | | | | **39** | W-63 | 61.223 | | | |
| **40** | Q-VIB | -87.421 | | | | **40** | W-75 | 14.960 | | | |
| **41** | Q-VIC | -74.018 | | | | **41** | W-90 | 53.995 | | | |
| **42** | Q-VID | -92.638 | | | | | | | | | |
| **43** | Q-VIE | -66.645 | | | | | | | | | |
| **44** | Q-VIEJ | -47.172 | | | | | | | | | |

Validation and reliability for price models are shown in Table 65.

**Table 65. Validation and reliability of the price models. For more information see Appendix 4.**

| Indicator | PINE AND SPRUCE | PINE | SPRUCE |
|---|---|---|---|
| **Number of steps** | 64 | 40 | 30 |
| **R** | 0.888 | 0.897 | 0.938 |
| **R-squared** | 0.788 | 0.805 | 0.879 |
| **Adjusted R-squared** | 0.785 | 0.801 | 0.877 |
| **R-squared Change** | 0.000 | 0.001 | 0.001 |
| **F Change** | 6.753 | 8.195 | 8.127 |
| **df1** | 1 | 1 | 1 |
| **df2** | 3771 | 2085 | 1673 |
| **Significant F Change** | 0.009 | 0.004 | 0.004 |

### 5.8.3.3 Discussion

According to model information, results (see Table 65) show that all three models are good or fairly good. Still, it must be said that no universal conclusions can be drawn from the presented analyses from the similar reasons listed in Section 5.1.8.

### Pine and spruce model

The price model with both wood species gives the base price at 165 € and the price for pine as 14 € more than for spruce. Among explanatory variables are wood species, 11 countries, 30 qualities and four end moisture content classes. The inclusion of qualities as explanatory variables tells about the great importance of qualities in price formation. For example, the price of quality U/S is 165+42 = 207 € and quality V 165–28 = 137 € according to the model. In addition, there are five thickness and width variables among the covariates of the model. The model arrives at a coefficient of determination R2 = 0.79, which can be considered fairly well.

### Pine model

The price model for pine has a coefficient of determination with magnitude of R2 = 0.81, which can be considered quite good or good. The model settles into 6 countries, four thicknesses and widths. All the remaining variables are qualities. There are no moisture content classes in the price model for pine. This indicates that end moisture content did not explain pine prices in 2000. Quality, on the other hand, can be regarded as the most important factor explaining prices.

### Spruce model

A coefficient of determination for spruce price model is R2 = 0.88. The model gives 15 countries, three thicknesses, but no moisture content classes. A difference between the pine and the spruce price models is that the spruce model clearly has fewer variables than the pine model, especially quality variables. However, the importance of qualities in the spruce price model is quite remarkable.

# 6 DISCUSSION AND CONCLUSIONS

## 6.1 Contribution

The main contribution of the thesis is the introduction of new information about the structure and functioning of coniferous sawnwood supply and demand as a product and profitable business. Furthermore, the thesis has shown that analysing sawnwood supply is possible on the basis of various methods (e.g. CRISP-DM 2005) used in the thesis. The most important general results of the study are listed in Table 66.

**Table 66. The most important general results.**

| No | General results | Examples of references in the thesis | Examples of references in literature |
|---|---|---|---|
| **1** | Use of new materials to (a) describe sawnwood as a product and (b) analysis of the development of sawmilling industry from 1995 to 2000. | Sections 5.1 and 5.6 | Juslin and Karppinen (1983), Timwood (1998), Pakkanen et al. (1999), Juslin and Hansen (2002) |
| **2** | Description of the correlations between sawnwood products, pricing, market regions and operating methods. | Sections 5.6 and 5.8.3 | Savolainen (1971), Luther (1986b), Sipi (2002), Roadmap 2010 (2004) |
| **3** | Description of the development of sawmilling industry from traditional shipping terminology to classes with more precise quality requirements. | Section 5.4 | Pakkanen et al. (1999), The Association of Finnish Sawmillmen (2002) |
| **4** | Description how the proportions of sawnwood classes and end-user segments have developed between 1995 and 2000 through pricing and market structures. | Sections 5.3, 5.5 and 5.6. | Profitable sawmill (1993, 1994), Timwood (1998) |
| **5** | Development and application of methods for reviewing the sawmilling industry that have not been used before in the sawmilling industry in way indicated by the study. | Sections 4.4, 5.1, 5.2 and 5.8. | Savolainen (1971), Juslin and Karppinen (1983) |
| **6** | Review of the operational models, situation and development alternatives of the sawmilling business when new methods need to be developed to ensure the profitability and prospecting future of the sawmilling business. | Chapter 5 | Profitable sawmill (1993, 1994), Paajanen (1997), Paajanen et al. (2000), Juslin and Hansen (2002), Roadmap 2010 (2004) |
| **No** | **Specific results** | **Examples of references in the thesis** | **Examples of references in literature** |
| **1** | The results of this study provide new information on the specific aspects of both global and local markets, supply, demand and consumption of coniferous sawnwood. This information can be used for (a) developing models of coniferous sawnwood supply and demand, particularly price and quantity models, (b) analysing quality from various perspectives including quality class, dimensions, end moisture content and user segments. | Chapters 4 and 5, Sections, 5.8.2 and 5.8.3 | Profitable sawmill (1993, 1994), Timwood (1998), Juslin and Hansen (2002), Roadmap 2010 (2004) |
| **2** | The methodology tested in the thesis is applied to analysing and creating new market information on sales of coniferous sawnwood. | Section 5.8 | Ripatti (1996), Laine (2003), CRISP-DM (2005) |
| **3** | A large coniferous sawnwood sales database, wood product database (WPDB), was created based on sales between Finnish sawmills and their customers (see). This product database provides much new and more specific information on specific supply issues. | Section 3.4.1 | Juslin and Karppinen (1983), Profitable sawmill (1993, 1994), Pakkanen et al. (1999), Juslin and Hansen (2002) |
| **4** | The basis pricing model of coniferous sawnwood provides new information on the specific aspects of coniferous sawnwood pricing. | Section 5.6 | Savolainen (1971), Luther (1986b), Juslin and Hansen (2002), Sipi (2002), Roadmap 2010 (2004) |
| **5** | New supply and demand analyses revealed factors affecting the following coniferous sawnwood supply and demand areas: end moisture content, price and batch size quantity. | Section 5.8 | Profitable sawmill (1993, 1994), Timwood (1998), Roadmap 2010 (2004) |

## 6.2 Approach choices

The thesis aimed at analysing sawnwood supply and demand in a way that can be applied to operations of sawmills. The motivation for the thesis can be rephrased by referring to Porter (1996) when he writes that information gives you competitive advantage: “It is very likely that information technology will play a strategic role in an industry that is characterised by …a large number of suppliers or customers with whom the company deals directly …a product line with many distinct product varieties and …a large number of steps in a company's manufacturing process."

As a result of Porter (1996), it can be concluded that analysing sawnwood supply and demand based on facts about a large number of suppliers and customers requires a database with lots of source information, but it gives a sawmilling company useful information and an opportunity to develop new tools for its operations. Therefore a sales database called wood product database (WPDB) was collected. The database covers coniferous sawnwood sales from Finnish sawmills between 1995 and 2000 altogether 19,222,277 m$^3$ of sawnwood and 63,774 sales. In addition, a country-based coniferous sawnwood database from FAOSTAT data (2004) was formed (see Section 3.4).

As to the analysis of sawnwood supply and demand, several alternative approaches can be applied. Traditionally, the themes of supply and demand of sawnwood and other forest products have been approached by time-series methods and defined sources of demand like construction, for instance GNP change, e.g. Hänninen (1998), Toppinen (1998), Hetemäki et al. (2001), Kanniainen and Kuuluvainen (1984), Enroth (1986), Hänninen et al. (2004). However, features and dynamics between the sawmilling industry and its customers have not attracted much attention. Particularly the specific sales information of Finnish sawnwood sales has not been focused on in detail. Juslin and Karppinen (1983) have also reported some similar results. On the other hand, today there are sales database data and analysis systems and approaches for sawmill related business intelligence analysis like CRISP-DM (2005) as well as other methods that did not exist twenty years ago.

Analysing sawnwood supply and demand through data mining and database approach include both positive and negative features:

- Positive features
    - It is possible to process large amounts of data for various purposes.
    - Large entities and small details of information (i.e. both macro and micro level information) are observable by this method.
    - Obtaining results is rapid, assuming the database has been organised properly.
    - The data do not need to be originally aimed for a particular study.
    - Knowing the nature of sawnwood business is not only a prerequisite to analysing but it also helps to focus on the right information.
- Negative features
    - The specific needs of careful database organising. It is necessary to organise the database carefully.
    - Evaluating the validity and reliability of database and its operations can be difficult.
    - The analyst cannot often affect the process of data collection.
    - The data set is often so large that its storage and retrieval must be carefully designed.
    - Some statistical problems may arise, for instance decisions made by computer algorithms and correlation among variables.

However, the positive features overcome the negative ones that can hopefully be solved with enhanced tools.

## 6.3 Tested propositions

Tested propositions were based on three hypotheses in the section 1.3. Tested propositions and their areas are listed in Table 67. All propositions were proved true with some restriction. In addition, the propositions were classified according to their area. These areas were Quantity (QTY), Quality (QLT), Price and value (PRI) and User segment (USE).

**Table 67. Tested propositions. Area of proposition: QTY, Quantity; QLT, Quality; PRI, Price and value; USE, User segment.**

| No | Proposition | QTY | QLT | PRI | USE |
|---|---|---|---|---|---|
| **1** | Changes in sawnwood consumption can be found in Finland during the time periods between 1961 and 2002. It is possible that the CSW consumption in Finland in 1961–1996 was significantly different from the CSW consumption in the years 1997–2002 and 1961–2002. | X | | | |
| **2** | For sawnwood produced in Finland in 2000, sawnwood trade was concentrated on main dimensions. Simultaneously, the number of dimensions was large. The Pareto principle assumption and its 20–80 rule applied to sawnwood dimensions. | X | | X | |
| **3** | The importance of large pine dimensions, as concerns sawnwood exported from Finland, decreased in the UK markets due to thickness approach between 1995 and 2000. | X | X | | |
| **4** | For sawnwood delivered from Finland, dimensions had big differences specific to country and species of sawnwood between 1995 and 2000. The dimensions of pine and spruce differed by country. | X | | | X |
| **5** | There was a market trend towards smaller batch sizes in sawnwood delivered from Finland between 1995 and 2000. | X | | | |
| **6** | Differences of length between pine and spruce sawnwood delivered from Finland were relatively small in 2000. | X | X | | |
| **7** | The development of end moisture content and quality distribution remained rather stable for both pine and spruce in the Finnish sawmilling industry in the years 1995–2000. | X | X | | |
| **8** | A logical sawnwood price system can be found for a set of sawnwood dimensions and species in Finland in 2000. In this system, a specific pine dimension of 50 x 150 mm (or close to this) set a basis price, and the prices of other dimensions could be derived from the basis price. Both pine and spruce pricing used the basis price system but it was more dominant with pine. | | X | X | |
| **9** | In the predominant quality classes (U/S, V, VI), a small number of special lots was priced differently in Finland in 2000, with a few lower and higher price classes. | | X | X | |
| **10** | Sawnwood supply distributions consisted primarily of the supply of standardised sawnwood in Finland in 2000. The number of special products was still small. Sawnwood supply can be estimated with both logistic and linear regression analyses. | X | X | | X |
| **11** | Sawnwood supply can be analysed by end moisture contents as well as batch sizes and prices. It is possible to create logistic and linear regression analyses for sawnwood supply distributions with the database approach. | X | X | X | X |
| **12** | A country's geographical area can be assessed as a factor for coniferous sawnwood consumption in Europe in 1999. | X | | | |
| **13** | Sawmills had not completed their user segmenting strategies in Finland in the years 1998–2000. They used a user segment system in their sales but still divided most of their production into the distribution segment as a general segment instead of more specified joinery, furniture, planing and strength grading segments. | X | X | X | X |

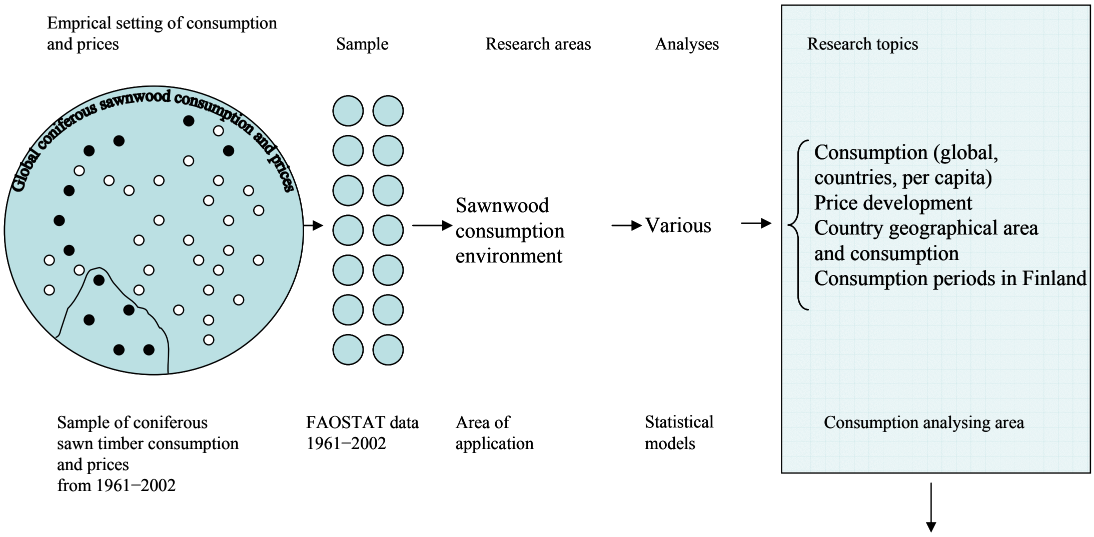
### 6.3.1 Sawnwood consumption environment

Chapter 4 describes the results of sawnwood (CSW) consumption volumes during the observed time periods, per capita consumption, price development, and geographical area as a factor for coniferous sawnwood consumption. The results provide information for consumption analyses from five perspectives, which are (1) volumes, (2) time periods, (3) per capita, (4) geographical area and (5) price. These perspectives are linked with the two propositions of sawnwood consumption environment in Figure 76.

Regionally, the global CSW consumption is centred in North America and Europe (Roadmap 2010, 2004). Typical features of CSW global consumption between 1961 and 2002 were large volumes and volume fluctuations as well as slow growth (e.g. Roadmap 2010, 2003); see Figure

47, Figure 48 and Figure 49). In addition, global sawnwood consumption curve resembles more a regressive logarithmic product consumption curve than a product consumption line with linear growth.

Four leading countries of global CSW consumption are the USA, Japan, Canada and Germany (see Figure 48). All of these countries have large annual CSW consumption fluctuations, particularly in the USA. On the other hand, the results show that global CSW consumption is high and this may be difficult for competitive products to unbalance in short term. Still according to JPC (2003a), the growing European production and the increasing imports from East Europe is expected to create a significant oversupply in West Europe by 2010.



| No | Tested propositions |
|---|---|
| 1 | Changes in sawnwood consumption can be found in Finland during the time periods between 1961 and 2002. It is possible that the CSW consumption in Finland in 1961–1996 was significantly different from the CSW consumption in the years 1997–2002 and 1961–2002. |
| 12 | A country's geographical area can be assessed as a factor for coniferous sawnwood consumption in Europe in 1999. |

**Figure 76. Tested propositions of sawnwood consumption environment. The propositions are linked with the implementation of the hypotheses in the area of sawnwood consumption environment.**

The relative sawnwood prices have decreased which has forced sawmills to seek ways of reducing unit costs (Figure 56). Price development of products has led to larger production sites, the implementation of cost saving technologies and merging of companies. However, the history of price development in the sawmilling industry does not provide a sufficient basis for drawing reliable conclusions about price levels in the future. According to JPC (2003a), increasing share of capacity in Western ownership of sawmills in East Europe drives the shift towards further processing and consequently enhances price opportunities.

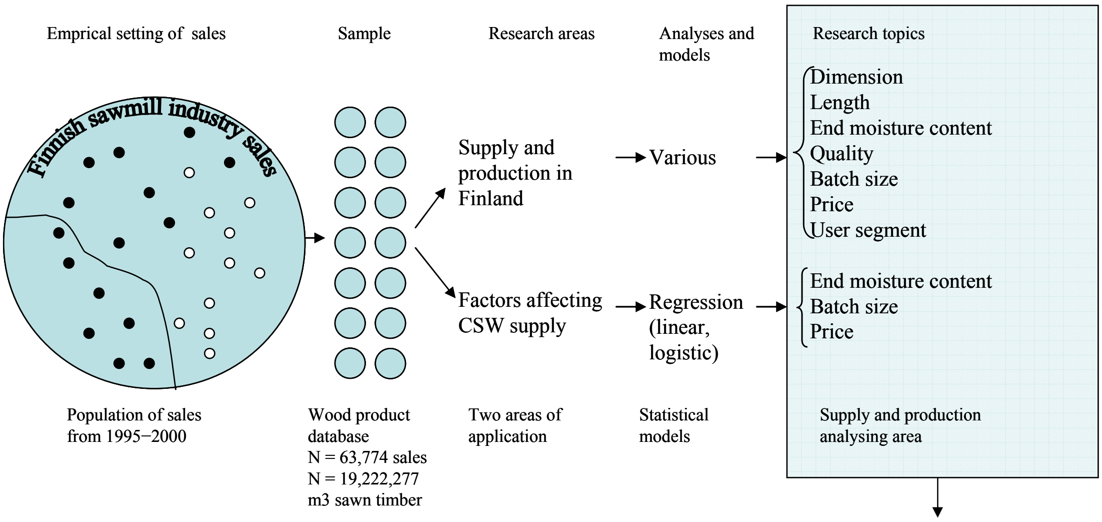
The results emphasise the role of local wood raw material to the local tradition of CSW consumption. This has also been observed, for instance, by Tiittanen (1986) and Relander (1986). Generally, CSW is used more in countries of the boreal coniferous forest zone as well as in the mountainous region of Central Europe. This is supported by e.g. Table 29 and Figure 57.

The results of the thesis give evidence of change in the sawnwood consumption between the time periods of 1961–1996, 1997–2002 and 1961–2002 in Finland. These changes cannot be categorised as a structural change with absolute certainty. Nevertheless, the result that sawnwood consumption has been higher between the years 1997–2002 than 1961–1996 would suggest a structural change of coniferous sawnwood consumption in Finland.

### 6.3.2 Sawnwood supply and production

From the perspective of dimensions, the supply for Finnish coniferous sawnwood is mostly concentrated on certain high-volume dimensions, although the total number of dimensions is large (see e.g. Table 33). This may indicate that sawmills are limiting their product range, focusing on few products with high volume (see e.g. Figure 59). Nevertheless, sawmills are not willing or they cannot refuse to take orders of small amounts of other dimensions. Propositions 2 and 3 are linked with dimension and they are included in the eleven propositions of sawnwood supply and production shown in Figure 77.

Finnish sawmills have traditionally concentrated on the production of centre yield, which has produced studs and other large dimensions (see e.g. Virtanen et al. 1997, Vuorilehto 2001, Usenius et al. 1983, Usenius and Viitaniemi 1976). Results (e.g. Table 33) show that side yield dimensions, side boards, are produced in large quantities. In this context, The Pareto principle assumption (see e.g. Juran and Godfrey 1999) works for sawnwood dimensions. The results (see e.g. Figure 59) make it reasonable to ask why the sawmilling industry produces such a wide range of dimensions if only a few dimensions bring in the largest volume. Comparing sawnwood distribution of quantity (m3) and value (€) (see Figure 60 and Table 35) reveals the standard product character of sawnwood. Still, the total number of produced dimensions, 890, can be regarded as large.



| No | Tested Propositions |
|---|---|
| 2 | For sawnwood produced in Finland in 2000, sawnwood trade was concentrated on main dimensions. Simultaneously, the number of dimensions was large. The Pareto principle assumption and its 20–80 rule applied to sawnwood dimensions. |
| 3 | The importance of large pine dimensions, as concerns sawnwood exported from Finland, decreased in the UK markets due to thickness approach between 1995 and 2000. |
| 4 | For sawnwood delivered from Finland, dimensions had big differences specific to country and species of sawnwood between 1995 and 2000. The dimensions of pine and spruce differed by country. |
| 5 | There was a market trend towards smaller batch sizes in sawnwood delivered from Finland between 1995 and 2000. |
| 6 | Differences of length between pine and spruce sawnwood delivered from Finland were relatively small in 2000. |
| 7 | The development of end moisture content and quality distribution remained rather stable for both pine and spruce in the Finnish sawmilling industry in the years 1995–2000. |
| 8 | A logical sawnwood price system can be found for a set of sawnwood dimensions and species in Finland in 2000. In this system, a specific pine dimension of 50 x 150 mm (or close to this) set a basis price, and the prices of other dimensions could be derived from the basis price. Both pine and spruce pricing used the basis price system but it was more dominant with pine. |
| 9 | In the predominant quality classes (U/S, V, VI), a small number of special lots was priced differently in Finland in 2000, with a few lower and higher price classes. |
| 10 | Sawnwood supply distributions consisted primarily of the supply of standardised sawnwood in Finland in 2000. The number of special products was still small. Sawnwood supply can be estimated with both logistic and linear regression analyses. |
| 11 | Sawnwood supply can be analysed by end moisture contents as well as batch sizes and prices. It is possible to create logistic and linear regression analyses for sawnwood supply distributions with the database approach. |
| 13 | Sawmills had not completed their user segmenting strategies in Finland in the years 1998–2000. They used a user segment system in their sales but still divided most of their production into the distribution segment as a general segment instead of more specified joinery, furniture, planing and strength grading segments. |

**Figure 77. Tested propositions of sawnwood supply and production. The propositions and linked with the implementation of the hypotheses in the area of supply and production.**

In different countries sawnwood supply and demand is distributed according to wood species. This raises the question why the ten sample countries mainly use only one of the two species, either pine or spruce (see Table 37)? The sawnwood export of Finnish sawmills has been directed to certain uses and user segments in certain countries for decades (see e.g. Juslin and Karppinen 1983 and Profitable Sawmill 1993 and 1994). This may affect both the supply of the species, described in the thesis, and the tradition of wood use in those countries (see e.g. Figure 49 and Figure 52). Generally, end-users search the most suitable quality with minimal costs (see e.g. Figure 71). The fact that supply is centralised in a few dimensions only (see e.g. Figure 59) may strengthen the image of the standard product character of sawnwood.

The supply analysis of the development of sawnwood thicknesses indicates that supply for thinner dimensions is slowly growing in the UK markets (see Table 100 and Figure 61). In addition, supply for other than standard thicknesses is also slowly growing in the UK markets. Nonetheless, supply of various thicknesses is relatively stable in the UK markets.

Lengthwise there was no significant difference in the distribution of pine and spruce (see Figure 63 and Table 101). There is a difference between the lengths of centre boards (including studs and larger dimensions) and side boards (see Table 39, Table 40 and Table 41). This can be attributed to supply of conical logs. Naturally, side boards are shorter.

The predominant position of MC 18% – over 90% of the moisture content distribution – supports the view of the standard product character of sawnwood supply and demand (see Table 42). The stable nature of supply is supported by an observation that the moisture content classes remained rather stable in the years 1995–2000, except the change between MC 16–18% and MC 18–20%. When analysing the distribution of the moisture content classes according to exporting countries (see Table 43), two important facts emerge in the data:

1. Finland has a central role in sawnwood supply and demand distribution of all moisture content classes (6–14%, 14–16%, 16–18%, 18–20%, Green).
2. The supply profiles of moisture content class distribution differ significantly in the other countries of the sample (see Table 43).

Regarding the pine main qualities, the development of distribution indicates economic optimisation in the years 1995 to 2000 (see Table 103, Figure 66 and Figure 67). During the same time period, the number of quality classes increased (see Table 45). The results indicate that sawmills try to keep the share of U/S, the most valuable of the main qualities, as stable as possible so that the share of U/S would not decrease. The spruce main quality distribution, on the other hand, seems to favour quality SF (see Figure 67). The observed changes were statistically significant for all the other quality classes of spruce except SF during 1995–2000 (see Table 103). The importance of modified special qualities increased in the years 1995–2000 (see Table 44 and Table 45). At the same time, there was a detectable balance movement in the opposite direction towards standard qualities (see Table 45).

In general, the importance of standard qualities may decrease in the Finnish sawmilling industry in the future. Furthermore, the importance of qualities that are linked with customer requirements, technical quality and product standards may increase. This may lead to more specified requirements for sawnwood quality classes and more specified product-based qualities instead of material-based qualities. In other words, the importance of the following quality requirements may increase: dimensional accuracy, particularly the sizes of the dimensions that are exactly agreed in sales; avoidance of mechanical defects and defects from kiln drying, and strength properties. Rydell (1992) has suggested a similar tendency towards sawn timber product development for joinery and furniture segments. The importance of dimensional accuracy is supported by Vuorilehto (2001).

Growth in the number of quality classes (see Table 46) is probably a consequence of customers' more detailed quality requirements, as well as the fact that machine vision systems are able to grade special qualities. These systems have become more common between 1995 and 2000. Interestingly, the growth in the number of quality classes has clearly been greater for pine than spruce. In addition, the average size of a sawnwood sale decreased from 456 $m^3$ to 242 $m^3$ between 1995–2000 (see Table 49). There was a statistically significant market trend towards smaller batch sizes in sawnwood delivered from Finland between 1995 and 2000.

The basis price system was still used in the sawmilling industry in the year 2000 (see Section 5.6.1) in the same way as Savolainen (1971) has described. According to the basis price system, factors affecting the price of sawnwood included productions costs, and size and definitions of raw material. The system was used more typically with pine than spruce sawnwood pricing.

Is end product – thinking evident in the data from the sawmills in the years 1995–2000? The results of this study show that distribution product segments are emphasised (see e.g. Table 53). This may indicate that sawmills do not know their customers well yet. Likewise, the results show that the traditional distribution channel, the distribution segment, is still important to Finnish sawmills. Of the sample countries, segmentation was clearly more advanced in Germany in the year 2000. France and Italy had also clearly made progress. Consequently, end product –thinking is not evident in product segmentation. In contrast, the processing of quality classes into end products shows signs of progress in end product –thinking in the Finnish sawmilling industry. This is evident in the growing number of special and customer qualities as well as in the decreasing batch sizes.

### 6.3.3 Analysing factors affecting sawnwood supply

The results of the research highlight the fact that supply for end moisture classes of CSW depends on certain countries, dimensions and segments. The results show also that there are great differences between end moisture classes. This supports the common perception that the supply for end moisture classes is fragmented. Standard thicknesses, widths and qualities are all related to end moisture classes with the highest volumes (MC18 and MC20). This in turn indicates that there is a difference between sawnwood supply for standard and special products.

The strong correlation between the standard qualities, widths and thicknesses indicates product standardisation of both sizes and qualities. The standardisation is a way of seeking profitability. Flexibility, an alternative to standardisation, is sought through substitutability in qualities. A pair of SF and V qualities stands out in the data as their supply profiles for dimensions seem interchangeable.

From the standpoint of sawnwood trade, several of the results related to user segments are logical. For instance, the strength grading segment favours firmness and strength, the planing segment standardisation and moisture control, and the joinery segment special qualities and special moisture contents. The distribution segment distributes both wood species for different end uses.

The results show that three general price models can be found in the sample. The models give price estimates of species, export countries, moisture contents and dimensions. The R2 statistics is relatively good, but the number of variables is too large for the models. All the models of price variables rely on linear regression, which can explain the results in detail and strengthen their practical applicability. The results given by the model confirmed the significance of quality classes in sawnwood price formation.

## *6.4 Validation, limitations and error sources*

The model equations are based on either FAOSTAT data (2004) or sales information and observations from Wood Product Database (WPDB). Even if WPDB were the largest ever collected database of coniferous sawnwood sales, it may have some restrictions. The selected logarithm and linear functions may have limitations in illustrating some features of supply and demand as well as some product features listed in the database.

Most of the model equations in their present forms fit the data well but they cannot be called compact because of the large number of variables in the models. However, model equations describe the essential factors in an effective manner. Furthermore, there are some models that cannot be regarded as useful, e.g. the batch size models. No universal conclusions can be drawn from the presented analyses and models as the data from the databases are limited to simple consumption by volume ($m^3$) and price ($\$/m^3$) in FAOSTAT data (2004); as well as to the sales information from Finnish sawmills from 1995 to 2000 in WPDB. Furthermore, WPDB is a fragmented database covering much sales dimension and quality class information, but lacking relatively much in the sales price information.

The short period of time, six years between 1995 and 2000, may not give a solid basis to draw drastic conclusions. Several differences can be due to different quantities of sales during the years (see e.g. Table 36 and Table 37) or even cyclical factors in supply and demand. On the other hand, the year 2000 was a cyclical peak as can be seen in the Figure 62. This could have had an effect on all changes during 1995–2000. However, wood product output as described in Figure 62 remained on a high level from 2001 to 2003 and reached its new peak in 2003.

Nor can one draw conclusions about the superiority of any of the model approaches, which are meant to be complementary rather than mutually exclusive to other approaches. The results are valid exclusively for the sample but can be verified by similar databases in sawmilling companies. Better understanding of sawnwood supply and demand would also require linking with information about sources of demand such as construction. Future studies with larger amount of sales information from similar sawnwood product databases may potentially reveal more detailed patterns of supply and demand.

Wood is a natural material with large quality variations and therefore it has large and complicated distributions in some contexts, as seen from the modelling perspective. Furthermore, sawnwood is produced in various sizes and lengths. Thus the presented models have some limitations. Quality, dimensions, end moisture content and other variables are often linked differently in different markets. In addition, inconsistencies in quality class naming and contents are another source of internal dispersion in the data. Although these factors play a role in the database, the results reveal other factors without too adverse variations that affect sawnwood supply and demand. Nevertheless, the results must be analysed with care in order to avoid misleading conclusions (see e.g. Sections 3.6.5.3, 3.6.6.4 and 3.7).

Future models may hopefully be improved by calculating elasticity of supply and demand of selected variables of construction and other sources of use for sawnwood. This may be implemented by companies when business intelligence practices, supply and demand models and similar databases are connected to give management improved decision support information.

## *6.5 Use of results*

### 6.5.1 Importance of propositions

Importance in Table 68 indicates importance of proposition to the Finnish sawmilling industry. Importance is measured by the following approaches: 1) profitability, 2) efficiency and cost competitiveness, 3) research and development, 4) strategic development and 5) sales promotion.

Please also note the following when reading the Table 68:

- The 16 interviewees expressed their opinions as individuals representing the Finnish sawmilling industry. At the same time, their opinions also reflect the company which they represent.
- The interviews were conducted by telephone or by meeting the interviewee in person. The interviews took place between June 16th and July 13th, 2005. The interviews were conducted in Finnish and English.
- The interviewees were asked to assess the propositions from five different approaches listed above.
- The interviewees were given an opportunity to give their comments. Some of the comments are presented in Table 69 and Table 70.
- The three highest values in each column of averages have been highlighted. The highest value is marked light orange, the second silver and the third light green.
- The questionnaire used in the interviews is in Appendix 8.

The highest average values (x) were given to different propositions in all evaluation areas. Depending on the evaluation area, the propositions 1, 8, 10, 11 and 13 were seen as the most important. However, standard deviations (s) were high for some propositions (e.g. propositions 6, 8, 9 and 12). This indicates different opinions of the importance.

**Table 68. Results of the query on the importance of the propositions. Sample: 16 interviews of experts in the Finnish sawmilling industry. Scale: 1-5, where 1 = not important, 5 = very important. Abbreviations: x = average, s = standard deviation.**

| No | Proposition | Profitability | | Efficiency and cost competitiveness | | Research and development | | Strategic development | | Sales promotion | | ROW TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | x | s | x | s | x | s | x | s | x | s | x | s |
| **1** | Changes in sawnwood consumption can be found in Finland during the time periods between 1961 and 2002. It is possible that the CSW consumption in Finland in 1961–1996 was significantly different from the CSW consumption in the years 1997–2002 and 1961–2002. | 3.13 | 1.26 | 3.22 | 0.98 | **3.31** | 0.79 | **3.56** | 0.81 | **3.69** | 0.95 | **3.38** | 0.97 |
| **2** | For sawnwood produced in Finland in 2000, sawnwood trade was concentrated on main dimensions. Simultaneously, the number of dimensions was large. The Pareto principle assumption and its 20–80 rule applied to sawnwood dimensions. | 3.13 | 1.02 | **3.97** | 0.64 | 2.44 | 0.96 | 3.19 | 1.05 | 2.59 | 1.2 | 3.06 | 1.11 |
| **3** | The importance of large pine dimensions, as concerns sawnwood exported from Finland, decreased in the UK markets due to thickness approach between 1995 and 2000. | **3.56** | 0.96 | 3.47 | 0.96 | 2.94 | 1.24 | 3.31 | 1.01 | 2.56 | 1.09 | 3.17 | 1.1 |
| **4** | For sawnwood delivered from Finland, dimensions had big differences specific to country and species of sawnwood between 1995 and 2000. The dimensions of pine and spruce differed by country. | 3.06 | 1.39 | 3.25 | 1.18 | 2.31 | 1.08 | 3.03 | 1.1 | 2.78 | 1.02 | 2.89 | 1.18 |
| **5** | There was a market trend towards smaller batch sizes in sawnwood delivered from Finland between 1995 and 2000. | 3.50 | 0.73 | **3.88** | 0.96 | 2.69 | 1.01 | 3.5 | 0.52 | 2.94 | 1.06 | 3.3 | 0.96 |
| **6** | Differences of length between pine and spruce sawnwood delivered from Finland were relatively small in 2000. | 2.38 | 1.36 | 2.88 | 1.2 | 2.00 | 1.26 | 2.25 | 1.24 | 1.69 | 1.2 | 2.24 | 1.29 |
| **7** | The development of end moisture content and quality distribution remained rather stable for both pine and spruce in the Finnish sawmilling industry in the years 1995–2000. | 2.78 | 1.25 | 3.31 | 1.08 | 2.75 | 1.18 | 2.88 | 1.02 | 2.31 | 0.95 | 2.81 | 1.12 |
| **8** | A logical sawnwood price system can be found for a set of sawnwood dimensions and species in Finland in 2000. In this system, a specific pine dimension of 50 x 150 mm (or close to this) set a basis price, and the prices of other dimensions could be derived from the basis price. Both pine and spruce pricing used the basis price system but it was more dominant with pine. | **3.75** | 1.34 | 2.72 | 1.46 | 2.13 | 1.15 | 2.69 | 1.35 | 2.19 | 0.91 | 2.69 | 1.36 |
| **9** | In the predominant quality classes (U/S, V, VI), a small number of special lots was priced differently in Finland in 2000, with a few lower and higher price classes. | 3.38 | 1.54 | 2.66 | 1.14 | 2.56 | 1.31 | 3.19 | 1.22 | 2.94 | 1.18 | 2.94 | 1.29 |
| **10** | Sawnwood supply distributions consisted primarily of the supply of standardised sawnwood in Finland in 2000. The number of special products was still small. Sawnwood supply can be estimated with both logistic and linear regression analyses. | **3.53** | 0.88 | **4.00** | 0.71 | 3.06 | 1.12 | **3.69** | 1.01 | 2.94 | 0.93 | **3.44** | 1 |
| **11** | Sawnwood supply can be analysed by end moisture contents as well as batch sizes and prices. It is possible to create logistic and linear regression analyses for sawnwood supply distributions with the database approach. | 3.06 | 0.93 | 3.19 | 0.98 | **3.38** | 0.81 | 3.38 | 1.02 | 3.00 | 0.89 | 3.2 | 0.92 |
| **12** | A country's geographical area can be assessed as a factor for coniferous sawnwood consumption in Europe in 1999. | 2.88 | 1.26 | 2.38 | 1.5 | 2.59 | 1.23 | 3.31 | 1.2 | **3.06** | 1.34 | 2.84 | 1.32 |
| **13** | Sawmills had not completed their user segmenting strategies in Finland in the years 1998–2000. They used a user segment system in their sales but still divided most of their production into the distribution segment as a general segment instead of more specified joinery, furniture, planing and strength grading segments. | 3.44 | 0.96 | 2.81 | 1.05 | **3.34** | 1.08 | **3.97** | 0.83 | **3.28** | 0.77 | **3.37** | 0.99 |
| | **COLUMN TOTAL: AVERAGE (X) OR STANDARD DEVIATION (S)** | 3.20 | 1.19 | 3.21 | 1.17 | 2.73 | 1.16 | 3.23 | 1.11 | 2.77 | 1.13 | | |

Meaning of colours in the columns of averages The highest 🟧 The second ▨ The third 🟩

The 16 interviewees were given an opportunity to give their comments. Some of the comments are presented in Table 69 and Table 70. However, the comments represent personal opinions.

**Table 69. Comments to the propositions 1-7 by 16 experts of Finnish sawmilling industry. Some propositions have been truncated.**

| No | Proposition | Comments by experts of Finnish sawmilling industry |
|---|---|---|
| 1 | Changes in sawnwood consumption can be found in Finland during the time periods between 1961 and 2002… | *"The change of consumption is related to the development of and campaigning for refined products in the Finnish sawmilling industry."*<br>*"In my opinion, the increased consumption has gone to exports through the domestic refining industry. A large part of this is apparent consumption."*<br>*"The profitability of the sawmilling industry might have been worse if the domestic consumption had not increased. On the other hand, the increase of consumption has affected the rise of production and material prices."*<br>*"Our confirmed idea is that the domestic consumption is a good measurement for a company's operations."*<br>*"The sales promotion operations of the Finnish sawmilling industry have influenced the European sales promotion operations."* |
| 2 | For sawnwood produced in Finland in 2000, sawnwood trade was concentrated on main dimensions. Simultaneously, the number of dimensions was large… | *"Part of the Finnish sawmilling industry probably concentrates on sawing few dimensions with large volumes. Another part probably does a very large variety of dimensions."*<br>*"Having a large number of dimensions has a very negative effect on efficiency."*<br>*"As the integrated large sawmilling industry has reduced its number of dimensions, opportunities have been generated for private sawmills."*<br>*"Large sawmilling companies may have a distribution of 10-90, and smaller companies 30-70."* |
| 3 | The importance of large pine dimensions, as concerns … | *"This trend has made sawmills less profitable and efficient."*<br>*"The result indicates that sawmills have less space for standard product markets in the UK markets."*<br>*"The result raises the question what this kind of development has been in the market."* |
| 4 | For sawnwood delivered from Finland, dimensions had big differences specific to country and species… | *"The observation is true for us as well. We avoid certain countries that are not profitable for us."*<br>*"We have noticed the same thing. For example, a certain dimension does not sell in the UK market but sells well in some other countries."*<br>*"In specifications we must work with several different markets."* |
| 5 | There was a market trend towards smaller batch sizes in sawnwood delivered from Finland between 1995 and 2000. | *"We have observed the same thing. Some buyers give up catalogues and buy more precisely."*<br>*"This has to do with automotive transport becoming more common instead of shipping."*<br>*"The result may indicate one species sawmill concept. In this concept, a sawmill uses only one species (pine or spruce)."*<br>*"The trend has decreased the efficiency of operations."* |
| 6 | Differences of length between pine and spruce sawnwood delivered from Finland were … | *"Interesting. For us, pine has traditionally been shorter."*<br>*"For us, the length distributions of pine and spruce are not the same, because we use product-specific length cutting."*<br>*"The average length influences profitability."*<br>*"For us, the lengths come directly from the forest. Thus the difference of length distributions is not significant."* |
| 7 | The development of end moisture content and quality distribution remained rather stable for both pine and spruce in the Finnish sawmilling industry in the years 1995–2000. | *"I would claim that the change was already taking place at markets, but Finnish sawmills were fighting it to the last moment."*<br>*"At the same time, there were a lot of investments in drying, kilns and machine vision. Why are the investments not reflected in the development? They may also be related to the concurrent growth of production capacity. Investments were needed anyway, as the production capacity grew."*<br>*"You cannot push sawnwood to markets from the production (production–push), the markets should also have a need for new qualities (market-pull)."*<br>*"The result indicates that the concurrent investments in chamber kilns have been used for other purposes than special drying."* |

**Table 70. Comments to the propositions 8-13 by 16 experts of Finnish sawmilling industry. Some propositions have been truncated.**

| No | Proposition | Comments by experts of Finnish sawmilling industry |
|---|---|---|
| 8 | A logical sawnwood price system can be found for a set of sawnwood dimensions and species in Finland in 2000… | *"We still use the basis system, but its use is decreasing each year. Nowadays the trend is to negotiate the prices of dimensions separately."*<br>*"I myself have an influence on how the products are priced."*<br>*"The result speaks of the difficulty of pricing sawnwood and perhaps about problems, too."* |
| 9 | In the predominant quality classes (U/S, V, VI), a small number of special lots was priced differently in Finland in 2000, with a few lower and higher price classes. | *"In our company it's still like this. For example, 25x100 U/S pine is sold cheaply, because it has a large supply. In contrast, 25x225 U/S pine is little supplied and its demand exceeds supply. Therefore you can get a good price for it. We try to attach the sales of 25x225 U/S pine to sales of other products."*<br>*"Yes but do you see the difference especially in pine sawnwood sideboard U/S and sixths?"*<br>*"For us, the influence of special lots is marginal. The expensive qualities are like cream. You get just a little of it."*<br>*"In my opinion, the result does not have significance to the industry, but it might be significant for a specific sawmill."*<br>*"Dimension-quality combinations can be divided into push and pull categories. Some are easy to sell, some aren't."*<br>*"The inexpensive qualities stimulate product development."* |
| 10 | Sawnwood supply distributions consisted primarily of the supply of standardised sawnwood… | *"The sawmilling industry must choose a strategy. Alternatives include at least standard or special products and some other strategies. The result is indicative of standard product strategy."*<br>*"We sell special products mostly for industrial customers."*<br>*"Concerning the expensive raw material and labour costs in Finland, the idea of standardised products is not viable for profit generation."* |
| 11 | Sawnwood supply can be analysed by end moisture contents as well as batch sizes and prices… | *"The result may give signposts for a tool that could be used for answering questions about the efficiency or strategic development of the sawmilling industry."*<br>*"The tool that predicts the MC and qualities is not so helpful. The knowledge should already be there. For instance, Denmark was one of the leaders of furniture industry. Now the production moves to lower cost countries. If the production moves to countries with their own raw material, there is no need to buy Finnish raw material."* |
| 12 | A country's geographical area can be assessed as a factor for coniferous sawnwood consumption in Europe in 1999… | *"The result may be considered unfortunate. It is to be hoped that coniferous sawnwood would be used also in areas where coniferous trees do not grow."*<br>*"I would claim that the more important factor was the forest reserves of countries. This has created traditional building methods and material selection for decoration."*<br>*"I think the result is significant for choosing a strategy."* |
| 13 | Sawmills had not completed their user segmenting strategies in Finland in the years 1998–2000. They used a user segment system in their sales but still divided most of their production… | *"I would say that geographical areas were the main segmenting principle. There the general segmenting was distribution segment. The joinery and other segments were added on top of these when sawmills implemented segmenting."*<br>*"Segmenting met with a lot of opposition at the time."*<br>*"In our experience, the significance of segmenting has to do with the size of the company. The larger the company, the more important segmenting is. For small companies, it may be more profitable to avoid segmenting because of costs and concentrate directly on customers."* |

Please also note the following when reading the Table 69 and Table 70:

- The information contained in the comments cannot be proved or disproved in this study.
- The comments are as accurate representations of the interviewees' intended statements as possible.
- All comments could not be included to avoid repetition. Similar comments were combined into one.

### 6.5.2 Application potential

The supply and demand analyses may be used to calculate scenarios and reveal information of sawnwood sales. Equally, they provide means to assess the effects on market changes to operations and product profitability of sawmills. These market changes can possibly be approached as stated in Table 71. A rather similar approach has been used by Juslin and Hansen (2002) (see Table 17). They suggest that companies can choose special or custom-made products to emphasise their commodity.

**Table 71. Potential sawnwood market changes from standard product to product system.**

| Product parameter | Standard product approach | Product based approach | Product system approach |
|---|---|---|---|
| **Quantity** | Volume | Specialised | System |
| **Price** | Specifications | Value added | Optimised system |
| **Quality** | Standard, tangible | Tangible and intangible | Tangible and intangible product systems |

The price models can be utilised in quality comparisons with product profitability as well as with development of new pricing systems. In practice, this can mean that sawmills may improve their internal accounting processes in order to obtain more accurate information on product costs.

The results and analysing methods can be used by sawmill management to improve profitability and competitiveness of their sawmills. At an initial stage the use of these analyses may require data processing with new software features. Nevertheless, it is preferable to use analyses to improve the performance of sawmills than to continue without a relevant accounting.

For example, the results can be used by sawmill managers, consultants and company business analysts for the following purposes:

1. Sawmill market risk analysis for operational risks. If the supply or demand of sawnwood goes down 5% in a country, what happens to the sawnwood supply? The method may provide information as shown in Table 58.
2. Price levels for qualities. There is research information available on sawnwood price levels for different qualities, including special qualities, in the thesis. This may help the sawmills and the research community to improve the product competitiveness.
3. Business analyses of the sawmilling industry. There is a need to develop business control methods to improve business management in the sawmilling industry. The results present some typical business features for the sawmilling industry. This can help both sawmills and management software suppliers to improve their processes.

In practice, the study aims to give the following benefits:

- Estimating the dependency of the sawmill’s business on markets and other factors.
- Estimating the operation dynamics of the sawmilling industry from the point of view of supply and operations control, for example how the Finnish sawmilling industry operates.
- Identifying and measuring the tendencies of changes in the supply for the sawmill’s products.
- Describing the pricing system of the sawmilling industry using the qualities.

Business environment tendencies can be identified so that sawnwood companies (sawmills and distribution companies) can adjust their strategy to these tendencies. For instance, if there is a market trend to smaller batch sizes and larger number of quality classes, sawmills are obliged to adjust their strategy to this trend.

### 6.5.3 Sawmill business implications

From a business perspective, sawmills have not completed their user segmenting strategies. Even though sawmills use a user segment system with their sales, much of their production still goes into the general distribution segment, rather than to more specific segments, such as joinery, furniture, planing and strength grading. On the other hand, some sawmills may avoid segmenting strategies and concentrate directly on customers.

What benefits do the results presented in the thesis give to a sawmill? To answer this, it is necessary to identify the target groups in the sawmilling industry. All groups of the sawmilling industry have their own points of view to consider. These groups include the managers of a single sawmill, the management of a sawmilling corporation owning several sawmills and the Business Intelligence (BI) analysts in the sawmilling industry.

The manager of a single sawmill is interested in the success of the sawmill, whereas the management of a sawmilling corporation owning several sawmills is often more interested in the success of the entire corporation. The business intelligence analysts are also interested in the success of sawmills. However, they are also concerned with the needs of the internal accounting in a company or corporation. These BI needs include the profitability of products, the generation of scenarios and the production of refined information for the decision-making process according to their customers' requirements.

### 6.5.4 Product strategy implications

Kotler (2005) classifies products on the basis of their characteristics: durability, tangibility, and usage (consumer or industrial). According to Kotler's (2005) use classification, sawnwood can be seen as an industrial product, a raw material or a natural product. A natural product, sawnwood is limited in supply. It must be moved from the producer to the user and usually it has a low unit value. Because users depend on sawnwood, long-term supply contracts are common. The unhomogenity of sawnwood limits the amount of demand-creation activity in marketing and sales. Sawnwood demand of joinery and furniture segments is based on preferences and visual taste more than operational requirements (e.g. machine efficiency) as Rydell (1992) has assumed. Price and delivery reliability of sawnwood are the major factors influencing the selection of suppliers.

According to Kotler's (2005) classification of durability and tangibility, products can be classified into three groups:

1. Nondurable goods. These are tangible goods that are normally consumed in one or few uses and purchased frequently. From a construction process perspective, sawnwood can be seen as a nondurable product, a commodity that is purchased frequently.
2. Durable goods. These are tangible goods that normally survive many uses. From an industrial end-user perspective, sawnwood can also be seen as one of durable goods, e.g. furniture.
3. Services. These are intangible, inseparable, variable, and perishable products. For instance, the services cover logistic services of sawnwood for customers.

Sawnwood needs product strategy and market segments to compete on the market. This may not be a simple task. Nevertheless, a solution of sawnwood competitiveness can be found in grouping of sawnwood products. Classification of sawnwood product groups and their strategies can be presented as in Table 72. The tendency is from commodity products towards system products. Kairi (2005, p. 53) has used a similar approach.

During the last 10 years, there has been several changes in the Finnish sawmilling industry. These are changes in (1) competition, (2) use of products and (3) marketing systems. This has lead to a situation where traditional operation modes and product strategies do not give sufficient profitability any longer. Competition leads to price competition, if a sawmill has chosen a commodity product strategy (Table 72). A sawmill will get a sale if it sells at the lowest price within business rules.

In ongoing price competition, all sawmills are obliged to operate on market price basis. This leads to a situation where quality and other sawnwood value adding features are not seen important. Distribution segment (see e.g. Table 53) supports the prevailing system, which does not benefit the Finnish sawmills. For the Finnish sawmilling industry, it can be asked how one can succeed in the price competition. The production of commodity products (Table 72) is not profitable in Finland where raw-material and production costs are higher than in East Europe.

The production of commodity products cannot probably be improved so fast that the sawmilling industry could prosper in price competition.

**Table 72. Classification of sawnwood product groups and their strategies according to this study.**

| Product group | Quality | Market segments | Strategy |
|---|---|---|---|
| **Commodity products** | Simple commodity quality, e.g. Nordic timber (1994) | Distribution | Standard product strategy or multi-product strategy |
| **Standardised products** | More measurable quality, e.g. strength grading qualities | Segments with process or/and product standards | Standard product strategy or multi-product strategy |
| **Special products** | Product group quality | Industrial end-users, DIY | Product based strategies 1) |
| **Customised products** | Specific quality for a customer | Single customers with large volumes, industrial end-users, DIY | Product based strategies 1) |
| **System products** | Quality defined by end product | Industrial end-users with a advanced quality systems | End product strategies |

1) Product based strategies are defined here strategies that are based on solutions with the customer. See more, for instance, in Kairi (2005, p. 53).

Where can the Finnish sawmills find a good product strategy? The Finnish sawmilling industry needs a change in strategy and its implementation. In addition, the sawmills also need change management from commodity products to standardised, special, customised or system products. Product strategy implications were strongly based on commodity product strategy from 1995 to 2000. During the same time, there were signals to product based strategies, as shown in the results of the thesis. As the Finnish sawmilling industry consists of companies of various sizes and integration level, it may be useful for them to consider different strategies.

### 6.5.5 Research implications

How will the results of the thesis benefit research and development work in the forestry cluster? In general, information on consumer behaviour, supply and demand are some of the most important economic models that science, particularly managerial economics, has to offer in many respects. In the market economy, the profitability of a business can be directly derived from the decision makers’ ability to accurately evaluate and satisfy the supply and demand for products. No matter how efficiently the sawmill production line operates and how carefully the financial assets of a sawmill are managed, supply and demand for the products remain the crucial condition for the continued survival of the sawmill (Peppers and Bails 1987). The question can be answered more specifically on two levels: (1) the results create new research topics and (2) they foster further development and application of new research methods.

Concerning new research topics, the thesis points out that sawmills have vast amounts of information. This raises a clear development need to learn to process this information in order to benefit the sawmill business. It is likely that exploitation of inter-company information will be a subject of many future research and development projects. There is still much work to do in the field.

Concerning the application and development of research methods, the thesis seeks to present methods that will give relevant information to sawmills and other segments of the forest cluster when applied in practice. These methods are introduced through the results. The useful methods include logistic regressions as well as other statistical tools. Applying these tools gives new insight to controlling business and dynamics of the supply and demand of sawnwood and other wood products.

# 7 REFERENCES

1. Abbott, L. 1955. Quality and competition, Columbia University Press, New York, USA.
2. Agresti, A., Finlay, B. 1986. Statistical methods for the social sciences, 2nd Edition. Pearson, San Francisco, USA. ISBN: 0-02-301120-3.
3. Ahvenainen, J. 1984. Suomen sahateollisuuden historia (History of the Finnish sawmilling industry). WSOY. Porvoo, Finland. ISBN: 951-0-12476-1. (In Finnish)
4. Anderson, R.C., Hansen, E.C. 2004. The impact of environmental certification on preferences for wood furniture: A conjoint analysis approach. Forest Products Journal, 54 (3), pp. 42–50.
5. Berenson, M.L, Levine, D.M., Krehbiel, T.C. 2002. Basic business statistics. Concepts and applications. 8th Edition. Prentice Hall, Upper Saddle River, USA. ISBN: 0-13-097070-0.
6. Bingham, E. 2003. Advances in independent component analysis with applications to data mining. Dissertation. Helsinki University of Technology, Computer and Information Science. Report D4. Espoo, Finland. ISBN: 951-22-6819-1. http://lib.tkk.fi/Diss/2003/isbn9512268205/isbn9512268205.pdf. Retrieved: 10th May 2005.
7. Blalock Jr, H.M. 1985. Social statistics. 2nd Edition. McGraw Hill, New York, USA.
8. Bowyer, J.L., Shmulsky, R., Haygreen, J.G. 2003. Forest products and wood science. An introduction. 4th Edition. Iowa State Press. USA. ISBN: 0-8138-2654-3.
9. Brekke, L., Larsen, M.D., Ausburn, M., Takaichi, L. 2002. Suburban water demand modeling using stepwise regression. American Water Works Association, 94 (10), pp. 65–75.
10. Broh, R.A. 1982. Managing quality for higher profits, McGraw-Hill Inc., New York, USA.
11. Casselbrant, S. (editor). 1992. Order- och leveransprecision – Kvalitetsspråk (Order and delivery precision), Förprojekt, Nordisk Träprogram - Delprogram 4, Trätek, Stockholm, Sweden. (In Swedish)
12. Casselbrant, S., Kristensen, K., Müller, M., Raknes, E., Sipi, M., Svensson, B. 2000. Pohjoismainen puualan laatukieli – havupuu (Nordic quality languange for wood sector – coniferous timber). Danish Technological Institute. Helsinki University of Technology. Norwegian Institute of Wood Technology. Trätek, Swedish Institute for Wood Technology Research. ISBN: 951-22-4863-8. (In Finnish)
13. CEI-Bois. 2003. The European Woodworking Industries in Figures. Brussels, Belgium. http://www.cei-bois.org/. Retrieved: 8th December 2003.
14. Cho, H.-J. 1997. Introduction to Categorical Data Analysis. The web center for social research methods. http://www.socialresearchmethods.net/tutorial/Cho/intro.htm. Retrieved: 19th May 2005.
15. Confederation. 2004. Public information. Confederation of Finnish Construction Industries. Source: http://www.rakennusteollisuus.fi/tilastot_julkaisut/tilastot_suhdanteet/taulukko_4.pdf. Retrieved: 2nd December 2004.
16. Confederation. 2005. Internal information. Confederation of Finnish Construction Industries. Helsinki, Finland.
17. Cox, L.A. 2002. Data mining and causal modeling of customer behaviours. Telecommunications Systems, 21 (2–4), pp. 349–381.
18. Cox, D.R., Hinkley, D.V. 1978. Problems and solutions in theoretical statistics, Chapman and Hall, London, UK. ISBN: 0-470-26299-0.
19. CRISP-DM. 2005. Cross industry standard process for data mining. Process model. http://www.crisp-dm.org/Process/index.htm. Retrieved: 10th May 2005.
20. Cronbach, L. J. 1947. Test "reliability": Its meaning and determination. Psychometrika, 12 (1), pp. 1-16.
21. Crosby, P.B. 1979. Quality is free: The art of making quality certain. McGraw-Hill, New York, USA. ISBN: 0-07-014512-1.
22. Damery, D.T., Fisette, P. 2001. Decision making in the purchase of siding: A survey of architects, contractors, and homeowners in U.S. northeast. Forest Products Journal, 51 (7/8), pp. 29–36.
23. Danielsson, L. 1981. Laatutermien merkitys, Laatutekniikan seminaari osa 1. (Meaning of quality terminology, Quality technology seminar, part 1). INSKO:n seminaarimonistesarja, Helsinki, Finland. (In Finnish)
24. Diesen, M. 1998. Economics of the pulp and paper industry. Papermaking Science and Technology, Book 1. Fapet, Helsinki, Finland. ISBN: 952-5216-01-2.
25. Dubin, J.A. 1986. A nested logit model of space and water heat system choice. Marketing Science, University of Florida, 5 (2).
26. ECE/FAO. 2000. ECE/FAO Forest products annual market review, 1999–2000. Timber Bulletin, LIII (3), http://www.unece.org/trade/timber/docs/rev-00/rev00.htm. Retrieved: 13th July 2005.
27. ECE/FAO. 2001. ECE/FAO Forest products annual market review, 2000–2001. Timber Bulletin LIV (3).
28. Edwards, C.D. 1968. The Meaning of Quality, Quality Progress, 1 (10), pp. 36-39.
29. EN 1611–1. 1999. Sawn timber. Appearance grading of softwoods. Part 1: European spruces, firs, pines, Douglas fir and larches. SFS-EN 1611–1/A1:en. SFS standards. Helsinki. Finland.
30. Englund, A. 1981. The Sawmill Industry 1979 – Part 1. Production and timber requirement. The Swedish University of Agricultural Sciences. Department of Forest Products. Report no. 119. Uppsala, Sweden.
31. Enroth, R.-R. 1986. Suomen sahatavaran vienti Länsi-Eurooppaan vuosina 1960–82 (Finnish sawnwood export to West Europe from 1960 to 1982). Licentiate's thesis. Helsinki University, Faculty of Agriculture and Forestry. Helsinki, Finland. (In Finnish)
32. Esping, B. 1988. Trätorkning 2. Torkningsfel – åtgärder (Drying defects – operations). TräteknikCentrum. Stockholm, Sweden. ISBN: 91-970513-6-5. (In Swedish)
33. Esping, B. 1992. Trätorkning 1a. Grunder i torkning (Basics of Drying). Trätek. Stockholm, Sweden. ISBN: 91-88170-06-3. (In Swedish)
34. Esping, B. 1996. Trätorkning 1b. Praktisk torkning (Practical Drying). Trätek. Stockholm, Sweden. ISBN: 91-88170-23-3. (In Swedish)
35. EU. 1999. The state of the competitiveness of the EU forest-based and related industries, Draft Communication to the Council, The European Parliament, The Economic and Social Committee and the Committee of the Regions. European Comission COM (1999) 457 Final. Brussels, Belgium.
36. Euroconstruct. 2000. Euroconstruct conference material: Country reports - Germany, UK, France. June 2000. Vienna, Austria.

37. Euroconstruct. 2004. Euroconstruct conference material. June 2004. Stockholm, Sweden.
38. European. 1996. European timber trends and prospects: Into the 21st century. Geneva timber and forest study papers. No. 11. United Nations, Economic Commission for Europe (UN-ECE). Geneva, Swizerland. http://www.fao.org/wairdocs/x6829e/x6829e00.htm. Retrieved: 13th July 2005.
39. FAO. 1995. State of world's forests. FAO. United Nations. http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/003/X6953E/X6953E00.HTM. Retrieved: 13th July 2005.
40. FAOSTAT data. 2004. FAO Database of forestry. Forestry data - Roundwood, sawnwood, wood-based panels. http://www.fao.org – statistical databases – forestry or http://faostat.fao.org/faostat/collections?subset=forestry. Retrieved: 7th July 2004.
41. Feigenbaum, A.V. 1961. Total quality control, McGraw-Hill, New York. USA.
42. Finnforest. 2004. Public information. Finnforest. Espoo, Finland. http://www.finnforest.com/. Retrieved: 8th July 2004.
43. Finnish Forest Industries. 1999. Visio 2010 Suomen puutuotealan visio (Vision 2010 Finnish wood product sector's vision). Askopaino, Meridian X, Helsinki, Finland. (In Finnish)
44. Finnish Forest Industries. 2002. Tilastoja (Statistics). Helsinki, Finland. (In Finnish)
45. Finnish Forest Industries. 2003. Facts and figures 2003. Helsinki, Finland.
46. Finnish Forest Industries. 2004. Yearbook 2004. Statistics from 2003. Helsinki, Finland.
47. Finnish Forest Industries. 2005. Tilastoja (Statistics). Helsinki, Finland. (In Finnish)
48. Finnish Forest Research Institute. 2002. Finnish forest sector economic outlook 2002–2003. Vantaa Research Centre. Vantaa, Finland.
49. Finnish Statistical Yearbook of Forestry. 2003. Finnish statistical yearbook of forestry. Editor A. Peltola. Finnish Forest Research Institute. Helsinki, Finland.
50. Fleishman, S., Eastin, I.L., Shook, S.R. 1999. Material substitution trends in residential construction. CINTRAFOR (Centre for International Trade of Forest Products). USA.
51. Flinkman, M. 2004. Construction in North Germany. Reports, No. 7. School of Industrial Engineering. Växjö University. Växjö, Sweden.
52. Foreign Trade Statistics. 2002. Official foreign trade statistics of Finland. Finnish Customs. Helsinki, Finland.
53. Forest. 1998. Forest product consumption, Market structures and buying processes in the German market for timber framed housing. Ligna con, Report to Nordic Timber Council. Nonnweiler.
54. Forest. 2004. Forest, environment and industry - a story of new ways forward. Finnish Forest Industries Federation. Helsinki, Finland.
55. Forsén, H., Ranta-Maunus, A., Hakala, J., Siimes, H. 1993. Sahatavaran halkeilu teollisuuden koekuivauksissa (Sawnwood cracking in industry test drying). Valtion teknillinen tutkimuskeskus, Puulaboratorio, VTT julkaisuja 787, Espoo, Finland. ISBN: 951-38-4135-9. (In Finnish)
56. Forsén, H., Tarvainen, V. 2003. Sahatavaran jatkojalostuksen asettamat vaatimukset kuivauslaadulla ja eri tuotteille sopivat kuivausmenetelmät (Drying quality requirements in sawnwood refining and suitable drying methods for different products). VTT publications 517, Espoo, Finland. ISBN: 951-38-6263-1. (In Finnish)
57. Garvin, D.A. 1988. Managing quality - The strategic and competitive edge. Simon & Schuster, New York, USA. ISBN: 0-02-911380-6.
58. Gibas, C., Jambeck, P. 2001. Developing bioinformatics computer skills, O'Reilly & Associates, Sebastopol, USA. ISBN: 1-56-592664-1.
59. Gibson, L.J., Ashby, M.F. 1988. Cellular solids, structures & properties, 1st edition, Pergamon Press, Oxford, UK. ISBN: 0-08-035910-8.
60. Gilmore, H.L. 1974. Product conformance cost, Quality Progress, 7 (6), pp. 16-19.
61. Grace, L.A. 1993. Using optical log scanners to determine log properties: Initial results from SCA's Munksund sawmill, Swedish University of Agricultural Sciencies, Report No. 232, Uppsala, Sweden.
62. Green book. 1960. Instructions for the grading of Export Timber (Vientisahatavaran lajitteluohjeet). The Association of Finnish Sawmillmen (Suomen sahateollisuusmiesten yhdistys). Helsinki, Finland.
63. Griffith, S. 2000. Business decisions demand an optimized enterprise. Wood Technology, November/December, pp. 22–24.
64. Gujarati, D. 1992. Essentials of econometrics. McGraw-Hill, New York, USA. ISBN: 0-07-025194-0.
65. Hakala, H. 1992. Mäntytukkien sahauksen järeyden mukainen taloudellinen tulos ja siihen vaikuttavia tekijöitä (Financial result of sawing pine logs as influenced by top diameter and other associated factors). Dissertation. Helsinki University. Acta Forestalia Fennica 226. Helsinki, Finland. ISBN: 951-651-093-0. (In Finnish)
66. Hartikainen, T. 1997. Late-industrial sawmill customers. The concept of industrial operating mode and its testing in secondary wood processing industry. Dissertation. Acta Forestalia Fennica 257. Helsinki, Finland. ISBN: 951-40-1571-1.
67. Hatirli, S.A., Ozkan, B., Aktas, A.R. 2004. Factors affecting fluid milk purchasing sources in Turkey. Food Quality and Preference, 15 (6), pp. 509–515. http://www.econturk.org/Turkisheconomy/factors_affecting.pdf. Retrieved: 13th July 2005.
68. Heiskanen, V., Asikainen, K. 1969. Havusahatukkien järeyden mukaiset arvosuhteet ja hinnoitteluperusteet. (The value relationships and pricing principles of coniferous saw logs on the basis of their diameter). Finnish Forest Research Institute, Commun. Inst. For. Fenn., 69 (3), pp. 1–122. (In Finnish)
69. Hetemäki, L., Hänninen, R., Toppinen, A. 2001. A system for short term forecasting of the Finnish forest sector (MESU): The case of sawnwood imports and sawlog demand. Finnish Forest Research Institute, Research Papers 805. Helsinki, Finland. ISBN: 951-40-1775-7.
70. Hilli, P., Kallio, M., Kallio, M. 2004. A forest product portfolio model. Industrial and market perspectives on the forest sector. Proceedings from the International Conference on Forest Industry and Markets. Växjö University. Växjö, Sweden.
71. Hosmer, D.W., Lemeshow, S. 1989. Applied logistic regression. John Wiley & Sons. New York, USA. ISBN: 0-47-161553-6.
72. Howard, J.L. 2001. U.S. Timber production, trade, consumption, and price statistics 1965–1999. USDA-Forest Service. Res. Pap. FPL-RP-595. USA.
73. Huang, R., Carribre, K.C. 1999. Using proxy information in linear regression model, University of Alberta, Edmonton. Proceedings of the Survey Research Methods Section, American Statistical Association. USA. pp. 807–812.

74. Hänninen, R. 1998. Demand for Finnish exports of forest products: Econometric analyses using time series data. Dissertation. University of Helsinki. Finnish Forest Research Institute, Research Papers 708. Helsinki, Finland. ISBN: 951-40-1650-5.
75. Hänninen, R., Toppinen, A., Toivonen, R. 2004. Vertical price relationships in Austrian, Finnish and Swedish sawmilling industry. Industrial and market perspectives on the forest sector. Proceedings from the International Conference on Forest Industry and Markets. Växjö University, Sweden.
76. Inmon, B. 1990. Data warehouse. http://www.sdgcomputing.com/glossary.htm. Retrieved: 31st August 2004.
77. Investorwords. 2005. Investing glossary. http://www.investorwords.com. Retrieved: 26th May 2005.
78. Jammernegg, W., Kischka, P. 2004. Dynamic, customer-oriented improvement of supply networks. European Journal of Operational Research, June 2004. Vienna, Austria.
79. Johansson, G., Kliger, R., Perstorper, M. 1993. Inköpsregler for byggnadsvirke (Buying rules for construction timber), Byggforskningsrådet, R20:1993, Stockholm, Sweden. ISBN: 91-540-5540-7. (In Swedish)
80. Johansson, G., Kliger, R., Perstorper, M. 1994a. Quality of structural timber-product specification system required by end-users, Holz als Roh- und Werkstoff, 52, pp. 42–48.
81. Johansson, G., Kliger, R., Perstorper, M. 1994b. Byggarna kräver funktionsduldigt virke. (Costructors demand sawnwood with proper function). Sågverken, 8, pp. 54–55. (In Swedish)
82. Johansson, G., Kliger, R., Perstorper, M. 1995. End-user satisfaction - performance of timber products and influence of raw material parameters. IUFRO World congress 1995. S5.01–05 Wood Properties Desired by End-Users.
83. Johansson, M. 2004. Allocating the timber cost to sawn products. Industrial and market perspectives on the forest sector. Proceedings from the International Conference on Forest Industry and Markets. Växjö University. Växjö, Sweden.
84. Johansson, M., Rosling, K. 2002. The timber cost of a board. Scandinavian Forest Economics, 39, pp. 229–239.
85. Jonsson, R. 2004. What governs the end-consumers choice of floorcovering in the UK. An exploratory study of substitute competition. Industrial and Market perspectives on the Forest Sector. Proceedings from the International Conference on Forest Industry and Markets. Växjö University. Växjö, Sweden.
86. JPC. 2003a. Key findings and conclusions market, Industry & forest resource analysis as part of the roadmap to 2010 process. Jaakko Pöyry Consulting. London, UK.
87. JPC. 2003b. Sawmilling industry – Top 15 global and European sawmilling companies in Q2–2003. Internal unpublished information. Jaakko Pöyry Consulting. Vantaa, Finland.
88. JPC. 2005. Sawmilling industry – Top 10 global and European sawmilling companies in 2004. Internal unpublished information. Jaakko Pöyry Consulting. Vantaa, Finland.
89. Juran, J.M. 1974. Quality control handbook, 3rd Edition, McGraw-Hill, New York, USA. ISBN: 0-07-033175-8.
90. Juran, J.M., Godfrey, A.B. 1999. Juran's quality handbook. 5th Edition. McGraw-Hill, New York, USA. ISBN: 0-07-034003-X.
91. Juslin, H., Hansen, E. 2002. Strategic marketing in the global forest industries, Authors Academic Press. Corvallis, USA. ISBN: 0-9703333-4-X.
92. Juslin, H., Karppinen, H. 1983. Suomen tärkeimpien asiakasmaiden sahatavaraostot 1970-luvulla (Sawnwood sales of Finland's most important client countries in the 1970s). Folia Forestalia 562. Finnish Forest Research Institute. Helsinki, Finland. ISBN: 951-40-0627-5. (In Finnish)
93. Juslin, H., Naylor, R. 2004. Development of forest products marketing – Dialogue between theory and practice. Industrial and market perspectives on the forest sector. Proceedings from the International Conference on Forest Industry and Markets. Växjö University. Växjö, Sweden.
94. Juslin. H. , Tarkkanen, T. 1987. Marketing strategies for the Finnish forest industries. Communicationes Instituti Forestalis Fenniae 143. Helsinki, Finland. ISBN: 951-40-0791-3.
95. Juvonen, R. 1974. Sahatavaran teknillisestä laadusta ja sen valvonnasta (Technical quality of sawnwood and its control). Dissertation. Technical Research Centre of Finland, Material and Process Technology, Helsinki University of Technology, Laboratory of Mechanical Wood Technology. Report 1. Espoo, Finland. ISBN: 951-38-0106-3. (In Finnish)
96. Jäppinen, A. 2000. Automatic sorting of sawlogs by grade. Dissertation. Swedish University of Agricultural Sciences. Department of Forest Management and Products. Uppsala, Sweden. ISBN: 91-576-5873-0.
97. Kairi, M. 2005. Interaction of R&D and business development in the wood product industry, case Kerto® - laminated veneer lumber (LVL). Dissertation. Helsinki University of Technology. Laboratory of Wood Technology. Report 95. Espoo, Finland. ISBN: 951-22-7705-0. http://wood.tkk.fi/julkaisut/index.html, 15th July, 2005.
98. Kallio, M, Dykstra, D., Binkley. C. 1987. The global forest sector: An analytical perspective. Wiley. New York, USA. ISBN: 0-471-91735-4.
99. Kangas, K., Baudin, A. 2004. Demand, supply and trade analysis and long-term projections for the European Forest Sector Outlook Studies (EFSOS). Industrial and market perspectives on the forest sector. Proceedings from the International Conference on Forest Industry and Markets. Växjö University. Växjö, Sweden.
100. Kanniainen, V., Kuuluvainen, J. 1984. On price adjustment in the sawlog and sawnwood export markets of the Finnish sawmill industry. Finnish Forest Research Institute, Research Papers 147. Helsinki, Finland. ISBN: 951-40-0955-X.
101. Kano, N. 1984. Attractive Q vs. must be Q., Hinshitsu (Quality), 14 (2), pp. 39–48. (Original in Japanese)
102. Katila, M., Riihinen, P. 1990. Modeling newsprint consumption: A Finnish case study for the period 1960–1986. Acta Forestalia Fennica 217. Helsinki, Finland. ISBN: 951-651-090-6.
103. Kemi. 1979. Kemi sawmill pricing system. Internal report. Obtained through Professor (emeritus) Tero Paajanen. Kemi, Finland.
104. Kettunen, U.-P. 1981. Laadun käsite, Laatuajattelu –seminaari. (Quality construct, Quality thinking seminar). INSKO:n seminaarimonistesarja, Helsinki, Finland. (In Finnish)
105. Key to Finnish Forest Industries. 2000. Report B5. Finnish Forest Industries, Helsinki, Finland.
106. Klus, J.P., Hirvensalo, R. 1997. The mechanical wood processing (PMT) and wood-based panels (PLT) technology programmes 1992–1996. Evaluation report. Tekes - National Technology Agency of Finland. Technology programme report 7/97. Helsinki, Finland. ISBN: 951-53-0759-7.
107. Korhonen, S., Niemelä, J.S. 2004. Strategic options of corporate growth – Rethinking growth strategies in the leading European and North American wood-industry companies in 1998–2001. Industrial and market perspectives on the forest sector. Proceedings from the International Conference on Forest Industry and Markets. Växjö University, Växjö, Sweden.

108. Koskela, K. 1999. Puun ominaisuuksien hajonnan vaikutus koesuunnitteluun puuteknisessä tutkimuksessa (Influence of standard deviation in wood properties on the experimental design in wood technology research). Licentiate's thesis. Helsinki University of Technology, Laboratory of Wood Technology, Espoo, Finland. (In Finnish)
109. Kotler, P. 1988. Marketing management. Analysis, planning, implementation, and control. 6th Edition. Prentice Hall, Upper Saddle River, USA. ISBN: 0-13-556267-8.
110. Kotler, P. 1990. Markkinoinnin käsikirja. Oy Rastor Ab/Rastor julkaisut, Helsinki, Finland. ISBN: 951-9415-53-X. (In Finnish)
111. Kotler, P. 2000. Marketing management. International edition. The millenium edition. Prentice Hall, Upper Saddle River, USA. ISBN: 0-13-012217-3.
112. Kotler, P. 2005. Marketing management. International edition. 11th Edition. Prentice Hall, Upper Saddle River, USA. ISBN: 0-13-049715-0.
113. Kozak, R., Spelter, H. 2003. Globalization revolutionizing sawn softwood markets in 2002–2004. ECE/FAO, Forest Products Annual Market Analysis. Timber Bulletin, LVI (3), pp. 45–54. http://www.unece.org/trade/timber/tc-publ.htm. Retrieved: 13th September 2004.
114. Krisher, O., Kast, W. 1978. Die wissenschaftlichen Grundlagen der Trocknungstechnik (Scientific basics of drying technology), Dritte, neubearbeitete Auflage, Springer Verlag, Berlin, Heidelberg, New York. (In German)
115. Krugman, P.R., Obstfeld, M. 2000. International economics. Theory and policy. 5th Edition. Addison-Wesley, Reading, USA. ISBN: 0-321-03387-6.
116. Kröll, K. 1978. Trockner und Trocknungsverfahren (Drying kiln and drying operations). Zweite Auflage. SpringerVerlag, Berlin, Heidelberg, New York. ISBN: 3-540-08108-9. (In German)
117. Kuehn, A.A., Day, R.L. 1962. Strategy of product quality, Harvard Business Review, November-December 1962. USA.
118. Kärnä, J. 2003. Environmental marketing strategy and its implementation in forest industries. Dissertation. University of Helsinki, Department of Forest Economics. Helsinki, Finland. ISBN: 952-10-0963-2.
119. Lacroix, Z., Critchlow, T. 2003. Bioinformatics: Managing scientific data. Morgan Kaufmann Publishers. ISBN: 1-55860-829-X.
120. Laine, S. 2003. Using visualization, variable selection and feature extraction to learn from industrial data. Dissertation. Helsinki University of Technology, Department of Computer Science and Engineering. Espoo, Finland. ISBN: 951-22-6669-5.
121. Laine, S., Hietala, J., Etherington, R., Pyhälahti, H. 2001. Building and living with wood in the UK. A qualitative study on the foreseeable changes in the end-user behaviour and value added chains to perceive new opportunities for the Finnish Wood Product Industry. Finnish Forest Industries Federation, Finpro. Helsinki, Finland.
122. Lamberg, J.-A. 2001. Yhtiö, joka ei välittänyt velasta eikä valtiosta (A Company that bothered neither debt nor state). In Book Näsi, J., Lamberg, J-A., Ojala. J., Sajasalo, P. Metsäteollisuusyritysten strategiset kehityspolut (Forest industry companies' strategic development paths). Tekes - National Technology Agency of Finland, Academy of Finland, Ministry of Agriculture and Forestry, Ministry of Trade and Industry, Wood Wisdom. Helsinki, Finland. ISBN 952-457-061-0. (In Finnish)
123. Latta, G.S., Adams, D.M., 2000. An econometric analysis of output supply and input demand in the Canadian softwood lumber industry. Canadian Journal of Forest Research, 30 (9), pp. 1419–1428.
124. Leffler, K.B. 1982. Ambiguous changes in product quality, American Economic Review, December 1982.
125. Lehto, J. 1995. Kannattavan sahan toimintaedellytykset, seminaariesitelmä (Profitable sawmill operation conditions, seminar presentation). Tekes - National Technology Agency of Finland. Annual seminar of wood technology programmes, May 10, 1995. Espoo, Finland. (In Finnish)
126. Leppänen. M. 1993. Sahateollisuus (Sawmilling industry). Toimialakatsaus (Branch review) 1993. Industrialization Fund of Finland Ltd, Helsinki, Finland.
127. Lillrank, P., 1990. Laatumaa - Johdatus Japanin talouselämään laatujohtamisen näkökulmasta (Quality land – Introduction to Japan's economy from quality management perspective), Gaudeamus, Helsinki, Finland. (In Finnish)
128. Lindblad, J., Tammiruusu, V., Lehtimäki, J., Kilpeläinen, H., Heräjärvi, H., Verkasalo, E. 2004. Pieniläpimittaisen koivun hyödyntäminen huonekaluteollisuuden tarpeisiin (Small diameter birch use for needs of furniture industry), Metsäntutkimuslaitoksen tiedonantoja 899. Finnish Forest Research Institute, Helsinki, Finland. ISBN: 951-40-1889-3. (In Finnish)
129. Luther. L, 1986a. Kotimaankauppa (Domestic trade). Chapter from Mekaaninen metsäteollisuus 2, Sahateollisuus (Mechanical forest industry 2, sawmilling industry). Ammattikasvatushallitus, Suomen puuteollisuusinsinöörien yhdistys r.y., Valtion painatuskeskus. Helsinki, Finland. ISBN: 951-859-690-5. (In Finnish)
130. Luther. L, 1986b. Sahatavaran markkinointi (Sawnwood marketing). Chapter from Mekaaninen metsäteollisuus 2, Sahateollisuus (Mechanical forest industry 2, sawmilling industry). Ammattikasvatushallitus, Suomen puuteollisuusinsinöörien yhdistys r.y., Valtion painatuskeskus. Helsinki, Finland. ISBN: 951-859-690-5. (In Finnish)
131. Martikainen, P. 1994. Strategic Marketing planning in the Finnish forest industries – A theoretical marketing planning model and its empirical testing. University of Helsinki. Department of Forest Economics. Reports 3. Espoo, Finland. ISBN: 951-45-6661-0.
132. Martikainen, P. 2002. Tuotannon kasvu Suomen rajojen ulkopuolella (Production growth out of Finland). Presentation, November 7, 2002. Finnish Forest Industries. Helsinki, Finland. (In Finnish)
133. Martin, R.M., Darr, D.R. 1997. Market responses to the U.S. timber demand-supply situation of the 1990s: Implications for sustainable forest management. Forest Products Journal, 47 (11/12), pp. 27–32.
134. Mater, J. 1994. Apply five-step plan to uphold industry, Wood Technology, January/February 1994.
135. Mater, J., Mater, M.S., Mater, C.M. 1992. Marketing forest products, gaining the competitive edge. Miller Freeman, San Francisco, USA. ISBN: 0-87930-193-7.
136. Mauno, A. 2003. European research resources in wood technology. Master's thesis. Helsinki University of Technology. Laboratory of Wood Technology. Espoo, Finland.
137. McClave, J. T., Benson G. P., Sincich T. 2005. Statistics for business and economics. 9th Edition. Prentice Hall, Upper Saddle River, USA. ISBN: 0-13-124698-4.
138. Menard, S. 1995. Applied logistic regression Analysis. Sage University Paper series on Quantitative Applications in the Social Sciencies, 07-106. Thousand Oaks, USA. ISBN: 0-8039-5757-2.
139. Microsoft®. 2002. Excel®. Software. SP-2. USA.

140. Mikkola, K., Riihimäki, M. 2002. Omakotitalorakentajien valmius ympäristöystävällisiin rakentamistapoihin (The readiness of one-family house constructors to environmentally friendly construction methods). VTT Tiedotteita – Research Notes 2170, Espoo, Finland. ISBN: 951-38-6095-7. (In Finnish)
141. Milton, J.S., Arnold, J.C. 1995. Introduction to probability and statistics. Principles and applications for engineering and the computing sciences. McGraw-Hill Inc., New York, USA. ISBN: 0-07-113535-9.
142. Morales, S., Fernández, P., Guesalaga, A., Irarrazaval, P. 2002. 3D Internal tree structure modelling using Magnetic Resonance Imaging (MRI). IUFRO WP S5.01–04 "Connection between forest resources and wood quality: modelling approaches and simulation software". British Columbia. Editor: G. Nepveu, INRA, Nancy. pp. 254–264.
143. Morén, T. 1993. Creep, Deformation and moisture redistribution during air convective wood drying and conditioning. Dissertation. Luleå University of Technology, Department of Wood Technology, Skellefteå Campus, Skellefteå, Sweden.
144. Mäki, P., Toivonen, R., Enroth, R.-R. 2003. Puutuotteiden vientimahdollisuudet Kiinaan (Export prospects for wood products to China). Pellervo Economic Research Institute Research Reports No. 187. Helsinki, Finland. ISBN: 952-5299-68-6. (In Finnish)
145. Määttä, O. 1986. Vientilajitteluohjeet sekä eri laatujen lankeaminen (Export grading rules and falling of different qualities). Chapter from Mekaaninen metsäteollisuus 2, Sahateollisuus (Mechanical forest industry 2, sawmilling industry). Ammattikasvatushallitus, Suomen puuteollisuusinsinöörien yhdistys r.y., Valtion painatuskeskus, Helsinki, Finland. ISBN: 951-859-690-5. (In Finnish)
146. Nationmaster. 2005. Nationmaster website. http://www.nationmaster.com/encyclopedia/Commonwealth-of-Independent-States. Retrieved: 8th August 2005.
147. National Statistics. 2005. National statistics website. http://www.statistics.gov.uk. Retrieved: 27th May 2005. UK.
148. NCSS®. 2000. Statistical software. NCSS® Help system. USA.
149. Niemelä, J.S. 1993. Marketing-oriented strategy concept and its empirical testing with large sawmills. Dissertation. Acta forestalia fennica 240, The Society of Forestry in Finland - Finnish Forest Research Institute, Helsinki, Finland. ISBN: 951-651-096-5.
150. Niemelä, J.S. 1994. Sahojen markkinointistrategiat asiakaslähtöisempiä Suomessa kuin Pohjois-Amerikassa (Sawmills' marketing strategies more customer oriented in Finland than in North America), Puumies 3/1994.
151. NIST. 2004. National institute of standards and technology. USA. http://www.itl.nist.gov/div898/handbook/eda/section3/eda35g.htm. Retrieved: 15th July 2004.
152. Nordic timber. 1994. Grading rules for Nordic pine (*Pinus sylvestris*) and spruce (*Picea Abies*). Suomen sahateollisuusmiesten yhdistys (The Association of Finnish Sawmillmen, STMY, Finland) - Förening Svenska Sågverksmän (FSS, Sweden) - Treindustriens Tekniske Forening (TTF, Norway), Helsinki, Stockholm, Oslo.
153. Nordiskt träteknik. 1993. Halverar kostnaderna för bristande kvalitet (Halve costs for lacking quality), Nordiskt träteknik - special, No. 3/1993. Sweden. (In Swedish)
154. Nordiskt träteknik. 1994. Iggesund lägger om kursen (Iggesund sets the course). Nordiskt träteknik, No. 5/1994. Sweden. (In Swedish)
155. Oja, J. 1997. Measuring knots and resin pockets in CT-images of Norway spruce. Licentiate's thesis. Division of Wood Technology, University of Technology, Luleå, Skellefteå,Sweden.
156. Oja, J., Grundberg, S., Grönlund, A. 2001. Predicting the stiffness of sawn products by X-ray scanning of Norway spruce saw logs. Scand. J. For. Res., 16, pp. 88–96.
157. Olkkonen. S. 1996. Strengths, weaknesses, opportunities and threats of the Finnish sawmill industry. Master's thesis. Department of Forest Economics. University of Helsinki. Helsinki, Finland.
158. Paajanen, T. 1988. Uudet tekniset sovellutukset sahatavaran kuivauksessa (New technological applications in sawnwood drying). Helsinki University of Technology, Laboratory of Wood Technology. Tiedonanto 52 (Bulletin 52), Espoo, Finland. ISBN: 951-754-709-9. (In Finnish)
159. Paajanen, T. 1997. Laatupuun arvonlisä – mikä on eri lopputuotteiden puustamaksukyky? (Quality stem value added – what is wood paying capacity for different end products?). Folia Forestalia. Finnish Forest Research Institute. Metsätieteen aikakauskirja, 1/1997. Helsinki, Finland. (In Finnish)
160. Paajanen, T., Niemelä, J.S., Lindgren, C., Ollikainen, C. 2000. Puutuotealan tutkija- ja kehittäjäkoulu sekä osaamisresurssit – Uuden osaamisen tarpeet puutuotealalla (Wood product branch graduate and developer school and competence resources – New competence needs on wood product branch). Helsinki University of Technology, Laboratory of Wood Technology. Espoo, Finland. ISBN: 951-22-4901-4. (In Finnish)
161. Paajanen, T., Hirvensalo, R., Mauno, A., Lahti, T., Vahtikari, K. 2004a. Puutuoteteollisuuden elinkeinopoliittisen ohjelman loppuraportti (Wood product industry business policy programme, Final report). Helsinki University of Technology, Laboratory of Wood Technology. Draft. Espoo, Finland. (In Finnish)
162. Paajanen, T., Kotilahti, T., Vahtikari, K., Hirvensalo, R. 2004b. Puusuomi-toimintaohjelman arviointi 2003 (Wood Finland plan of action evaluation 2003), Helsinki University of Technology, Department of Forest Products Technology, Laboratory of wood technology, Tiedonanto 90 (Bulletin 90), Espoo, Finland. ISBN: 951-22-7152-4. (In Finnish)
163. Pajakkala, P. 2004. Presentation. Puumarkkinapäivä 1.11.2004. (Wood Market Day 1.11.2004). Presentation material. VTT. Tampere, Finland. (In Finnish)
164. Pajuoja, H. 1998. Metsäteollisuustuotteiden kysyntä kasvaa edelleen (Forest products' demand keeps on growing). Article from Vihreä valtakunta, Suomen metsäklusteri (Green empire – Finnish forest cluster), pp. 70–78. Helsinki, Finland. ISBN: 951-1-15652-7. (In Finnish)
165. Pajuoja, H., Brooks, D. 1996. Long term forecasts of word consumption and production of roundwood and forest products. Proceedings of the biennial meeting of the Scandinavian Society of Forest Economics. Scandinavian Forest Economics, 36.
166. Pakkanen, M., Virtanen, J., Paajanen, T. 1999. Raaka-aineen saatavuus ja potentiaali sahatavaran jalostukseen Suomessa (Availability and potential of the raw material of sawnwood in Finland). Helsinki University of Technology, Laboratory of Wood Technology, Tiedonanto 76 (Bulletin 76) Espoo, Finland. ISBN: 951-22-4450-0. (In Finnish)
167. Palo, M. 2004. Globalization of forest industries: opportunities and threats for Finland and Sweden. Industrial and market perspectives on the forest sector. Proceedings from the International Conference on Forest Industry and Markets. Växjö University. Växjö, Sweden.
168. Paloposki, T.J. 1970. Suomen sahanomistajayhdistys 1895–1970 (Finnish sawmill owners' association). 75 vuotta sahateollisuuden yhteistoimintaa (75 years of cooperation in sawmilling). Helsinki, Finland. (In Finnish)

169. Parkin, M. 1999. Economics. 5th Edition. Addison-Wesley. Reading, USA. ISBN: 0-201-45845-4.
170. Pekkarinen, J., Sutela, P. 1985. Kansantaloustiede 1 (Economics 1). 3rd Edition. Obtained through Vaara (1998). Helsinki, Finland. (In Finnish)
171. Pelkonen, H. 1986. Sahatukkien laatumääritykset ja laadun merkitys (Quality definitions of sawn logs and importance of quality). Chapter from Mekaaninen metsäteollisuus 2, Sahateollisuus (Mechanical forest industry 2, sawmilling industry). Ammattikasvatushallitus, Suomen puuteollisuusinsinöörien yhdistys r.y., Valtion painatuskeskus. Helsinki, Finland. (In Finnish)
172. Peppers, L.C., Bails, D.G. 1987. Managerial economics: Theory and applications for decision making. Prentice Hall, Upper Saddle River, USA. ISBN: 0-135-49586-5.
173. Perstorper, M. 1994. Quality of structural timber - end-user requirements and performance control. Dissertation. Chalmers University of Technology, Publ. 94:2, Göteborg, Sweden.
174. Peura, P. 2001. The European construction network. Presentation in seminar November 7th, 2001. Lahti, Finland.
175. PFC. 2005. Pacific forestry centre. Natural resources Canada. http://www.pfc.forestry.ca/profiles/wulder/mvstats/, Retrieved: 18th August 2005.
176. Phillips, D., Soltis, J., 1998, Perspectives on learning, 3rd Edition, Teachers college press. Obtained through Laine (2003). New York, USA. ISBN: 0-8077-3703-8.
177. Pindyck R.S., Rubinfeld D.L. 1998. Econometric models and econometric forecasts, 4th Edition, McGraw-Hill. New York, USA.
178. Pinto, I. 2004. Raw material characteristics of maritime pine (*Pinus pinaster Ait.*) and their influence on simulated sawing yield. Dissertation. Helsinki University of Technology. Department of Forest Products Technology. VTT Publications 533. Espoo, Finland. ISBN: 951-38-6373-5.
179. PMT-programme. 1995. PMT -ohjelman synergia (Synergy of PMT-programme). Wood mechanical processing programme. Bulletin. Tekes - National Technology Agency of Finland. Helsinki, Finland. (In Finnish)
180. Porter, M. E. 1996. On competition. A Harvard Business Review Book. ISBN: 0-8758-4795-1.
181. Poutanen, T. 2000. Puurakentamisen mahdollisuudet (Opportunities for wood construction). From book Seppälä, R. (editor) 2000. Suomen metsäklusteri tienhaarassa (The Finnish forest cluster at a cross road). The Finnish Forest Cluster Research Programme Wood Wisdom. Helsinki, Finland. (In Finnish)
182. Profitable Sawmill. 1993. Analysis of market opportunities for the profitable sawmill 2000 project. Finnish Wood Research Ltd. Internal report. Espoo, Finland.
183. Profitable Sawmill. 1994. Kannattava saha - Sahateollisuuden toimintaedellytykset 1990–luvulla (Profitable sawmill – sawmilling industry operation conditions in 1990s). Suomen Puututkimus Oy (Finnish wood Research Ltd.). Yhteenveto (summary), Espoo, Finland. (In Finnish)
184. PS 20–70. 1970. American softwood lumber. Voluntary Product Standard PS 20–70. U.S. Department of Commerce (USDC). National Bureau of Standards, Washington, D.C., USA.
185. PTT. 2004. PTT-katsaus (review) 1/2004 (13th April 2004), Suhdannekuva (Economic cycle view), 2004. Pellervo Economic Research Institute. Helsinki, Finland. (In Finnish)
186. Putkisto, K. 1970. Sahapuun korjuun ja käsittely kehitys viime vuosisadalta nykypäivään. (Development of saw log harvesting from last century to the present). Suomen sahanomistajayhdistys (Finnish sawmill owner association). 75 vuotta sahateollisuuden yhteistoimintaa (75 Years of cooperation in sawmilling). Helsinki, Finland. (In Finnish)
187. Puun mekaanisen jalostuksen teknologiaohjelma. 1997. Puun mekaanisen jalostuksen teknologiaohjelma (Wood mechanical processing technology programme). Bulletin May 1997. Tekes - National Technology Agency of Finland. Helsinki, Finland. (In Finnish)
188. Puuteollisuus. 1964. Mekaaninen puuteollisuus I (Mechanical wood industry I). Heikinheimo. O. (editor). Suomen puuteollisuusinsinöörien yhdistys r.y. Seinäjoki, Finland. (In Finnish)
189. Pöyhönen, I. 1991. Suomen sahateollisuuden kehityksen keskeiset muutokset vuoteen 2000 (The key changes in the development of the Finnish sawmilling industry until the year 2000). Dissertation. Helsinki University of Technology. Laboratory of Mechanical Wood Technology. Espoo, Finland. ISBN: 951-22-0805-9. (In Finnish).
190. Rasimus, T. 1996. Itsenäisen sahateollisuuden toimintaedellytykset – Benchmarking-tutkimus (Operational preconditions of independent sawmilling industry – benchmarking-research). Ministry of Trade and Industry. Research papers and reports 11/1996. Helsinki, Finland. ISBN: 951-739-162-5. (In Finnish)
191. Rauste-von Wright, M., von Wright, J. 1998. Oppiminen ja koulutus (Learning and education). WSOY. Helsinki, Finland. ISBN: 951-0-20024-7. (In Finnish)
192. Relander, I. 1986. Itävallan sahateollisuus ja sen laitemarkkinat (Austrian sawmilling industry and its markets for machinery), Vientikoulutussäätiö (Training foundation for international business), Publications No. 5, pp. 205–248. ISBN: 951-833-222-3. (In Finnish)
193. Ripatti, P. 1996. Factors affecting partitioning of private forest holdings in Finland. A logit analysis. Dissertation. Helsinki University. Acta Forestalia Fennica 252. The Finnish Society of Forest Science – Finnish Forest Research Institute. Helsinki, Finland. ISBN: 951-40-1534-7.
194. Roadmap 2010. 2003. Roadmap 2010 for the European woodworking industries. European Confederation of Woodworking Industries. Brussels, Belgium.
195. Roadmap 2010. 2004. Executive Summary. Prepared by Timwood AB. Final editing by CEI-Bois. Stockholm, Sweden – Brussels, Belgium.
196. Rosenkilde, A. 2002. Moisture content profiles and surface phenomena during drying of wood. Dissertation. Kungliga Tekniska Högskolan, Byggnadsmaterial. Stockholm, Sweden.
197. RT. 2004. Rakennusteollisuuden vuosikirja 2004 (Yearbook 2004 - Confederation of Finnish Construction Industries), Confederation of Finnish Construction Industries. Helsinki, Finland.
198. Rydell, R. 1992. Framtida krav på virke till snickerier och möbler (Future requirements of sawnwood for joinery and furniture), Trätek kontenta 9203022, Stockholm, Sweden. (In Swedish)
199. Rytkönen, A. 2003. Puun loppukäyttö rakentamisessa (Wood end-use in construction), Foreco Oy. Internal report. Porvoo, Finland. (In Finnish)
200. Rämö, A-K., Järvinen, E., Toivonen, R., Enroth, R-R. 2003. Rakennepuutuotteiden tulevaisuus Saksan markkinoilla (Market prospects of engineered wood products in Germany). Pellervo Economic Research Institute Working Papers, No. 64. Helsinki, Finland. ISBN: 952-5299-67-8. (In Finnish)

201. Saksan sahateollisuus. 1992. Saksan sahateollisuus 1995 – Vaikutukset Suomeen (Sawmilling Industry in Germany 1995 – Effects on Finland). Suomen Puututkimus Oy (Finnish Wood Research Ltd.). Jaakko Pöyry Ltd. Internal report. Espoo, Finland. (In Finnish)
202. Salin, J.-G. 1990. Simulation of the timber drying process. Prediction of moisture and quality changes. Dissertation. Åbo Akademi University. Helsinki, Finland.
203. Salin, J.-G. 2000. Optimering av konditioneringen vid virkestorkning (Optimization of conditioning in kiln drying). Trätek, Rapport P 0002004. Stockholm, Sweden. (In Swedish)
204. Salin, J.-G. 2001. Inre sprickor och mikrosprickor vid virkestorkning (Internal checks (cracks) and microchecks during timber drying). Trätek, Rapport P 0104009. Stockholm, Sweden. (In Swedish)
205. Sandberg, R. 1996. Sahatavaran tasausvara (A study of excess lengths for high quality spruce and pine timber). Master's thesis. Helsinki University of Technology, Department of Forest Products Technology, Laboratory of wood technology, Espoo, Finland. (In Finnish)
206. Sandholm, L. 1988. Kvalitetsstyrning (Quality control), Studentlitteratur, Lund, Sweden. ISBN: 91-44-17182-X. (In Swedish)
207. Savolainen, M. 1971. Sahatavaran markkinointi ja laivaus (Sawnwood marketing and shipping). Otava, Helsinki, Finland. (In Finnish)
208. Senge, P.M., Kleiner, A., Roberts, C., Ross, R., Smith, B. 1998. The fifth discipline fieldbook: strategies and tools for building a learning organization. Nicholas Brealey Publishing. London, UK.
209. SFS 5878. 2000. INSTA 142. Sahatavaran visuaalisen lujuuslajittelun pohjoismaiset säännöt. Nordic visual strength grading rules for timber. 2000–10–02. 1st Edition. Helsinki, Finland. (In Finnish)
210. SFS-EN 338. 2003. Structural timber. Strength classes. Helsinki, Finland.
211. SFS-EN 1611–1/A1. 2002. Sawn timber. Appearance grading of softwoods. Part 1: European spruces, firs, pines, Douglas fir and larches. Helsinki, Finland.
212. SFS-EN 1611–1. 2000. Sawn timber. Appearance grading of softwoods. Part 1: European spruces, firs, pines and Douglas firs. Helsinki, Finland.
213. SFS-EN 1912. 1998. Rakennesahatavara. Lujuusluokat. Visuaalisten laatuluokkien ja puulajien määritys. Structural timber. Strength classes. Assignment of visual grades and species. December 21, 1998, Julk./publ. May 21, 2001 (In Finnish). 1st Edition. Helsinki, Finland.
214. Sharma, S. 1996. Applied Multivariate Techniques. John Wiley & Sons, USA. ISBN: 0-471-31064-6.
215. Shutt, R.C. 1995. Economics for the Construction Industry. 3rd Edition. Longman Scientific & Technical, Harlow, UK. ISBN: 0-582-22912-x.
216. Siekkinen, V., Pajuoja, H. 1990. Suomen piensahat 1990 (Small sawmills in Finland, 1990), Folia Forestalia 784, Finnish Forest Research Institute, Helsinki, Finland. ISBN: 951-40-1193-7. (In Finnish)
217. Siikaluoma, S.O. 1995. Pientukkien sahaus osana erään sahan liiketoimintaa (A Small Log Sawing as a Separate Business Area). Master's thesis. Helsinki University of Technology, Laboratory of Wood Technology, Espoo, Finland 1995. (In Finnish)
218. Siimes, F.E. 1945. Sahatavaran lajittelu sen käyttövaatimuksia silmälläpitäen (Sawnwood grading scanning its user requirements). Ministry of trade and industry. Helsinki, Finland. (In Finnish)
219. Siimes, H., Kuusela, J. 1983. Mekaanisen metsäteollisuuden energiatutkimus 1980–1982. Esilajittelun merkitys kuivauskapasiteettiin ja sahatavaran laatuun. (Energy research in the mechanical forest industry 1980–1982. The influence of pre-grading on drying capacity and quality of sawnwood). VTT, Research Reports 148. Espoo, Finland. (In Finnish)
220. Sinclair, S.A. 1992. Forest Products Marketing, McGraw-Hill, New York, USA.
221. Sipi, M. 1991. Havusahatavaran lajittelun perusteita (Fundamentals of sawnwood grading). Dissertation. Helsinki University of Technology. Laboratory of Mechanical Wood Technology. Espoo, Finland. ISBN: 951-22-0590-4. (In Finnish)
222. Sipi. M. 2002. Sahatavaratuotanto (Sawnwood production). Opetushallitus. Helsinki, Finland. ISBN: 952-13-1309-6. (In Finnish)
223. Sipi, M., Rajaniemi, K., Virtanen, J. 1995. Tuotepohjainen sahatavaran lajittelusäännöstö (Product based sawnwood grading rules). Helsinki University of Technology. Laboratory of Wood Technology. Espoo, Finland. (In Finnish)
224. Skogsordlista. 1994. Forest vocabulary. Tekniska nomenklaturcentralens publikationer nr 96, Sverges Skogsvårdsförbund, Västervik, Sweden. (In Swedish)
225. Sloman, J. 1991. Economics. Harvester Wheatsheaf. Prentice Hall. New York, USA. ISBN: 0-7450-0860-7.
226. Soin, S. S. 1992. Total quality control essentials − Key elements, methodologies, and managing for success. McGraw-Hill, New York, USA. ISBN: 0-07-059548-8.
227. Sonntag, G. 1995. Potential and limitations to harvester logging in volatile markets. IUFRO World Congress 1995. Session P3.07–00 Harvesting, Wood Delivery and Utilization - Tree Harvesting/Processing for Value: Data Gathering, Optimization and System Design. Tampere, Finland.
228. SPSS®. 2003. SPSS® 12.0 for Windows. Help, case studies. Chicago, USA.
229. SS 020104. 1987. Kvalitet – terminology (Quality, terminology), Standardiserings-kommissionen i Sverige. Stockholm, Sweden. (In Swedish)
230. Statistisches Bundesamt. 2003. Bauen und Wohnen (Construction and housing statistics). Statistisches Bundesamt (Federal Statistical Office Germany). Germany. (In German)
231. Statistics Finland. 2004. Construction statistics. Statistics Finland. Helsinki, Finland.
232. STAT. 2004. Cost-of-living index (1951:10 = 100). Statistics Finland. Helsinki, Finland. http://www.stat.fi, Retrieved: July 23rd 2004.
233. STAT. 2005. Output in basis price, wood products, fixed prices. Statistics Finland. http://www.stat.fi, Retrieved: April 18th 2005.
234. Statistix®. 1992. Statistix® Version 4.0 User's manual. Analytical Software, St. Paul, USA.
235. Stora Enso Timber. Public information. 2004. http://www.storaenso.com/timber. Retrieved: 8th July 2004.
236. Stora Enso Timber. 2005. Internal report. Porvoo, Finland.
237. Studenmund. A.H. 2001. Using econometrics. A practical guide. 4th Edition. Occidental college. Addison Wesley Longman. Boston, USA. ISBN: 0-321-06481-X.

238. Sun, C. 2001. Issues in the forest products trade: Deforestation, price volatility, and exchange rate uncertainty. Dissertation. Auburn University. Auburn, USA.
239. Sågverken. 1993. Vattna varsamt! (Damp carefully). Sågverken, 4, pp. 11–13. (In Swedish)
240. Tarkkonen, L. 1987. On reliability of composite scales. Statistical studies 7. Finnish Statistical Society, Statistical studies. Helsinki, Finland. ISBN: 951-95421-0-8.
241. Tasanen, T. 2004. Läksi puut ylenemähän. Metsien hoidon historia Suomessa keskiajalta metsäteollisuuden läpimurtoon 1870-luvulla (The history of silviculture in Finland from the mediaeval to the breakthrough of forest industry in 1870s). Dissertation. Finnish Forest Research Institute. Metsäntutkimuslaitoksen tiedonantoja 920. Helsinki University. Helsinki, Finland. ISBN 951-40-1920-2. (In Finnish)
242. TEKES. 2003. Tukista tuplaksi (Double the Log). Tekes - National Technology Agency of Finland. Technology programme closing seminar, September 30th, 2003. (In Finnish)
243. Teriö, O., Kauranen, H., Mikkola, K. 2005. Puurakentamisen prosessien re-engineering (The re-engineering of wood construction processes). Woodfocus and VTT Rakennus- ja yhdyskuntatekniikka (VTT Building and transport). Espoo, Finland. (In Finnish)
244. Tervo, M., Janatuinen, A., 1988. Suomen havusahatavaran viennin suhdanneindikaattorit (Business cycle indicators for Finnish sawnwood exports). Metsäntutkimuslaitoksen tiedonantoja 312. Finnish Forest Research Institute, Bulletin 312. Helsinki, Finland. ISBN: 951-40-1021-3. (In Finnish)
245. The Association of Finnish Sawmillmen. 2002. Pohjoismainen sahatavara, Sahatavarakaupan käsikirja (Nordic timber, Sawnwood contract handbook). Suomen sahateollisuusmiesten yhdistys (The Association of Finnish Sawmillmen, STMY, Finland). Helsinki, Finland. (In Finnish)
246. The First European Wood Conference. 2002. Wood industry in Europe – growing together, 1st European Wood Conference, Congress Centrum Hamburg, October 7–9, 2002. German Society of Wood Research. Hamburg, Germany.
247. The Pennsylvania State University. 2003. Information: PARETO analysis strategy 2003. Applied Research Laboratory, The Pennsylvania State University - State College, Pennsylvania, USA. http://www.bmpcoe.org/bestpractices/internal/arlps/ arlps_30.html. Retrieved: 21st October 2003.
248. The Sawn Timber. 1982. The sawn timber and products Swedish and Finnish redwood and whitewood. The Swedish Finnish Timber Council. Retford, UK.
249. Thörnqvist, T. 1990. Trä och kvalitet (Wood and quality), Rapport R77:1990, Byggforskningsrådet. Stockholm, Sweden. (In Swedish)
250. Tiittanen, K. 1986. Saksan liittotasavallan sahateollisuus ja sen laitemarkkinat (Sawmilling industry and its markets for machinery in German Federal Rebublic), Vientikoulutussäätiö (Training foundation for international business), Publications No. 5. Helsinki, Finland. ISBN: 951-833-234-7. (In Finnish)
251. Tikka, S. 1997. Sahatavaran ja puupohjaisten tuotteiden maailmanmarkkinat (World markets of sawnwood and wood-based products). Joensuu University, Faculty of Forestry, Joensuu, Finland. ISBN: 951-708-504-4. (In Finnish)
252. Tilli, T., Toivonen, R., Hänninen, R., Toppinen, A. 2001. Suomen sahatavaramarkkinat ja Suomen sahatavaravienti Saksaan (Sawnwood markets in Germany and Finnish sawnwood imports in Germany). Pellervon taloudellinen tutkimuslaitos PTT (Pellervo economic research institute PTT). Työpaperit (Working papers) No. 45. Helsinki, Finland. (In Finnish)
253. Timwood. 1998. Global drivers and megatrends in the wood products industry to year 2010. Stockholm.
254. Toivonen, R. 1995. Electronic information systems in marketing – A customer service oriented approach. Licentiate's thesis. Forest Products Marketing, Faculty of Agriculture and Forestry, University of Helsinki. Helsinki, Finland.
255. Toivonen, R., Enroth, R.-R., Järvinen, E. 2004. Competitive position of the Nordic wood industry on German markets – focusing on intangible product dimensions. Industrial and market perspectives on the forest sector. Proceedings from the International Conference on Forest Industry and Markets. Växjö University, Växjö, Sweden.
256. Toppinen, A. 1998. Econometric models on the Finnish roundwood market. Dissertation. University of Helsinki. Finnish Forest Research Institute, Research Papers 701. Helsinki, Finland. ISBN: 951-40-1642-4.
257. Tronstad, S., Sandland, K.M., Toverød, H. 2001. Drying quality of softwood based on 140 industrial tests in Norwegian sawmills and actions to improve the quality. COST E15, 3rd European COST E15 workshop on wood drying: Softwood drying to specific end-uses. June 1–13, 2001 at Scandic Hotel Kalastajatorppa, Helsinki, Finland. http://www.vtt.fi/rte/bss/coste15/indexe.html, Retrieved: 15th July 2005.
258. Tuchman, B.M. 1980. The decline of quality, New York Times Magazine, November 2.
259. Tuottavuus. 2004. Tuottavuus metsäteollisuudessa (Productivity in Forest Industries), Metsäteollisuus ry. (Finnish Forest Industries Federation). Helsinki, Finland. (In Finnish)
260. United Nations. 1997. Glossary of environment statistics. Studies in Methods, Series F, No. 67.
261. Uotila, T. 1994. Suomalainen sahateollisuus ja sen tulevaisuus: Toimintaympäristömuutosten vaikutukset alan yritysten toimintatapoihin. (The Finnish sawmilling industry and its future: effects of operation environment changes to company operations of the branch). Licentiate's thesis. Talousmaantieteen laitos. Turun kauppakorkeakoulu (Turku University of Business and Admininstration), Turku, Finland. ISBN: 951-37-1506-X. (In Finnish)
262. Urga, G., Walters. C. 2003. Dynamic translog and linear logit models: a factor demand analysis of interfuel substitution in US industrial energy demand. Energy Economics, 25, pp. 1–21.
263. Usenius, A. 1980. Sahausasetteen simulointimalli (Sawing pattern simulation model). Dissertation. VTT Technical Research Centre of Finland, Wood laboratory. Helsinki University of Technology. Tiedonanto 5. Espoo, Finland. ISBN: 951-38-1015-1. (In Finnish)
264. Usenius, A., Halinen, M., Hemmilä, P., Sommardahl, K.O. 1987. Sahapuurunkojen apteerauksen kehittäminen (Development of sawnwood logs length cutting). VTT Technical Research Centre of Finland, Wood laboratory. Raportti No. 491, Espoo, Finland. ISBN: 951-38-2952-9. (In Finnish)
265. Usenius, A. 2002a. Experiences from industrial implementations of forest-wood chain models. Proceedings of fourth workshop on "Connection between silviculture and wood quality through modelling approaches and simulations software". Nepveu G (ed). INRA, France.
266. Usenius, A. 2002b. Monitoring of wood raw material flow and intelligent control of conversion chain – Marking of wood raw material and wood products for identifying purposes. Final report of the Wood Wisdom Research Programme (1998–2001). Report 3, pp. 357–360. Helsinki, Finland.

267. Usenius, A. 2005. Advanced supply chain management. Internal report. VTT Technical Research Centre of Finland. Espoo, Finland.
268. Usenius, A., Sommardahl, K.O., Halonen, E. 1983. Sahatavaran mittatarkkuus ja pinnansileys sekä hakkeen ja purun laatu eräillä sahauslinjoilla (Dimensional accuracy and surface smoothness of sawn timber and the quality of chips and sawdust achieved in some saw lines). VTT Technical Research Centre of Finland, Wood laboratory. Research report 194. Espoo, Finland. ISBN: 951-38-1807-1. (In Finnish)
269. Usenius, A., Viitaniemi, P. 1976. Jäätyneen puun vannesahaus (Bandsawing of frozen wood). VTT Technical Research Centre of Finland, Wood laboratory. Research report 12. Espoo, Finland. ISBN: 951-38-0391-0. (In Finnish)
270. Uusitalo, J. 1995. Pre-harvest measurement of pine stands for sawing production planning. Dissertation. University of Helsinki, Department of Forest Resource Management, Publications 9. Helsinki, Finland. ISBN: 951-45-7231-9.
271. Uusvaara, O. 1985. The quality and value of sawn goods from plantation-grown scots pine. Finnish Forest Research Institute. Commun. Inst. For. Fenn. 130. Helsinki, Finland.
272. Vaara, L. 1998. Toimitus- ja pystykauppapuun hintasuhteet ja puunkorjuun rationaalisuus (The price relations between delivery-sales timber and standing-sales timber and the rationality of logging). Dissertation. Department of Forest Economics, Publication 5. University of Helsinki. Helsinki, Finland. ISBN: 951-45-8034-6. (In Finnish)
273. Varian, H.R. 1992. Microeconomic analysis. 3rd Edition, W.W. Norton & Company. New York, USA. ISBN: 0-393-95735-7.
274. Vehkalahti, K. 2000. Reliability of measurement scales. Tarkkonen's general method supersedes Cronbach's alpha. Dissertation. University of Helsinki. Finnish Statistical Society, Statistical studies. Helsinki, Finland. ISBN: 952-91-2818-5.
275. Virtanen, J. 1995. Asiakaslähtöisyyden vaikutuksia sahatavaran lajittelun muutoksiin. (Effects of customer-based operation on changes of sawnwood grading). Licentiate's thesis. Helsinki University of Technology. Laboratory of Wood Technology. Espoo, Finland. (In Finnish)
276. Virtanen, J. 2001. Effect of end use segment on sawn timber target moisture content in Finnish sawmilling industry in 2000. COST E15, 3rd European COST E15 workshop on wood drying: Softwood drying to specific end-uses. 1–13 June 2001 at Scandic Hotel Kalastajatorppa. Helsinki, Finland. http://www.vtt.fi/rte/bss/coste15/indexe.html, Retrieved: 15th July 2005.
277. Virtanen, J., Ruohonen, H., Pulkkinen, P., Paajanen, T. 1997. Jakosahausmenetelmien vertailu (Comparison of two resawing methods). Helsinki University of Technology, Laboratory of Wood Technology, Report 1997/70. Espoo, Finland. ISBN: 951-22-3814-4. (In Finnish)
278. VTT. 2004a. Sahatavaran ja puulevyjen käyttö Suomessa 2003–2004 (Use of sawnwood and wood panels in Finland 2003–2004). Internal report. Woodfocus. VTT Building and transport. Business intelligence group. Tampere, Finland. (In Finnish)
279. VTT. 2004b. Internal report. VTT Building and transport. Business intelligence group. Tampere, Finland.
280. Vuorilehto, J. 2001. Size control of sawn timber by optical means in breakdown saw machines. Dissertation. Helsinki University of Technology. Laboratory of Wood Technology. Report 88. Espoo, Finland. ISBN: 951-22-5661-4.
281. Warensjö, M. 2003. Compression wood in Scots pine and Norway spruce - Distribution in relation to external geometry and the impact on dimensional stability in sawn wood. Dissertation. The Swedish University of Agricultural Sciences, Department of Forest Products and Markets. Uppsala, Sweden.
282. Warensjö, M., Jäppinen, A. 1997. Såg 95, del 2, Sågverkens utrustning, produktivitet, sågutbyten m.m. 1995 (The sawmilling industry 1995. Part 2. Technology, productivity, volume recovery, etc.). The Swedish University of Agricultural Sciences, Department of Forest Products. Report No. 252. Uppsala, Sweden. (In Swedish)
283. Webster. 2004. Webster's 1913 dictionary. Dictionary of computing. USA. http://www.webster-dictionary.org/. Retrieved: 15th July 2004.
284. Williamson, T.G. (editor) 2002. Engineered wood handbook. APA, McGraw-Hill, New York.
285. Wisa. 2004. Public information. UPM-Kymmene, Wood products. Lahti, Finland. http://w3.wisa.upm-kymmene.com/. Retrieved: 8th July 2004.
286. Witten, I.H., Frank, E. 1999. Data mining, practical machine learning tools and techniques with java implementations. Morgan Kaufmann Publishers, San Francisco, USA.
287. Wood. 1999. Wood handbook − Wood as an engineering material. U.S. Department of Agriculture. USA. ISBN: 1-5912-4170-1. http://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/fplgtr113.htm. Retrieved: 13th July 2005.
288. Woodfocus. 2003. Examples of end-use for the different grades of sawn timber. http://www.woodfocus.fi/, Retrieved: 20th November 2003.
289. Wood wisdom. 2002. Research programme WOOD WISDOM (1998–2001). Results from the self-evaluation process. Tekes - National Technology Agency of Finland. Helsinki, Finland.
290. Yearbook. 2004. Paper and wood. Statistics 2003. Finnish Forest Industries Federation. Helsinki, Finland.
291. Ympäristönsuojelun vuosikirja. 1995. Environment protection yearbook. Metsäteollisuus ry, Finnish Forest Industries Federation. Helsinki, Finland. (In Finnish)
292. Ympäristönsuojelun vuosikirja. 1999. Saha- ja levyteollisuus. Environment protection yearbook. Sawmilling and wood panel industry. Metsäteollisuus ry. Finnish Forest Industries Federation. Helsinki, Finland. (In Finnish)
293. Ympäristönsuojelun vuosikirja. 2000. Saha- ja levyteollisuus. Environment protection yearbook. Sawmilling and wood panel industry. Metsäteollisuus ry. Finnish Forest Industries Federation. Helsinki, Finland. (In Finnish)

# APPENDICES

## *APPENDIX 1: INDICES FOR CONIFEROUS SAWNWOOD PRICE*

Appendix 1 presents coniferous sawnwood price indices and the effect of quality, width (WTH) and thickness (THS) on prices in 2000. This appendix supports the material to Section 5.6 about the basis price system and 5.8.3 about the price models. All the prices here are averages. For abbreviation see Table 1.

### A 1.1 Indices as test material

The effect of quality, width (WTH) and thickness (THS) on prices in 2000 were tested using a sample of prices for sales of pine and spruce CSW to the following countries: Finland, Sweden (only pine), Italy, Denmark, Norway (only pine), Germany, UK, Austria (only pine), France, the Netherlands. WPDB yielded price information for 3,830 sales out of which 2,126 were pine and 1,704 spruce in 2000. These data were used as basis for calculating he price indices by setting a country specific index value 100 for pine of U/S 50 x 150 or U/S 50 x 175 in special cases.

The use of indices can be demonstrated by setting a market price for a known quality and dimension. For instance, if a market price value is set to 185 €/m$^3$ for Finnish U/S of 50 x 150 the value of other qualities, widths and thicknesses can be calculated based as described in Table 73.

**Table 73. An example of use of pine price indices. Prices in Finland for a sample of qualities, widths and thicknesses if the market price value is assumed to be 185 €/m$^3$ for U/S of 50 x 150. The prices are based on indices shown in Table 72.**

| Value, €/m$^3$ | | WIDTH | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **63** | **75** | **100** | **125** | **150** | **175** | **200** | **225** | **250** |
| **Q-US** | **19** | | | 278 | 316 | 294 | | | | |
| | **25** | | | 250 | 259 | 268 | 281 | 279 | | |
| | **32** | | | 189 | | | | | 209 | |
| | **38** | | | 218 | 207 | 228 | 213 | | 216 | |
| | **50** | | 200 | 179 | 191 | **185** | 185 | 192 | 183 | 204 |
| | **63** | | | 181 | | 191 | 189 | 185 | 189 | |
| | **75** | | | | | 187 | | 189 | 194 | |
| **Q-US13** | **38** | | | | | 257 | | | | |
| **Q-USSP** | **25** | | | | | | 181 | 181 | | |
| | **38** | 272 | | | | | | | | |
| | **50** | | 209 | | 209 | | | | | |
| **Q-USCCA** | **19** | | | 403 | 400 | | | | | |
| | **38** | | | | | 346 | | | | |
| **Q-USSQ** | **50** | | | 292 | | | | | | |

# A1.2 Tables of CSW price indices in selected countries

The tables in this section are tables of CSW price indices.

FINLAND

## Table 74. Pine price indices for U/S and its derivates in Finland.

PINE PRICE INDICES: PRICE FOR U/S 50 X 150 PINE = 100
PRICES FOR U/S AND ITS DERIVATES, MARKET AREA: FINLAND

| Value, €/m$^3$ | | WIDTH | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **63** | **75** | **100** | **125** | **150** | **175** | **200** | **225** | **250** |
| **Q-US** | **19** | | | 150 | 171 | 159 | | | | |
| | **25** | | | 135 | 140 | 145 | 152 | 151 | | |
| | **32** | | | 102 | | | | | 113 | |
| | **38** | | | 118 | 112 | 123 | 115 | | 117 | |
| | **50** | | 108 | 97 | 103 | 100 | 100 | 104 | 99 | 110 |
| | **63** | | | 98 | | 103 | 102 | 100 | 102 | |
| | **75** | | | | | 101 | | 102 | 105 | |
| **Q-US13** | **38** | | | | | 139 | | | | |
| **Q-USSP** | **25** | | | | | | 98 | 98 | | |
| | **38** | 147 | | | | | | | | |
| | **50** | | 113 | | 113 | | | | | |
| **Q-USCCA** | **19** | | | 218 | 216 | | | | | |
| | **38** | | | | | 187 | | | | |
| **Q-USSQ** | **50** | | | 158 | | | | | | |

## Table 75. Pine price indices for V and its derivates in Finland.

PINE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR V AND ITS DERIVATES, MARKET AREA: FINLAND

| Value, €/m$^3$ | | WIDTH | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **100** | **115** | **125** | **130** | **150** | **175** | **200** | **225** |
| **Q-V** | **16** | 81 | | | | | | | |
| | **19** | 89 | | 71 | | 88 | | | |
| | **25** | 97 | | 95 | | 88 | | | |
| | **38** | 79 | | 77 | | 72 | 73 | | 79 |
| | **50** | 77 | | 78 | 97 | 77 | 74 | 78 | 76 |
| | **63** | | | 79 | | 74 | 76 | 75 | 78 |
| | **75** | 74 | | | | 77 | 71 | 69 | 72 |
| **Q-VA** | **25** | | | | | 58 | | | |
| | **32** | | | | | 74 | | | |
| | **38** | | | | | 64 | | | |
| | **50** | | | 76 | | | 74 | | |
| **Q-VSP** | **100** | 86 | | | | | | | |
| **Q-VM** | **38** | 72 | | | | | | | |
| | **50** | 77 | 74 | 74 | | 76 | | | |
| | **53** | | | 79 | | | | | |
| | **55** | | | | | 84 | | | |

## Table 76. Pine price indices for VI and its derivates in Finland.

PINE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR VI AND ITS DERIVATES, MARKET AREA: FINLAND

| Value, €/m$^3$ | | WIDTH | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **50** | **75** | **100** | **125** | **150** | **175** | **200** | **225** |
| **Q-VIC** | **25** | | | | 58 | | | | |
| **Q-VIJ** | **25** | | | | 56 | 43 | | | |
| | **38** | | | | | | | | 63 |
| **Q-VID** | **19** | | | 38 | 44 | 44 | | | |
| | **23** | | | | | | | | |
| | **25** | | | 34 | 38 | 43 | 39 | | |
| | **32** | | | | 51 | | | | |
| | **36** | | | | | | | | |
| | **38** | | | | 38 | 44 | | 47 | 48 |
| | **50** | | | 48 | 46 | 52 | 48 | 48 | 48 |
| | **63** | | | | 40 | 40 | 50 | | 40 |
| | **75** | | | 47 | 47 | 47 | 47 | 47 | 47 |
| **Q-VIB** | **19** | | | 49 | | | | | |
| **Q-VIE** | **19** | | | 57 | 57 | 55 | | | |
| | **22** | 53 | | | | | 53 | | |
| | **25** | | | 56 | 57 | 57 | | | |
| | **32** | | 46 | 58 | | | | 63 | |
| | **38** | | | 62 | 61 | 72 | | | |
| | **47** | | | 67 | | | | | |
| | **50** | 60 | 60 | 63 | 63 | 63 | 60 | 58 | 58 |
| | **63** | | | 61 | 77 | 55 | 53 | 55 | 53 |
| | **75** | | | 59 | 61 | 61 | | 53 | 53 |
| | **100** | | | 68 | | | | | |
| **Q-VIEJ** | **16** | 10 | | | | | | | |
| | **19** | | 29 | 75 | | | | | |
| | **22** | | 64 | 67 | 73 | 55 | 22 | | |
| | **25** | 71 | 44 | 81 | 80 | 78 | 47 | | |
| | **32** | | | 84 | 79 | 79 | | | |
| | **38** | 85 | 89 | 82 | 79 | 83 | | 58 | |
| | **50** | 68 | 71 | 76 | 78 | 82 | | 79 | |
| | **63** | | | 83 | | | | | |
| | **75** | | 75 | | | | | 79 | |
| | **100** | | | 80 | | | | 81 | |

## Table 77. Pine price indices for side boards and customer qualities in Finland.

PINE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR SIDE BOARDS AND CUSTOMER QUALITIES, MARKET AREA: FINLAND

| Value, €/m$^3$ | | WIDTH | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **75** | **98** | **100** | **122** | **125** | **150** | **168** | **175** |
| **Q-KNO** | **16** | | | | | 91 | | | |
| | **19** | | | | | 98 | 97 | | |
| | **22** | | | | | | 96 | | |
| | **25** | | | 78 | | | 93 | | 99 |
| | **32** | | | 95 | | | 105 | | |
| | **38** | | | | | | 111 | | 99 |
| | **45** | | | | | | | | |
| **Q-PLKNL** | **19** | | | 132 | | | | | |
| | **25** | | | 148 | | | | | |
| **Q-PLKL** | **16** | 35 | | 41 | | | | | |
| | **19** | 19 | | 39 | | | | | |
| | **22** | 21 | | | | | | | |
| | **25** | | | 44 | | | | | |
| **Q-PLKL J** | **16** | | | 36 | | | | | |
| | **19** | | | 34 | | | | | |
| | **25** | | | 24 | | | | | |
| **Q-PLVL1** | **16** | | | 46 | | | | | |
| | **19** | | | 46 | | | | | |
| | **25** | | | 48 | | | | | |
| | **32** | | | 50 | | | | | |
| | **36** | | | 54 | | | | | |
| | **38** | | | 56 | | | | | |
| | **44** | | | 57 | | | | | |
| | **47** | | | 51 | | | | | |
| | **50** | | | 51 | | | | | |
| **Q-PLVL1 QA** | | | | 47 | | | | | |
| **Q-PLVL2** | **50** | | | 66 | | | | | |
| **Q-PLVLB** | **19** | | | 40 | | | | | |
| **Q-PLVLPLA** | **19** | | | 36 | | | | | |
| **Q-PLVLJ** | **19** | 34 | | 59 | | 32 | | | |
| | **22** | | | 54 | | 23 | | | |
| | **25** | | | 61 | | | | | |
| | **32** | | | 71 | | 72 | | | |
| | **38** | | | | | 27 | 27 | | |
| | **50** | | | 56 | | | 56 | | |
| **Q-KNOT** | **38** | | | 79 | | | | | |
| | **50** | | | | | | 92 | | |
| | **63** | | | | | | 83 | | |
| **Q-FRA** | **50** | 164 | | 180 | | 210 | | | |
| | **56** | | | | 221 | | | | |
| | **65** | | 219 | | | | | | |
| **Q-GLUE** | **46** | | | | 197 | | | 206 | |
| | **56** | | | | 223 | | | 224 | |
| | **65** | | 219 | | | | | | |

## Table 78. Spruce price indices for U/S and V in Finland.

SPRUCE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR U/S AND V, MARKET AREA: FINLAND

| Value, €/m$^3$ | | WIDTH | | | | | |
|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **100** | **125** | **150** | **175** | **200** | **225** |
| **Q-US** | **22** | | | 86 | | | |
| | **25** | | | 87 | | | |
| | **32** | 88 | | | | | |
| | **50** | 82 | 85 | 87 | 86 | | 78 |
| | **63** | | | 87 | | | |
| | **75** | | | | 86 | 86 | 88 |
| **Q-V** | **22** | 73 | 75 | 72 | | | |
| | **25** | 65 | | | | | |
| | **32** | 77 | 70 | 69 | | | |
| | **38** | | | | 77 | | |
| | **44** | | | | | | 74 |
| | **50** | 69 | 72 | 108 | 72 | 74 | 69 |
| | **63** | | | | | 69 | |
| | **75** | | | | | 73 | |

## Table 79. Pine price indices for VI, SF and their derivates in Finland.

SPRUCE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR VI, SF AND THEIR DERIVATES, MARKET AREA: FINLAND

| Value, €/m$^3$ | | WIDTH | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **66** | **100** | **110** | **115** | **125** | **150** | **175** | **185** | **190** | **200** | **225** |
| **Q-VIJ** | **47** | 0 | | | | | | | | | 57 | |
| **Q-VID** | **19** | | 39 | | | | | | | | | |
| | **22** | | 39 | | | 45 | 44 | 41 | | | 40 | |
| | **23** | | | | | | | | | | | |
| | **25** | | 37 | 40 | | 37 | 44 | 38 | 37 | | 39 | 39 |
| | **26** | | | | | | | | | | | |
| | **28** | | | | | | | | | | | |
| | **30** | | | 38 | | | | | | | | |
| | **32** | | 46 | 46 | | 40 | 40 | 39 | | | 40 | 43 |
| | **33** | | | 43 | | | | | | | | |
| | **34** | | | | | 47 | | | | | | |
| | **35** | | | | | | | | | | | |
| | **38** | | 40 | | 42 | 44 | 41 | | | 47 | 41 | 39 |
| | **40** | | | | | | | | | | | |
| | **41** | | 42 | | | | | | | 44 | | |
| | **42** | | | | | | 38 | 35 | | | 43 | 40 |
| | **44** | | 41 | | 46 | 40 | 40 | 46 | | | 41 | 45 |
| | **47** | | 42 | | | 45 | 36 | 38 | | 38 | 38 | 38 |
| | **50** | | 42 | | 42 | 38 | 41 | 41 | | | 45 | 40 |
| | **60** | | | | | | 38 | | | | 38 | |
| | **63** | | | 38 | | 37 | 38 | 40 | | | 39 | |
| | **65** | | | | | | | | | | 38 | |
| | **66** | 26 | | | | | | | | | | |
| | **75** | | | | | 46 | 46 | 47 | | | 46 | 46 |
| | **100** | | | | | | | | | | 47 | |
| **Q-VIE** | **22** | | 57 | | | 57 | 57 | | | | | |
| | **25** | | 59 | | | | 57 | | | | | |
| | **32** | | 61 | | | 59 | 52 | | | | | |
| | **35** | | 42 | | | 42 | | | | | | |
| | **38** | | 58 | | | 61 | 55 | | | | | |
| | **44** | | 59 | | 58 | 58 | 58 | 58 | | | 58 | 57 |
| | **47** | | 67 | | | 58 | 60 | 58 | | | | |
| | **50** | | 60 | | 52 | 61 | 60 | 59 | | | 57 | 59 |
| | **63** | | | | | 60 | 57 | | | | 59 | |
| | **75** | | | | | 58 | 59 | | | | 61 | 60 |
| | **100** | | | | | | | | | | 61 | 63 |
| **Q-VIEJ** | **22** | | | | | 41 | 71 | | | | | |
| | **38** | | | | | | 80 | | | | | |
| | **50** | | | | | | 77 | | | | | |
| **Q-SF15** | **22** | | 68 | | | 76 | 76 | | | | | |
| | **25** | | | 83 | | 82 | | | | | | |
| | **32** | | 75 | 79 | | 80 | 72 | | | | | |
| | **34** | | | | | 78 | | | | | | |
| | **38** | | 79 | | | 78 | 71 | 80 | | | | |
| | **44** | | 74 | | | 74 | 74 | 75 | | | 73 | 75 |
| | **47** | | | | | | | | | | 80 | |
| | **50** | | 77 | | | 78 | 72 | 74 | | | 72 | 70 |
| | **63** | | | | | 73 | 77 | 74 | | | 78 | |
| | **75** | | | | | | 73 | | | | 72 | |
| | **100** | | | | | | | | | | 77 | 74 |
| **Q-SF16** | **22** | | | | | 73 | | | | | | |
| | **25** | | 65 | 87 | | 53 | | | 75 | | | |
| | **32** | | | | | | 70 | | | | | |
| | **33** | | 82 | | | | | | | | | |
| | **38** | | | | | 70 | 74 | | | | | |
| | **41** | | 61 | | | | | | | | | |
| | **44** | | 81 | | | 57 | | 60 | | | | |
| | **50** | | 73 | 65 | | 73 | 71 | | | | 73 | 73 |
| | **63** | | | | | 76 | | 76 | | | | |
| **Q-SF56** | **38** | | | | | | 65 | | | | | |
| | **47** | | 60 | | | | | | | | | |
| | **50** | | | | | 68 | | | | | | |
| **Q-SFSG** | **35** | | | | | 42 | | | | | | |

## Table 80. Spruce price indices for side boards in Finland.

SPRUCE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR SIDE BOARDS, MARKET AREA: FINLAND

| Value, €/m$^3$ | | WIDTH | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **100** | **102** | **110** | **112** | **125** | **128** | **130** | **150** | **RA** |
| **HVS** | **19** | 78 | | | | | | | | 78 |
| | **22** | 71 | | | | | | | | 71 |
| | **25** | 68 | | | | | | | | 68 |
| **Q-LAMA** | **25** | | | 85 | 86 | | | | | 85 |
| | **28** | | | | | | 88 | | | 88 |
| | **34** | | | 72 | | | | | | 72 |
| | **35** | | | | | | | 76 | | 76 |
| **Q-KNO** | **16** | | | | | 81 | | | | 81 |
| | **19** | | | | | 56 | | | 96 | 77 |
| | **25** | | | | | 67 | | | 69 | 68 |
| **Q-PLKL** | **19** | 23 | | | | | | | | 23 |
| | **22** | 40 | | | | | | | | 40 |
| | **25** | 37 | | | | | | | | 37 |
| **Q-PLVL1** | **16** | 39 | | | | | | | | 39 |
| | **19** | 46 | | | | | | | | 46 |
| | **22** | 46 | | | | | | | | 46 |
| | **25** | 47 | | | | | | | | 47 |
| | **32** | 51 | 51 | | | | | | | 51 |
| **Q-PLVL2** | **25** | 48 | | | | | | | | 48 |

SWEDEN

## Table 81. Pine price indices for all qualities in Sweden.

PINE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: SWEDEN, YEAR 2000

| Value, €/m$^3$ | | WIDTH | | | |
|---|---|---|---|---|---|
| **Quality** | **THS** | **100** | **125** | **150** | **RA** |
| **Q-US** | **19** | | | 100 | 100 |
| **Q-V** | **100** | 71 | | | 71 |
| **Q-VM** | **50** | | 56 | 53 | 56 |
| **Q-VIE** | **25** | | 32 | | 32 |
| | **75** | 37 | | | 37 |
| **Q-PLKNL** | **19** | 89 | | | 89 |
| | **25** | 93 | | | 93 |
| **Q-PLVL1** | **25** | 28 | | | 28 |
| **Q-PLVLB** | **19** | 26 | | | 26 |

ITALY

## Table 82. Pine price indices for all qualities in Italy.

PINE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: ITALY, YEAR 2000 SAMPLE

| Value, €/m$^3$ | | WIDTH | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **75** | **87** | **90** | **92** | **100** | **115** | **125** | **150** | **175** | **200** | **225** | **250** |
| **Q-US** | **19** | | | | | 147 | | 150 | 158 | | | | |
| | **25** | | | | | 122 | | 127 | 138 | 135 | 136 | | |
| | **38** | | | | | | | | | 109 | 111 | | |
| | **50** | | | | | | | | 100 | 97 | 102 | 108 | 110 |
| | **63** | | | | | | | | 99 | 100 | 103 | | |
| | **75** | | | | | | | | 94 | 100 | 103 | 108 | |
| **Q-USSP** | **50** | | | | 129 | 140 | | | | | | | |
| | **63** | 135 | | 138 | | | | | | | 108 | | |
| | **75** | | | 139 | | | | | | | | | |
| **Q-USF** | **50** | | | 131 | | 135 | | | | | | | |
| | **63** | 129 | | 132 | | | | | | | | | |
| **Q-V** | **25** | | | | | | | | | 91 | 91.3 | | |
| | **38** | | | | | | | | | 71 | 73 | | |
| | **50** | | | | | | | 75 | 76 | 75 | 74.1 | | |
| | **63** | | | | | | | | 78 | 73 | 75 | | |
| | **75** | | | | | | | | | | 73.2 | | |
| **Q-VM** | **38** | | | | | | | | 84 | | | | |
| | **50** | | | | | 78 | 81 | 77 | 77 | | | | |
| **Q-VIJ** | **38** | | | | | | | | 66 | | | | |
| **Q-VIE** | **19** | | | | | | | 61 | | | | | |
| | **25** | | | | | 61 | | | | | | | |
| | **100** | | | | | | | | | | 54.7 | | |
| **Q-SF15** | **50** | | | | | 72 | | | | | | | |
| **Q-SF15F** | **63** | | | | | | | | | | | 108 | |
| **Q-SF56** | **38** | | | | | 65 | | | | | | | |
| **Q-SFSP** | **65** | | 113 | | | | | | | | | | |
| **Q-HVS2** | **19** | 0 | | | | 101 | | | | | | | |
| | **25** | | | | | 99 | | | | | | | |
| **Q-KNOT** | **36** | | | | | 81 | | | | | | | |
| | **38** | | | | | 79 | | | | | | | |
| | **63** | | | | | | | 81 | | | | | |
| | **75** | | | | | | | | 78 | | | | |
| **Q-PLKNL** | **19** | | | | | 123 | | | | | | | |
| **Q-PLVLB** | **19** | | | | | 34 | | | | | | | |

## Table 83. Spruce price indices for all qualities in Italy.

SPRUCE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: ITALY, YEAR 2000 SAMPLE

| Value, €/m³ | | WIDTH | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **100** | **125** | **135** | **150** | **175** | **200** | **225** |
| **Q-US** | **19** | 87 | | | | | | |
| | **25** | 87 | | | 89 | | 88 | |
| | **32** | | | | 85 | 86 | 88 | 90 |
| | **38** | | | | 88 | 83 | 84 | |
| | **50** | | 79 | | 81 | | 79 | 75 |
| | **63** | | | | 78 | 81 | 80 | 80 |
| | **75** | | | | | 72 | 81 | 80 |
| **Q-V** | **50** | | | | | | 65 | |
| **Q-VIE** | **22** | | | | 47 | | | |
| **Q-SF15** | **63** | | | | 75 | | | |
| | **75** | | | | | 76 | | |
| **Q-SF16** | **22** | | | | 75 | | | |
| | **38** | | | 68 | | | | |
| | **75** | | | | 63 | | | |

DENMARK

## Table 84. Pine price indices for all qualities in Denmark.

PINE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: DENMARK, YEAR 2000

| Value, €/m³ | | WIDTH | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **63** | **75** | **92** | **100** | **115** | **125** | **150** | **175** | **200** | **225** |
| **Q-US** | **19** | | | | 155 | | 161 | 160 | 160 | | |
| | **25** | | | | 129 | | 132 | 137 | 144 | 144 | |
| | **32** | | | | | | 92 | | | | |
| | **38** | | | | 94 | | 104 | 104 | 107 | | |
| | **50** | | | | 94 | | 108 | 100 | 99 | 103 | 120 |
| | **63** | | | | 90 | | 94 | 100 | 99 | | |
| | **75** | | | | | | | 102 | | | |
| **Q-US13** | **38** | 168 | | | | | | | | | |
| | **50** | | 145 | | | | | | | | |
| | **63** | 142 | | | | | | | | | |
| **Q-USSP** | **38** | 172 | | | | | | | | | |
| | **50** | 149 | 151 | | | | | | | 123 | |
| | **63** | | 156 | | | | | | | | |
| **Q-V** | **19** | | | | 86 | | 95 | 87 | 85 | | |
| | **25** | | | | 92 | | 93 | 93 | 89 | 127 | |
| | **32** | | | | | | 72 | 80 | | | |
| | **38** | | | | 79 | | 77 | 76 | 78 | | |
| | **50** | | | | 80 | | 80 | 79 | 77 | 80.3 | |
| | **63** | | | | | | 81 | 72 | | | |
| | **75** | | | | | | | 81 | | | |
| **Q-VA** | **19** | | | | | | 66 | | | | |
| **Q-VM** | **50** | | | | 83 | 92 | 83 | 93 | | | |
| **Q-VI** | **19** | | | | 56 | | 65 | | | | |
| **Q-VIE** | **19** | | | | 58 | | 65 | | 56 | | |
| | **25** | | | | 61 | | 60 | 61 | 56 | 60.3 | |
| | **32** | | | | 69 | | 68 | 67 | | | |
| | **38** | | | | 63 | | 63 | 60 | | | |
| | **50** | | | | 67 | 67 | 69 | 68 | | | |
| | **63** | | | | | | 92 | | | | |
| | **66** | | 48 | | | | 48 | | | | |
| **Q-SF15** | **38** | | | | 74 | | | | | | |
| | **50** | | | | 79 | | | | | | |
| **Q-SF16** | **32** | | | | | | | 73 | | | |
| | **50** | | | | 76 | | | 95 | | | |
| **Q-SF56** | **50** | | | | 72 | | 74 | | | | |
| **Q-SFSP** | **50** | | 95 | | | | 95 | | | | |
| | **63** | | 95 | | | | 95 | | | | |
| | **66** | | 110 | | | | 110 | | | | |
| **Q-SFFQ** | **50** | | | | | | 71 | 82 | | | |
| **Q-SFMB** | **38** | | | | | | 77 | | | | |
| | **42** | | | 76 | | | | | | | |
| | **50** | | | | 74 | 85 | 85 | 76 | | | |
| | **55** | | | | 70 | | | | | | |
| **Q-PLVL1** | **19** | | | | 45 | | | | | | |
| | **25** | | | | 45 | | | | | | |
| **Q-KNOT** | **38** | | | | 74 | | | | | | |

## Table 85. Spruce price indices for all qualities in Denmark.

SPRUCE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: DENMARK, YEAR 2000

| Value, €/m³ | | WIDTH | |
|---|---|---|---|
| **Quality** | **THS** | **100** | **RA** |
| **Q-PLVL1** | **19** | 47 | 47 |
| **Q-SF16** | **32** | 74 | 74 |

NORWAY

## Table 86. Pine price indices for all qualities in Norway.

PINE PRICE INDICES: PRICE FOR QVM 50 x 150 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: NORWAY, YEAR 2000

| Value, €/m³ | | WIDTH | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **50** | **75** | **100** | **125** | **150** | **175** | **200** |
| **Q-VM** | **50** | 0 | 0 | 0 | 98 | 100 | 0 | 0 |
| **Q-KNO** | **16** | 0 | 0 | 0 | 137 | 0 | 0 | 0 |
| | **19** | 0 | 0 | 0 | 139 | 141 | 0 | 0 |
| **Q-PLKL** | **19** | 0 | 0 | 70 | 0 | 0 | 0 | 0 |
| **Q-PLVLJ** | **16** | 0 | 0 | 75 | 0 | 0 | 0 | 0 |
| | **19** | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| **Q-VID** | **75** | 0 | 0 | 76 | 0 | 0 | 0 | 0 |
| **Q-VIE** | **38** | 87 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Q-VIEJ** | **19** | 0 | 123 | 0 | 0 | 0 | 0 | 0 |
| | **22** | 0 | 0 | 0 | 109 | 105 | 0 | 0 |
| | **25** | 0 | 0 | 98 | 119 | 115 | 0 | 0 |
| | **32** | 0 | 0 | 116 | 117 | 0 | 0 | 0 |
| | **38** | 99 | 109 | 0 | 112 | 114 | 0 | 0 |
| | **50** | 124 | 118 | 109 | 0 | 109 | 118 | 109 |

GERMANY

## Table 87. Pine price indices for all qualities in Germany.

PINE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: GERMANY, YEAR 2000

| Value, €/m³ | | WIDTH | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **100** | **125** | **150** | **175** | **200** | **225** | **250** |
| **Q-US** | **19** | 156 | 162 | 164 | 166 | 156 | | |
| | **25** | 139 | 140 | 145 | 140 | 154 | 162 | |
| | **50** | | | 100 | | | | 110 |
| | **75** | | | 108 | | 104 | | |
| **Q-V** | **19** | 88 | 87 | 88 | 88 | 78 | | |
| | **25** | 89 | 90 | | 88 | | | |
| | **38** | | | | 76 | | | |
| | **50** | | | 76 | | 74 | | |
| **Q-VIE** | **19** | | | 57 | | | | |
| | **25** | | | 60 | 59 | | | |
| | **38** | | | | 61 | | | |
| **Q-PLKNL** | **19** | 144 | | | | | | |

## Table 88. Spruce price indices for all qualities in Germany.

SPRUCE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: GERMANY, YEAR 2000

| Value, €/m³ | | WIDTH | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **100** | **110** | **115** | **125** | **132** | **150** | **165** | **175** | **200** | **225** | **250** |
| **Q-US** | **25** | | | | | | 90 | | | | | |
| | **32** | | | | | | 84 | | | 87 | | |
| | **38** | | | | | | | | | | 82 | |
| | **50** | 80 | | | 85 | | 85 | | 86 | 72.1 | 84 | |
| | **63** | | | | | | 82 | | 85 | 83.7 | | |
| | **75** | | | | | | | | 70 | 86 | 82 | |
| **Q-V** | **50** | 0 | | | 76 | | | | | 76.6 | | |
| | **63** | | | | | | 75 | | | | | |
| **Q-VIE** | **22** | 64 | | | | | | | | | | |
| | **32** | | | | | | | | | 63.3 | | |
| | **38** | | | | | | | | | 58.3 | | |
| | **44** | 63 | | | 64 | | 62 | | | | | |
| | **50** | | | | 64 | | 63 | | | 59.2 | | |
| | **63** | | | | 63 | | 64 | | 63 | 64.1 | 63 | |
| | **75** | | | | | | | | | 62.9 | | |
| **Q-SF15** | **22** | 72 | | | | | | | | | | |
| | **32** | | | | | | 81 | | | 79.8 | | |
| | **38** | 82 | | | 81 | | 82 | | | | | |
| | **44** | 80 | | | 81 | | 80 | | 81 | 81.2 | | |
| | **50** | 83 | | | 80 | | 80 | | 79 | 78.8 | 80 | |
| | **63** | 81 | | | 80 | | 79 | | 81 | 79 | | |
| | **75** | | | | | | 81 | | | 80.7 | 80 | |
| | **100** | | | | | | | | | 83.4 | | |
| **Q-SF16** | **38** | 74 | 74 | | | | 78 | | | | | |
| | **44** | | | | 82 | | | | | | | |
| | **47** | | | | | | 80 | | | | | |
| | **50** | | | 79 | | | | | | | | |
| | **55** | | | 78 | | 77 | | | | | | |
| | **56** | | | 78 | 80 | | 79 | | | | | |
| | **59** | 77 | | | | | | | | | | |
| | **63** | 78 | | | 67 | | | 66 | | 77.1 | | 74 |
| | **75** | | | | | | 83 | | | | | |
| | **83** | | | | | | | | | 72.7 | | |
| **Q-SF56** | **50** | | | | 81 | | | | | | | |
| **Q-SFUSV** | **50** | | | | 84 | | | | | | | |
| **Q-PLVL1** | **19** | 43 | | | | | | | | | | |
| | **22** | 46 | | | | | | | | | | |

UK

## Table 89. Pine price indices for all qualities in UK.

PINE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: UK, YEAR 2000 SAMPLE

| Value, €/m³ | | WIDTH | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **63** | **75** | **100** | **125** | **150** | **175** | **200** | **225** | **250** |
| **Q-US** | **19** | | | 149 | 148 | 149 | | | | |
| | **25** | | | 122 | 130 | 142 | 135 | 138 | 160 | |
| | **32** | | | | 123 | 119 | | 123 | 130 | |
| | **38** | | | 106 | 110 | 108 | 109 | 124 | 130 | |
| | **50** | | | 100 | 101 | 100 | 100 | 102 | 111 | 113 |
| | **63** | | | 104 | 98 | 98 | 101 | 106 | 112 | |
| | **75** | | | 102 | 102 | 102 | 102 | 104 | 110 | |
| | **100** | | | 137 | | | | 123 | | |
| **Q-USSP** | **25** | | | | | 143 | | | 160 | |
| | **50** | | 114 | | | | | | | |
| | **75** | | 119 | 117 | | | | | | |
| | **100** | | | 152 | | | | | | |
| **Q-USF** | **100** | | | 151 | | | | | | |
| **Q-V** | **19** | | | 91 | 92 | 94 | 96 | | | |
| | **25** | | | 86 | 89 | 92 | 91 | 95 | 99 | |
| | **32** | | | | 80 | 75 | | 81 | 82 | |
| | **38** | | | 76 | 76 | 76 | 79 | 80 | 81 | |
| | **50** | | | 73 | 72 | 73 | 74 | 75 | 75 | 79 |
| | **63** | | | 74 | 71 | 72 | 71 | 74 | 74 | |
| | **75** | | | 74 | 76 | 73 | 73 | 74 | 75 | |
| | **100** | | | 78 | | | | 81 | | |
| **Q-VA** | **32** | | | | | 67 | | | | |
| | **38** | | | | | 68 | | | | |
| | **50** | | | | 67 | 65 | 68 | | | |
| **Q-VSP** | **25** | | | | | 101 | | | 109 | |
| | **100** | | | 83 | | | | | | |
| **Q-VIC** | **25** | | | | | 51 | | | | |
| **Q-VIJ** | **25** | | | 56 | 56 | 55 | 54 | 54 | | |
| | **38** | | | | 52 | 53 | | | | |
| **Q-VIE** | **19** | | | 52 | 51 | 57 | | | | |
| | **25** | | | 56 | 54 | 53 | 55 | 54 | 55 | |
| | **32** | | | | 60 | 53 | | | | |
| | **38** | | | 55 | 58 | 58 | 60 | | | |
| | **50** | | | 59 | 58 | 60 | 60 | 60 | 60 | |
| | **63** | 39 | | | 42 | | | | | |
| | **75** | | | | | 61 | | 61 | | |
| **Q-SF15** | **25** | | | | | 95 | 92 | | | |
| | **38** | | | 78 | | | | | | |
| | **50** | | | 74 | | 67 | 91 | | | |
| | **75** | | | 73 | | | | | | |
| **Q-SF15F** | **50** | | | | | | 90 | | | |
| | **63** | | | | | | | | 115 | |
| **Q-SF16** | **32** | | | | 67 | | | | | |
| | **38** | | | | | 76 | | | | |
| | **44** | | | 75 | | | | | | |
| **Q-SFSP** | **25** | | | | | 98 | 98 | | | |
| | **63** | | 94 | | | | | | | |
| | **100** | | | 135 | | | | | | |
| **Q-SFUSV** | **50** | | | 85 | 89 | 87 | 91 | 93 | 94 | |
| | **63** | | | | 88 | | 87 | 91 | | |
| | **75** | | | | | 88 | 90 | 90 | 91 | |
| **Q-HVS2** | **25** | | | 105 | | | | | | |
| **Q-PLVL1** | **25** | | | 44 | | | | | | |

## Table 90. Spruce price indices for all qualities in UK.

SPRUCE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: UK, YEAR 2000 SAMPLE

| Value, €/m³ | | WIDTH | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **100** | **125** | **128** | **150** | **153** | **175** | **200** | **225** |
| **Q-US** | **22** | | 74 | | 87 | | | | |
| | **32** | | | | 85 | | | | |
| | **75** | | | | | | | | 76 |
| **Q-V** | **22** | 59 | 69 | | 65 | | | 72 | |
| | **25** | 68 | | | 68 | | | 67 | |
| | **38** | | | | | | | | 70 |
| | **63** | | | | | | 69 | | 69 |
| | **75** | | | | | | | | 68 |
| **Q-LAMB** | **28** | | | 37 | | | | | |
| **Q-VIJ** | **47** | | | | | 50 | 52 | 52 | 51 |
| **Q-VIE** | **19** | 49 | | | | | | | |
| | **22** | 58 | 57 | | 55 | | | 56 | |
| | **32** | | 59 | | 58 | | 57 | | |
| | **38** | | | | 58 | | | | 59 |
| | **47** | 55 | 55 | | 54 | 53 | 54 | 54 | 53 |
| | **50** | | 57 | | 58 | | 48 | 54 | 58 |
| | **63** | | | | 59 | | 57 | 53 | 50 |
| | **75** | | | | | | | 57 | 60 |
| **Q-SF15** | **22** | 67 | 64 | | 69 | | | | |
| | **25** | | | | | | 72 | | 76 |
| | **32** | | | | 69 | | | | |
| | **38** | 75 | 75 | | 61 | | | | 71 |
| | **44** | 76 | 76 | | 76 | | | | |
| | **47** | | | | | | 70 | | |
| | **50** | 74 | 72 | | 76 | | | | |
| | **63** | | | | 71 | | | | |
| | **75** | | | | | | 71 | | 72 |
| | **100** | | | | | | | 75 | |
| **Q-SF16** | **25** | | | | 60 | | | 60 | |
| | **47** | | | | 70 | | | | |
| | **75** | | | | 70 | | | | |
| **Q-SFSG** | **47** | 75 | 75 | | 68 | | 69 | 70 | 67 |
| | **75** | | | | | | | | 60 |

AUSTRIA

## Table 91. Pine price indices for all qualities in Austria.

PINE PRICE INDICES: PRICE FOR 50 x 100 QSF56 MÄ = 100
PRICES FOR ALL QUALITIES, MARKET AREA: AUSTRIA, YEAR 2000 SAMPLE

| Value, €/m³ | | WIDTH | | | |
|---|---|---|---|---|---|
| **Quality** | **THS** | **100** | **112** | **116** | **127** |
| **Q-US** | **25** | 166 | | | |
| **Q-SF16** | **38** | | | 59 | |
| **Q-SF56** | **50** | 100 | | | |
| **Q-LAMA** | **36** | 0 | 88 | | 88 |

FRANCE

## Table 92. Pine price indices for all qualities in France.

PINE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: FRANCE, YEAR 2000 SAMPLE

| Value, €/m³ | | WIDTH | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **100** | **115** | **125** | **150** | **175** | **200** | **225** |
| **Q-US** | **19** | 159 | | 170 | | 164 | | |
| | **25** | | | 156 | 145 | 144 | 167 | 170 |
| | **32** | | | | 121 | | 131 | 129 |
| | **38** | | | | 108 | | 130 | 133 |

## Table 93. Spruce price indices for all qualities in France.

SPRUCE PRICE INDICES: PRICE FOR U/S 50 x 150 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: FRANCE, YEAR 2000 SAMPLE

| Value, €/m$^3$ | | WIDTH | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **75** | **100** | **112** | **115** | **125** | **130** | **150** | **160** | **175** | **200** | **225** |
| **Q-US** | **19** | | 94 | | | | | | | | | |
| | **25** | | 97 | | | | | 98 | | | 97 | |
| | **30** | | | | | | | | | | 99 | |
| | **32** | | | | 96 | 97 | | 97 | | 94.7 | 97 | 98 |
| | **38** | | | | | | | 95 | | 95.7 | 96 | 96 |
| | **44** | | | | | | | | | | | 91 |
| | **50** | | | | | 93 | | 92 | | 93.4 | 92 | 93 |
| | **63** | | | | | | | 90 | 92 | 91.2 | 92 | 92 |
| | **75** | | | | | | | 95 | | 92 | 93 | 92 |
| **Q-V** | **22** | | 78 | | | 77 | | 78 | | | | |
| | **25** | | 77 | | | | | 78 | | | 79 | |
| | **30** | | | | | | | | | | 77 | |
| | **32** | | 79 | | | 75 | | 78 | | | 78 | 76 |
| | **38** | | | | | | | 79 | | | 93 | 75 |
| | **50** | | 78 | | | 75 | | 79 | | 78.7 | 78 | 78 |
| | **63** | | | | | | | 75 | | 78.7 | 78 | |
| | **75** | | | | | | | | | | 75 | 77 |
| **Q-VID** | **22** | | 34 | | | | | | | | | |
| **Q-VIE** | **15** | | | | | | | | | | 69 | |
| | **22** | | | | | | | 62 | | | | |
| | **25** | | 63 | 50 | | 62 | | 64 | | | 64 | 64 |
| | **30** | | | | | | | | | | 63 | |
| | **32** | | 65 | | 66 | 62 | | 56 | | 55.4 | 62 | |
| | **35** | | | | | | 56 | 67 | | | 64 | |
| | **38** | | 63 | | | 64 | | 64 | | | | 67 |
| | **44** | | | | | | | 64 | | | | |
| | **47** | 60 | 65 | | | | | 62 | | | | 62 |
| | **50** | | 64 | | 65 | 62 | | 63 | | 63.2 | 62 | 63 |
| | **60** | | | | | | | 61 | | | | |
| | **63** | | | | | | | 62 | | 61.9 | 63 | 61 |
| | **75** | | | | | | | 64 | | 61.6 | 63 | 64 |
| | **100** | | | | | | | | | | 64 | |
| **Q-SF15** | **22** | | 74 | | | 83 | | 80 | | | | |
| | **25** | | | | | | | | | 84.2 | | 95 |
| | **32** | | 83 | | 71 | | | 81 | | 79.6 | 82 | |
| | **38** | | 74 | | | 83 | | 62 | | 81.8 | | |
| | **44** | | 82 | | | | | | | | | |
| | **47** | | 83 | | | | | 81 | | | | |
| | **50** | | 82 | | 82 | 81 | | 82 | | 82.2 | 82 | 81 |
| | **63** | | | | | 84 | | 81 | | 81.4 | 81 | |
| | **75** | | | | | | | 80 | | 82.3 | | 83 |
| | **100** | | | | | | | | | | 83 | |
| **Q-SF16** | **30** | | | | | | | | | | 80 | |
| | **32** | | | | 79 | | | 64 | | | 82 | |
| | **35** | | | | | | | 51 | | | | |
| | **38** | | 82 | | 80 | | | 63 | | 82.4 | 70 | 86 |
| | **44** | | 82 | | | | | | | | | |
| | **47** | | 80 | | | 81 | | 80 | | 80.5 | 80 | |
| | **50** | | 81 | | 80 | 83 | | 79 | 81 | 81.1 | | 79 |
| | **63** | | | | | | | 80 | 81 | 67 | 78 | |
| | **75** | | | | | | | | | 81.8 | 70 | |
| | **100** | | | | | | | | | | 80 | 80 |
| **Q-SF56** | **21** | | | | | | | | | | | 92 |
| | **25** | | | | | | | 84 | | | | |
| | **32** | | | | | | | 72 | | | 74 | 73 |
| | **38** | | | | | | | 73 | | | 71 | 73 |
| | **47** | | | | | | | 69 | | | | |
| | **50** | | 69 | | | 72 | | 71 | | 72 | 73 | |
| | **63** | 71 | | | | | | 71 | | 69.4 | 73 | 70 |
| | **75** | | | | | | | | | 73.5 | 69 | 71 |
| **lamina B** | **25** | | | 49 | | | | | | | | |
| | **26** | | | 46 | | | | | | | | |
| | **35** | | | | | | 60 | | | | | |
| | **36** | | | | | | 60 | | | | | |
| | **37** | | | | 54 | | 55 | | | | | |
| **Q-PLVL1** | **22** | | 45 | | | | | | | | | |

THE NETHERLANDS

## Table 94. Pine price indices for all qualities in the Netherlands.

PINE PRICE INDICES: PRICE FOR U/S 50 X 175 PINE = 100. PRICES FOR ALL QUALITIES, MARKET AREA: THE NETHERLANDS, YEAR 2000 SAMPLE

| Value, €/m$^3$ | | WIDTH | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **100** | **115** | **125** | **150** | **175** | **200** | **225** |
| **Q-US** | **19** | 138 | | | | | | |
| | **25** | 129 | | | 140 | | 143 | 168 |
| | **38** | | | | 109 | | | |
| | **50** | | | | | 100 | | |
| | **75** | | | 97 | | | | |
| **Q-V** | **38** | | | | 78 | | | |
| | **50** | | | | 73 | 72 | | |
| **Q-VF** | **25** | | | | | | 77 | |
| **Q-VIE** | **25** | 47 | | | | | 60 | |
| | **50** | | | | 58 | | | |
| | **63** | | | | | 54 | | |
| | **75** | | | | | | | 57 |
| **Q-HVS2** | **25** | 101 | | | | | | |
| **Q-LAMA** | **36** | | 74 | | | | | |
| **Q-PLKNL** | **19** | 144 | | | | | | |

## Table 95. Spruce price indices for all qualities in the Netherlands.

SPRUCE PRICE INDICES: PRICE FOR U/S 50 X 175 PINE = 100
PRICES FOR ALL QUALITIES, MARKET AREA: THE NETHERLANDS, YEAR 2000 SAMPLE

| Value, €/m$^3$ | | WIDTH | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quality** | **THS** | **100** | **115** | **125** | **150** | **155** | **160** | **175** | **190** | **200** | **225** |
| **Q-US** | **19** | 89 | | | | | | | | | |
| | **22** | 87 | | 87 | 88 | | | | | 89 | |
| | **25** | 91 | | | 87 | | | | | 90 | |
| | **32** | 89 | | 89 | 89 | | | | | 91 | 90 |
| | **38** | | | | 90 | | | | | 87 | 89 |
| | **44** | | | | | | | | | | 90 |
| | **50** | 85 | | 84 | 85 | | | 86 | | 87 | 85 |
| | **63** | | | | 85 | | 80 | 85 | | | |
| | **75** | | | 86 | | | | | | 85 | |
| **Q-V** | **19** | 68 | | | | | | | | | |
| | **22** | 67 | | 72 | 75 | | | | | 75 | |
| | **25** | 75 | | | 76 | | | | | 74 | |
| | **32** | 75 | | 75 | 75 | | | 75 | | 76 | 74 |
| | **38** | | | | 76 | | | 75 | | 75 | 75 |
| | **44** | | | | | | | | | | 75 |
| | **50** | 74 | | 75 | 73 | | | 75 | | 74 | 75 |
| | **63** | | | | 74 | | 73 | 73 | | 73 | 73 |
| | **75** | | | 73 | | | | 72 | | 73 | 73 |
| **Q-VIE** | **19** | 59 | | | | | | | | | |
| | **22** | 55 | | 57 | 59 | | | | | 60 | |
| | **25** | 59 | | 58 | 59 | | | 57 | | 60 | |
| | **32** | 59 | | 60 | 59 | | | 55 | | 58 | |
| | **38** | 55 | | 58 | 59 | | | 58 | | 59 | 59 |
| | **44** | 58 | | | 60 | | | 58 | | | |
| | **47** | 60 | | | 59 | | | | | | |
| | **50** | 59 | | 59 | 58 | | | 59 | | 58 | |
| | **63** | 59 | | 58 | 59 | | 59 | 59 | | | |
| | **75** | | | 59 | 59 | | | 59 | | 59 | 59 |
| | **100** | | | | | | | | | 59 | |
| **Q-SF15** | **22** | 67 | | 71 | 74 | | | | | | |
| | **25** | | | 74 | | | | | | | |
| | **32** | 75 | | 75 | 75 | | | 71 | | | |
| | **38** | 73 | | 75 | 75 | | | 77 | | | |
| | **44** | 73 | | 69 | 74 | | | 74 | | 74 | 72 |
| | **47** | 75 | | | 74 | | | 73 | | 72 | 72 |
| | **50** | 75 | 77 | 74 | 73 | | | 72 | | | 74 |
| | **63** | 72 | | 72 | 72 | | 74 | 73 | | 70 | |
| | **75** | | | 72 | 73 | | | 73 | | 73 | 73 |
| | **100** | | | | | | | | | 74 | |
| **Q-SF15B** | **47** | | | | | | | 59 | | | |
| **Q-SF16** | **27** | | | | | 90.4 | | | 90 | | |
| | **28** | | | | | | | | | | |
| | **32** | 74 | | 76 | | | | 77 | | 80 | |
| | **34** | | | | | | | | 65 | | |
| | **38** | 62 | | | 72 | | | 76 | 72 | | |
| | **41** | | | | | | | | 74 | | |
| | **42** | | | | | | | | 71 | | |
| | **43** | | | | | | | | 88 | | |
| | **44** | | | | 75 | | | 76 | | | |
| | **47** | | | | | | | 76 | | | |
| | **48** | | | 94 | | 92.6 | | | | | |
| | **50** | | 72 | | 74 | | | | | | |
| | **55** | | | | | | | | | | |
| | **63** | 74 | | 74 | | | 72 | | | | |
| | **65** | | | | | | | | | 77 | |
| | **75** | 74 | | 75 | 73 | | | 75 | | 75 | |
| | **100** | | | | | | | | | 75 | 75 |
| **Q-SF56** | **32** | | | | 70 | | | | | | |
| | **50** | | | | 69 | | | | | | |
| **Q-SFSG** | **47** | | | | 74 | | | | | | |
| **Q-LAMA** | **25** | | | | | | | | | | |
| | **37** | | 80 | | | | | | | | |
| **Q-PLVL1** | **19** | 40 | | | | | | | | | |
| | **22** | 42 | | | | | | | | | |
| **Q-PLVL2** | **25** | 40 | | | | | | | | | |

# APPENDIX 2: GEOGRAPHICAL LOCATION AS A CONIFEROUS SAWNWOOD CONSUMPTION FACTOR

The appendix provides support material for the geographical location as being a sawnwood consumption factor discussed in Section 4.4. where the results of the analysis are presented.

**Table 96. A sample of CSW consumption per capita in 46 countries in 1999. The countries are divided into four Northern latitude classes.**

| | | NORTHERN LATITUDE CLASS | | | | | | NORTHERN LATITUDE CLASS | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | CSW-con-pc | >55 | [55,45[ | [45,35[ | <35 | Country | CSW-con-pc | >55 | [55,45[ | [45,35[ | <35 |
| Finland | 0.902 | 1 | | | | Italy | 0.109 | | | 1 | |
| Denmark | 0.900 | 1 | | | | Spain | 0.102 | | | 1 | |
| Canada | 0.667 | 1 | | | | Portugal | 0.082 | | | 1 | |
| Austria | 0.616 | | 1 | | | Faeroe Islands | 0.079 | 1 | | | |
| Norway | 0.530 | 1 | | | | Hungary | 0.078 | | 1 | | |
| Sweden | 0.415 | 1 | | | | Poland | 0.072 | | 1 | | |
| USA | 0.376 | | | 1 | | Russian Federation | 0.071 | | 1 | | |
| Latvia | 0.301 | 1 | | | | Greece | 0.062 | | | 1 | |
| Estonia | 0.291 | 1 | | | | Croatia | 0.048 | | | 1 | |
| Ireland | 0.272 | | 1 | | | Yugoslavia Fed Rep of | 0.042 | | | 1 | |
| Iceland | 0.263 | 1 | | | | Tunisia | 0.040 | | | | 1 |
| Germany | 0.217 | | 1 | | | Macedonia The Fmr Yug Rp | 0.039 | | | 1 | |
| Switzerland | 0.211 | | 1 | | | Egypt | 0.034 | | | | 1 |
| Japan | 0.203 | | | 1 | | Slovenia | 0.032 | | 1 | | |
| Czech Republic | 0.189 | | 1 | | | Malta | 0.028 | | | 1 | |
| the Netherlands | 0.180 | | 1 | | | Moldova Republic of | 0.019 | | 1 | | |
| Belgium-Luxembourg | 0.178 | | 1 | | | Algeria | 0.018 | | | | 1 |
| France | 0.156 | | 1 | | | Romania | 0.016 | | 1 | | |
| Lithuania | 0.155 | 1 | | | | Bulgaria | 0.015 | | | 1 | |
| UK | 0.151 | | 1 | | | Morocco | 0.015 | | | | 1 |
| Slovakia | 0.121 | | 1 | | | China | 0.008 | | | | 1 |
| Andorra | 0.120 | | | 1 | | Libya | 0.007 | | | | 1 |
| Belarus | 0.115 | | 1 | | | Albania | 0.002 | | | 1 | |

**Table 97. Results and conclusions – classification table for CSW PC consumption classes.**

| | NORTHERN LATITUDE CLASS | | | | |
|---|---|---|---|---|---|
| PC CLASS | OVER 55 | 55–45 | 45–35 | UNDER 35 | TOTAL |
| 1–0.3 | 6 | 1 | 1 | 0 | 8 |
| 0.299–0.15 | 3 | 8 | 1 | 0 | 12 |
| 0.1499–0.05 | 1 | 5 | 5 | 0 | 11 |
| 0.0499–0 | 0 | 3 | 6 | 6 | 15 |
| TOTAL | 10 | 17 | 13 | 6 | 46 |

**Table 98. Results and conclusions – correspondence analysis report.**

```
Results                                                         Correspondence Analysis Report
Variables                         OVER_55 to UNDER_35
Raw Data Section
PCCLASS                      OVER_55        X55_45        X45_35      UNDER_35         Total
1–0.3                              6             1             1             0             8
0.299–0.15                         3             8             1             0            12
0.1499–0.05                        1             5             5             0            11
0.0499–0                           0             3             6             6            15
Total                             10            17            13             6            46
Row Profiles Section
PCCLASS                      OVER_55        X55_45        X45_35      UNDER_35         Total
1–0.3                          75.00         12.50         12.50          0.00        100.00
0.299–0.15                     25.00         66.67          8.33          0.00        100.00
0.1499–0.05                     9.09         45.45         45.45          0.00        100.00
0.0499–0                        0.00         20.00         40.00         40.00        100.00
Total                          21.74         36.96         28.26         13.04        100.00
Column Profiles Section
PCCLASS                      OVER_55        X55_45        X45_35      UNDER_35         Total
1–0.3                          60.00          5.88          7.69          0.00         17.39
0.299–0.15                     30.00         47.06          7.69          0.00         26.09
0.1499–0.05                    10.00         29.41         38.46          0.00         23.91
0.0499–0                        0.00         17.65         46.15        100.00         32.61
Total                         100.00        100.00        100.00        100.00        100.00
Plot Detail Section for Rows
                                                              --------  Axis1  1)   --------     --------  Axis2  1)   --------
Name   2)         Quality 3)     Mass 4)     Inertia 5)    Factor 6)    COR 7)    CTR 8)      Factor       COR        CTR
1 1–0.3                0.996       0.174         0.366        1.070      0.679     0.384      –0.731      0.317      0.422
2 0.299–0.15           0.825       0.261         0.168        0.457      0.406     0.105       0.465      0.419      0.256
3 0.1499–0.05          0.553       0.239         0.098       –0.051      0.008     0.001       0.423      0.545      0.195
4 0.0499–0             0.992       0.326         0.367       –0.899      0.897     0.509      –0.292      0.095      0.127
Principal Coordinate Section for  Rows - Axis 1
Name                           Mass     Inertia        Distance         Factor    COR      CTR            Angle     Eigenvalue
1 1–0.3                       0.174     0.366             1.685          1.070    0.679    0.384           34.5     0.199011
2 0.299–0.15                  0.261     0.168             0.515          0.457    0.406    0.105           50.4     0.054534
3 0.1499–0.05                 0.239     0.098             0.328         –0.051    0.008    0.001           84.9     0.000614
4 0.0499–0                    0.326     0.367             0.901         –0.899    0.897    0.509           18.7     0.263625
Principal Coordinate Section for  Rows - Axis 2
Name                     Mass              Inertia   Distance        Factor         COR       CTR       Angle    Eigenvalue
1 1–0.3                 0.174                0.366      1.685        –0.731       0.317     0.422        55.7      0.092850
2 0.299–0.15            0.261                0.168      0.515         0.465       0.419     0.256        49.6      0.056289
3 0.1499–0.05           0.239                0.098      0.328         0.423       0.545     0.195        42.4      0.042794
4 0.0499–0              0.326                0.367      0.901        –0.292       0.095     0.127        72.1      0.027831
```

Remarks (Source: NCSS© 2000):

1. The two axes (coordinates or dimensions) that are reported on here.
2. The name of the dimension (profile) being reported about on this line of the report.
3. The sum of the two COR values. It is the proportion of the variation in this profile that is reproduced by the two factors being reported on here.
4. The mass (or weight) is the proportion of the whole table that is in the category represented by this row. It is the ratio of the row count to the total table count.
5. The weighted average of the Chi-square distances between the row profiles and their average profile.
6. The coordinate of the profile along this axis. This is the value of the row profile projected onto the line defined by this axis. It is the value that is plotted.
7. This is the correlation between this profile and the axis to allow to determine which of the axes represent the profile well. This is the proportion of the variance in a profile explained by the axis.
8. The contribution of this profile to the inertia of this axis. This is the proportion of variance in the axis accounted for by this profile.

# APPENDIX 3: THE MOISTURE CONTENT MODELS – LOGISTIC REGRESSION

Table 99. Binary logistic regression. Variables in the moisture content (MC) models.

| MC8 | B | S.E. | Wald | Sig. | Exp(B) |
|---|---|---|---|---|---|
| C-DE | 2.689 | 0.499 | 29.055 | 0.000 | 0.068 |
| C-DK | 2.691 | 0.387 | 48.359 | 0.000 | 0.068 |
| C-FI | 2.887 | 0.350 | 67.992 | 0.000 | 0.056 |
| C-IE | 2.374 | 0.624 | 14.479 | 0.000 | 0.093 |
| PINE | 2.341 | 0.332 | 49.836 | 0.000 | 0.096 |
| Q-SF | 1.505 | 0.178 | 71.185 | 0.000 | 0.222 |
| SOUTH | 2.303 | 0.437 | 27.804 | 0.000 | 0.100 |
| S-DIST | 1.143 | 0.240 | 22.782 | 0.000 | 0.319 |
| S-FUR | 1.403 | 0.365 | 14.737 | 0.000 | 0.246 |
| T-50 | 2.396 | 0.205 | 136.154 | 0.000 | 0.091 |
| T-63 | 0.996 | 0.323 | 9.539 | 0.002 | 0.369 |
| WEST | 1.614 | 0.435 | 13.748 | 0.000 | 0.199 |
| W-200 | –2.325 | 0.722 | 10.383 | 0.001 | 10.227 |
| Constant | –9.419 | 1.546 | 37.132 | 0.000 | 12325.132 |
| MC10 | B | S.E. | Wald | Sig. | Exp(B) |
| C-DE | 2.340 | 0.338 | 47.806 | 0.000 | 0.096 |
| C-DK | 2.409 | 0.263 | 84.014 | 0.000 | 0.090 |
| C-FI | 1.988 | 0.239 | 69.479 | 0.000 | 0.137 |
| C-JP | 2.227 | 0.658 | 11.461 | 0.001 | 0.108 |
| PINE | 1.881 | 0.247 | 57.917 | 0.000 | 0.152 |
| Q-SF | 1.233 | 0.178 | 47.862 | 0.000 | 0.291 |
| Q-US | 0.648 | 0.196 | 10.955 | 0.001 | 0.523 |
| S-DIST | 1.628 | 0.293 | 30.906 | 0.000 | 0.196 |
| S-FUR | 2.637 | 0.352 | 56.231 | 0.000 | 0.072 |
| S-PLAN | 1.299 | 0.391 | 11.019 | 0.001 | 0.273 |
| T-19 | –1.195 | 0.397 | 9.063 | 0.003 | 3.305 |
| T-50 | 0.426 | 0.155 | 7.535 | 0.006 | 0.653 |
| WEST | –1.014 | 0.164 | 38.047 | 0.000 | 2.756 |
| W-175 | –2.275 | 0.715 | 10.135 | 0.001 | 9.730 |
| W-200 | –2.558 | 0.715 | 12.797 | 0.000 | 12.913 |
| W-225 | –1.470 | 0.590 | 6.213 | 0.013 | 4.350 |
| Constant | –1.758 | 1.737 | 1.024 | 0.312 | 5.798 |
| MC12 | B | S.E. | Wald | Sig. | Exp(B) |
| C-DE | 0.971 | 0.375 | 6.701 | 0.010 | 0.379 |
| C-DK | 1.484 | 0.232 | 41.065 | 0.000 | 0.227 |
| C-FI | 0.888 | 0.212 | 17.566 | 0.000 | 0.411 |
| C-GB | –1.048 | 0.362 | 8.382 | 0.004 | 2.853 |
| C-IT | 1.265 | 0.286 | 19.541 | 0.000 | 0.282 |
| C-JP | 1.423 | 0.525 | 7.339 | 0.007 | 0.241 |
| EAST | –1.909 | 0.393 | 23.575 | 0.000 | 6.749 |
| PINE | 2.401 | 0.303 | 62.594 | 0.000 | 0.091 |
| Q-SF | 0.972 | 0.199 | 23.814 | 0.000 | 0.378 |
| Q-US | 1.182 | 0.172 | 47.165 | 0.000 | 0.307 |
| S-DIST | 0.571 | 0.192 | 8.893 | 0.003 | 0.565 |
| S-JOI | 1.635 | 0.281 | 33.907 | 0.000 | 0.195 |
| T-19 | –2.528 | 0.597 | 17.921 | 0.000 | 12.532 |
| T-25 | –1.697 | 0.381 | 19.826 | 0.000 | 5.459 |
| T-32 | –2.023 | 0.591 | 11.734 | 0.001 | 7.562 |
| T-63 | 1.058 | 0.163 | 42.007 | 0.000 | 0.347 |
| T-75 | 0.835 | 0.225 | 13.735 | 0.000 | 0.434 |
| W-100 | –1.113 | 0.201 | 30.534 | 0.000 | 3.042 |
| W-125 | –1.068 | 0.199 | 28.654 | 0.000 | 2.909 |
| W-150 | –2.291 | 0.253 | 81.813 | 0.000 | 9.888 |
| W-175 | –1.624 | 0.262 | 38.527 | 0.000 | 5.076 |
| W-200 | –2.132 | 0.275 | 60.245 | 0.000 | 8.434 |
| W-225 | –2.916 | 0.526 | 30.669 | 0.000 | 18.459 |
| Constant | 11.861 | 1.830 | 42.013 | 0.000 | 0.000 |
| MC14 | B | S.E. | Wald | Sig. | Exp(B) |
| C-DE | 3.052 | 0.658 | 21.529 | 0.000 | 0.047 |
| C-FI | 2.046 | 0.497 | 16.965 | 0.000 | 0.129 |
| C-NL | 3.685 | 0.503 | 53.703 | 0.000 | 0.025 |
| SOUTH | –2.701 | 1.014 | 7.102 | 0.008 | 14.895 |
| S-DIST | 1.624 | 0.485 | 11.211 | 0.001 | 0.197 |
| S-STGR | 3.605 | 0.564 | 40.921 | 0.000 | 0.027 |
| T-47 | 2.319 | 0.609 | 14.514 | 0.000 | 0.098 |
| T-50 | 1.232 | 0.393 | 9.819 | 0.002 | 0.292 |
| T-63 | 2.011 | 0.395 | 25.910 | 0.000 | 0.134 |
| T-75 | 1.869 | 0.434 | 18.518 | 0.000 | 0.154 |
| Constant | –9.158 | 1.941 | 22.269 | 0.000 | 9486.638 |
| MC18 | B | S.E. | Wald | Sig. | Exp(B) |
| C-DK | –0.653 | 0.091 | 51.794 | 0.000 | 1.921 |
| C-ES | –0.880 | 0.100 | 78.122 | 0.000 | 2.410 |
| C-FI | –0.348 | 0.055 | 40.581 | 0.000 | 1.416 |
| C-GB | –0.740 | 0.072 | 106.618 | 0.000 | 2.096 |
| C-IE | –0.891 | 0.168 | 27.992 | 0.000 | 2.437 |
| C-NL | –0.322 | 0.113 | 8.145 | 0.004 | 1.380 |
| EAST | –7.684 | 1.008 | 58.131 | 0.000 | 2173.825 |
| PINE | 0.341 | 0.052 | 43.520 | 0.000 | 0.711 |
| Q-SIDE | –0.413 | 0.098 | 17.756 | 0.000 | 1.511 |
| Q-STGR | 5.368 | 1.009 | 28.299 | 0.000 | 0.005 |
| Q-VI | 0.333 | 0.050 | 44.755 | 0.000 | 0.717 |
| SOUTH | –3.562 | 1.008 | 12.476 | 0.000 | 35.220 |
| S-DIST | 1.152 | 0.080 | 207.105 | 0.000 | 0.316 |
| S-FUR | –0.633 | 0.214 | 8.711 | 0.003 | 1.883 |
| S-JOI | 0.563 | 0.151 | 13.895 | 0.000 | 0.570 |
| S-PLAN | 1.288 | 0.104 | 152.588 | 0.000 | 0.276 |
| S-STGR | 3.594 | 0.265 | 183.647 | 0.000 | 0.027 |
| T-19 | 0.387 | 0.094 | 17.074 | 0.000 | 0.679 |
| T-22 | 0.518 | 0.096 | 29.037 | 0.000 | 0.596 |
| T-25 | 0.326 | 0.067 | 23.668 | 0.000 | 0.722 |
| T-44 | 0.464 | 0.108 | 18.524 | 0.000 | 0.629 |
| T-63 | –0.234 | 0.071 | 10.972 | 0.001 | 1.264 |
| WEST | –6.168 | 1.008 | 37.447 | 0.000 | 477.454 |
| W-100 | 0.807 | 0.085 | 89.992 | 0.000 | 0.446 |
| W-125 | 0.750 | 0.087 | 74.921 | 0.000 | 0.473 |
| W-150 | 0.726 | 0.083 | 76.983 | 0.000 | 0.484 |
| W-175 | 0.772 | 0.095 | 65.514 | 0.000 | 0.462 |
| W-200 | 0.625 | 0.092 | 45.983 | 0.000 | 0.535 |
| W-225 | 0.418 | 0.102 | 16.884 | 0.000 | 0.658 |
| Constant | –0.188 | 2.340 | 0.006 | 0.936 | 1.207 |

# APPENDIX 4: PRICE MODELS – MULTIPLE REGRESSION

Dependent Variable: PRICE

| **PINE AND SPRUCE** | | | | | | |
|---|---|---|---|---|---|---|
| **ANOVA** | | | | | | |
| **Model** | | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| **64** | **Regression** | 11933264 | 58 | 205745.92 | 241.63 | 0.000 |
| | **Residual** | 3210921 | 3771 | 851.48 | | |
| **N = 3830** | **Total** | 15144185 | 3829 | | | |
| **PINE** | | | | | | |
| **ANOVA** | | | | | | |
| **Model** | | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| **40** | **Regression** | 9234456.914 | 40 | 230861.42 | 214.85 | 0.000 |
| | **Residual** | 2240351 | 2085 | 1074.51 | | |
| **N = 2126** | **Total** | 11474808 | 2125 | | | |
| **SPRUCE** | | | | | | |
| **ANOVA** | | | | | | |
| **Model** | | **Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| **30** | **Regression** | 2334924 | 30 | 77830.81 | 406.99 | 0.000 |
| | **Residual** | 319936 | 1673 | 191.23 | | |
| **N = 1704** | **Total** | 2654860 | 1703 | | | |

| **PINE AND SPRUCE** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Model 64** | **Coefficients** | **Unstandardised Coefficients** | | **Standardised Coefficients** | **t** | **Sig.** | **95% Confidence Interval for B** | | **Collinearity Statistics 1)** | |
| | | **B 2)** | **Std. Error** | **Beta** | | | **Lower Bound** | **Upper Bound** | **Tolerance 3)** | **VIF 4)** |
| **1** | **(Constant)** | 165.425 | 4.352 | | 38.008 | 0.000 | 156.892 | 173.959 | | |
| **2** | **C-AU** | 84.936 | 11.225 | 0.058 | 7.567 | 0.000 | 62.928 | 106.944 | 0.967 | 1.034 |
| **3** | **C-CN** | 27.048 | 5.024 | 0.041 | 5.384 | 0.000 | 17.199 | 36.898 | 0.973 | 1.028 |
| **4** | **C-DK** | 13.604 | 2.690 | 0.041 | 5.056 | 0.000 | 8.329 | 18.879 | 0.866 | 1.155 |
| **5** | **C-EG** | -16.256 | 1.739 | -0.083 | -9.348 | 0.000 | -19.665 | -12.846 | 0.706 | 1.416 |
| **6** | **C-GB** | 18.750 | 1.855 | 0.079 | 10.109 | 0.000 | 15.113 | 22.386 | 0.912 | 1.097 |
| **7** | **C-HK** | 27.431 | 8.556 | 0.024 | 3.206 | 0.001 | 10.657 | 44.205 | 0.972 | 1.028 |
| **8** | **C-HU** | 25.541 | 9.829 | 0.020 | 2.599 | 0.009 | 6.271 | 44.811 | 0.982 | 1.019 |
| **9** | **C-JP** | 50.068 | 2.356 | 0.182 | 21.256 | 0.000 | 45.450 | 54.686 | 0.763 | 1.311 |
| **10** | **C-MY** | 22.570 | 6.494 | 0.027 | 3.475 | 0.001 | 9.838 | 35.303 | 0.923 | 1.084 |
| **11** | **C-NO** | 36.881 | 6.018 | 0.052 | 6.129 | 0.000 | 25.083 | 48.679 | 0.790 | 1.266 |
| **12** | **C-TW** | 17.275 | 4.191 | 0.031 | 4.122 | 0.000 | 9.057 | 25.492 | 0.963 | 1.038 |
| **13** | **MC10** | 25.799 | 7.028 | 0.032 | 3.671 | 0.000 | 12.019 | 39.579 | 0.754 | 1.326 |
| **14** | **MC12** | 29.628 | 8.401 | 0.029 | 3.527 | 0.000 | 13.157 | 46.100 | 0.807 | 1.238 |
| **15** | **MC16** | 24.193 | 6.739 | 0.032 | 3.590 | 0.000 | 10.980 | 37.406 | 0.726 | 1.377 |
| **16** | **MC18** | 17.454 | 3.427 | 0.054 | 5.093 | 0.000 | 10.735 | 24.174 | 0.500 | 2.001 |
| **17** | **PINE** | 13.522 | 1.156 | 0.107 | 11.700 | 0.000 | 11.256 | 15.787 | 0.674 | 1.484 |
| **18** | **Q-FRA** | 217.035 | 10.059 | 0.167 | 21.575 | 0.000 | 197.312 | 236.757 | 0.937 | 1.067 |
| **19** | **Q-GLUE** | 246.709 | 10.133 | 0.190 | 24.348 | 0.000 | 226.843 | 266.575 | 0.924 | 1.083 |
| **20** | **Q-HVS2** | 32.820 | 10.102 | 0.025 | 3.249 | 0.001 | 13.014 | 52.625 | 0.929 | 1.076 |
| **21** | **Q-LAMA** | -25.868 | 6.103 | -0.037 | -4.238 | 0.000 | -37.834 | -13.902 | 0.743 | 1.345 |
| **22** | **Q-LAMB** | -90.590 | 5.583 | -0.145 | -16.225 | 0.000 | -101.537 | -79.643 | 0.708 | 1.413 |
| **23** | **Q-OTH1** | -104.204 | 3.338 | -0.353 | -31.217 | 0.000 | -110.748 | -97.659 | 0.441 | 2.268 |
| **24** | **Q-OTH2** | -121.332 | 7.004 | -0.139 | -17.323 | 0.000 | -135.064 | -107.600 | 0.872 | 1.146 |
| **25** | **Q-PL** | -80.513 | 6.873 | -0.095 | -11.714 | 0.000 | -93.989 | -67.037 | 0.863 | 1.159 |
| **26** | **Q-PLKL** | 93.302 | 9.254 | 0.079 | 10.083 | 0.000 | 75.160 | 111.445 | 0.907 | 1.103 |
| **27** | **Q-PLVL1** | -93.488 | 4.595 | -0.186 | -20.345 | 0.000 | -102.497 | -84.479 | 0.672 | 1.489 |
| **28** | **Q-PLVL2** | -88.907 | 10.731 | -0.065 | -8.285 | 0.000 | -109.946 | -67.867 | 0.926 | 1.080 |
| **29** | **Q-SF15** | -24.578 | 3.125 | -0.108 | -7.864 | 0.000 | -30.705 | -18.451 | 0.298 | 3.354 |
| **30** | **Q-SF15B** | -31.136 | 7.754 | -0.033 | -4.015 | 0.000 | -46.338 | -15.933 | 0.837 | 1.195 |
| **31** | **Q-SF16** | -31.140 | 3.195 | -0.130 | -9.748 | 0.000 | -37.403 | -24.877 | 0.315 | 3.172 |
| **32** | **Q-SF56** | -38.992 | 4.984 | -0.068 | -7.823 | 0.000 | -48.764 | -29.221 | 0.738 | 1.354 |
| **33** | **Q-SFLQ** | -47.086 | 11.339 | -0.032 | -4.152 | 0.000 | -69.318 | -24.854 | 0.948 | 1.055 |
| **34** | **Q-SFMB** | -29.645 | 6.921 | -0.036 | -4.283 | 0.000 | -43.215 | -16.074 | 0.777 | 1.286 |
| **35** | **Q-SFSG** | -39.193 | 8.031 | -0.039 | -4.880 | 0.000 | -54.938 | -23.448 | 0.884 | 1.132 |
| **36** | **Q-US** | 42.275 | 2.823 | 0.228 | 14.976 | 0.000 | 36.741 | 47.810 | 0.242 | 4.124 |
| **37** | **Q-USSP** | 73.783 | 6.325 | 0.098 | 11.665 | 0.000 | 61.381 | 86.185 | 0.794 | 1.260 |
| **38** | **Q-V** | -27.539 | 2.818 | -0.149 | -9.771 | 0.000 | -33.065 | -22.014 | 0.241 | 4.145 |
| **39** | **Q-VA** | -38.485 | 5.421 | -0.061 | -7.100 | 0.000 | -49.112 | -27.857 | 0.770 | 1.298 |
| **40** | **Q-VIB** | -87.421 | 10.183 | -0.067 | -8.585 | 0.000 | -107.386 | -67.455 | 0.914 | 1.094 |
| **41** | **Q-VIC** | -74.018 | 6.048 | -0.102 | -12.238 | 0.000 | -85.875 | -62.160 | 0.809 | 1.236 |
| **42** | **Q-VID** | -92.638 | 3.033 | -0.482 | -30.545 | 0.000 | -98.584 | -86.692 | 0.226 | 4.430 |
| **43** | **Q-VIE** | -66.645 | 2.745 | -0.423 | -24.280 | 0.000 | -72.026 | -61.263 | 0.186 | 5.390 |
| **44** | **Q-VIEJ** | -47.172 | 4.925 | -0.091 | -9.577 | 0.000 | -56.828 | -37.515 | 0.625 | 1.600 |
| **45** | **Q-VIJ** | -74.579 | 4.507 | -0.151 | -16.549 | 0.000 | -83.415 | -65.744 | 0.677 | 1.478 |
| **46** | **Q-VIM** | -60.702 | 11.342 | -0.041 | -5.352 | 0.000 | -82.940 | -38.464 | 0.947 | 1.056 |
| **47** | **Q-VIW** | -75.727 | 6.569 | -0.097 | -11.529 | 0.000 | -88.605 | -62.849 | 0.795 | 1.259 |
| **48** | **Q-VM** | -19.633 | 4.688 | -0.039 | -4.188 | 0.000 | -28.824 | -10.442 | 0.656 | 1.524 |
| **49** | **T-100** | 17.437 | 4.429 | 0.030 | 3.937 | 0.000 | 8.753 | 26.121 | 0.976 | 1.025 |
| **50** | **T-16** | -21.446 | 6.834 | -0.025 | -3.138 | 0.002 | -34.845 | -8.048 | 0.916 | 1.091 |
| **51** | **T-19** | 15.286 | 2.176 | 0.059 | 7.023 | 0.000 | 11.019 | 19.553 | 0.809 | 1.237 |
| **52** | **T-25** | 11.963 | 1.435 | 0.068 | 8.336 | 0.000 | 9.149 | 14.776 | 0.847 | 1.180 |
| **53** | **T-63** | -5.532 | 1.688 | -0.026 | -3.277 | 0.001 | -8.842 | -2.222 | 0.914 | 1.094 |
| **54** | **T-75** | -6.774 | 1.850 | -0.029 | -3.661 | 0.000 | -10.401 | -3.147 | 0.914 | 1.095 |
| **55** | **W-100** | -5.087 | 1.389 | -0.031 | -3.663 | 0.000 | -7.810 | -2.364 | 0.803 | 1.245 |
| **56** | **W-50** | 32.756 | 7.138 | 0.036 | 4.589 | 0.000 | 18.761 | 46.751 | 0.933 | 1.072 |
| **57** | **W-63** | 55.275 | 11.466 | 0.038 | 4.821 | 0.000 | 32.794 | 77.756 | 0.927 | 1.079 |
| **58** | **W-75** | 13.966 | 4.681 | 0.024 | 2.984 | 0.003 | 4.789 | 23.143 | 0.874 | 1.144 |
| **59** | **W-90** | 42.398 | 11.306 | 0.029 | 3.750 | 0.000 | 20.231 | 64.565 | 0.953 | 1.049 |

1. Collinearity (or multicollinearity) is the undesirable situation when one independent variable is almost a linear function of other independent variables. Source: SPSS® 2003.
2. Partial regression coefficients represent the importance of the variable. Source: PFC 2005.
3. Tolerance has a range from zero to one. The closer the tolerance value is to zero relates a level of multicollinearity. Source: PFC 2005.
4. VIF, Variance Inflation Factor, reflects the presence or absence of multicollinearity. A high VIF, much larger than one, the variable may be affected by multicollinearity. The VIF has a range 1 to infinity. Source: PFC 2005.

**PINE**

| Model 40 | Coefficients | Unstandardised Coefficients | | Standardised Coefficients | t | Sig. | 95% Confidence Interval for B | | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound | Tolerance | VIF |
| **1** | **(Constant)** | 195.908 | 2.971 | | 65.930 | 0.000 | 190.081 | 201.736 | | |
| **2** | **C-AU** | 72.773 | 12.617 | 0.057 | 5.768 | 0.000 | 48.030 | 97.517 | 0.967 | 1.034 |
| **3** | **C-DK** | 10.886 | 3.056 | 0.037 | 3.562 | 0.000 | 4.893 | 16.879 | 0.886 | 1.129 |
| **4** | **C-GB** | 18.673 | 2.482 | 0.076 | 7.525 | 0.000 | 13.806 | 23.539 | 0.907 | 1.103 |
| **5** | **C-JP** | 42.106 | 6.298 | 0.078 | 6.686 | 0.000 | 29.755 | 54.457 | 0.690 | 1.449 |
| **6** | **C-MY** | 27.045 | 8.343 | 0.033 | 3.242 | 0.001 | 10.685 | 43.406 | 0.915 | 1.092 |
| **7** | **C-NO** | 37.918 | 7.086 | 0.059 | 5.351 | 0.000 | 24.021 | 51.815 | 0.774 | 1.291 |
| **8** | **Q-FRA** | 210.160 | 11.537 | 0.186 | 18.215 | 0.000 | 187.534 | 232.786 | 0.901 | 1.110 |
| **9** | **Q-GLUE** | 232.530 | 12.336 | 0.205 | 18.850 | 0.000 | 208.339 | 256.722 | 0.788 | 1.269 |
| **10** | **Q-LAMA** | -34.549 | 12.069 | -0.031 | -2.863 | 0.004 | -58.217 | -10.881 | 0.823 | 1.215 |
| **11** | **Q-OTH1** | -144.952 | 4.375 | -0.416 | -33.132 | 0.000 | -153.532 | -136.372 | 0.595 | 1.681 |
| **12** | **Q-OTH2** | -140.954 | 8.439 | -0.171 | -16.702 | 0.000 | -157.504 | -124.404 | 0.895 | 1.118 |
| **13** | **Q-PL** | -88.732 | 7.714 | -0.119 | -11.503 | 0.000 | -103.859 | -73.604 | 0.868 | 1.151 |
| **14** | **Q-PLKL** | 81.859 | 10.403 | 0.080 | 7.869 | 0.000 | 61.457 | 102.260 | 0.907 | 1.102 |
| **15** | **Q-PLVL1** | -110.711 | 6.392 | -0.186 | -17.319 | 0.000 | -123.247 | -98.175 | 0.809 | 1.235 |
| **16** | **Q-SF15** | -30.423 | 6.213 | -0.053 | -4.897 | 0.000 | -42.608 | -18.239 | 0.787 | 1.271 |
| **17** | **Q-SF16** | -45.402 | 5.342 | -0.110 | -8.499 | 0.000 | -55.879 | -34.925 | 0.556 | 1.798 |
| **18** | **Q-SF56** | -43.908 | 8.168 | -0.056 | -5.376 | 0.000 | -59.926 | -27.890 | 0.855 | 1.169 |
| **19** | **Q-SFLQ** | -50.109 | 12.741 | -0.039 | -3.933 | 0.000 | -75.095 | -25.122 | 0.949 | 1.054 |
| **20** | **Q-SFMB** | -36.351 | 7.621 | -0.051 | -4.770 | 0.000 | -51.296 | -21.406 | 0.813 | 1.230 |
| **21** | **Q-US** | 51.333 | 3.298 | 0.270 | 15.564 | 0.000 | 44.865 | 57.801 | 0.311 | 3.211 |
| **22** | **Q-USSP** | 69.087 | 7.103 | 0.105 | 9.726 | 0.000 | 55.157 | 83.017 | 0.799 | 1.252 |
| **23** | **Q-V** | -31.407 | 3.329 | -0.162 | -9.435 | 0.000 | -37.936 | -24.879 | 0.319 | 3.132 |
| **24** | **Q-VA** | -44.201 | 6.102 | -0.080 | -7.244 | 0.000 | -56.167 | -32.235 | 0.773 | 1.293 |
| **25** | **Q-VIB** | -110.999 | 11.350 | -0.098 | -9.780 | 0.000 | -133.257 | -88.741 | 0.931 | 1.074 |
| **26** | **Q-VIC** | -84.530 | 6.797 | -0.133 | -12.436 | 0.000 | -97.860 | -71.200 | 0.813 | 1.230 |
| **27** | **Q-VID** | -103.317 | 3.892 | -0.373 | -26.546 | 0.000 | -110.950 | -95.685 | 0.474 | 2.110 |
| **28** | **Q-VIE** | -77.344 | 3.269 | -0.416 | -23.658 | 0.000 | -83.755 | -70.933 | 0.303 | 3.298 |
| **29** | **Q-VIEJ** | -52.763 | 5.797 | -0.112 | -9.102 | 0.000 | -64.131 | -41.395 | 0.619 | 1.616 |
| **30** | **Q-VIJ** | -87.095 | 5.920 | -0.163 | -14.711 | 0.000 | -98.705 | -75.484 | 0.762 | 1.312 |
| **31** | **Q-VIM** | -60.209 | 12.741 | -0.047 | -4.726 | 0.000 | -85.195 | -35.223 | 0.949 | 1.054 |
| **32** | **Q-VIW** | -94.166 | 7.172 | -0.138 | -13.131 | 0.000 | -108.230 | -80.102 | 0.846 | 1.183 |
| **33** | **Q-VM** | -19.735 | 5.262 | -0.044 | -3.750 | 0.000 | -30.055 | -9.415 | 0.665 | 1.503 |
| **34** | **T-100** | 26.168 | 6.985 | 0.037 | 3.746 | 0.000 | 12.470 | 39.866 | 0.968 | 1.033 |
| **35** | **T-19** | 21.390 | 2.545 | 0.087 | 8.406 | 0.000 | 16.399 | 26.380 | 0.873 | 1.145 |
| **36** | **T-25** | 22.166 | 1.952 | 0.117 | 11.355 | 0.000 | 18.338 | 25.994 | 0.880 | 1.136 |
| **37** | **T-56** | 60.225 | 21.006 | 0.031 | 2.867 | 0.004 | 19.030 | 101.420 | 0.813 | 1.230 |
| **38** | **W-50** | 37.084 | 8.013 | 0.046 | 4.628 | 0.000 | 21.370 | 52.798 | 0.938 | 1.066 |
| **39** | **W-63** | 61.223 | 12.863 | 0.048 | 4.760 | 0.000 | 35.997 | 86.448 | 0.931 | 1.074 |
| **40** | **W-75** | 14.960 | 5.608 | 0.028 | 2.668 | 0.008 | 3.963 | 25.958 | 0.871 | 1.149 |
| **41** | **W-90** | 53.995 | 13.819 | 0.039 | 3.907 | 0.000 | 26.895 | 81.095 | 0.940 | 1.063 |

**SPRUCE**

| Model 30 | Coefficients | Unstandardised Coefficients | | Standardised Coefficients | t | Sig. | 95% Confidence Interval for B | | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound | Tolerance | VIF |
| **1** | **(Constant)** | 158.606 | 0.856 | | 185.318 | 0.000 | 156.928 | 160.285 | | |
| **2** | **C-CN** | 21.631 | 2.534 | 0.074 | 8.535 | 0.000 | 16.660 | 26.602 | 0.948 | 1.055 |
| **3** | **C-EG** | -25.653 | 1.350 | -0.208 | -19.007 | 0.000 | -28.300 | -23.005 | 0.600 | 1.667 |
| **4** | **C-FI** | -7.861 | 1.064 | -0.078 | -7.390 | 0.000 | -9.948 | -5.775 | 0.641 | 1.560 |
| **5** | **C-FR** | -4.144 | 1.194 | -0.034 | -3.472 | 0.001 | -6.485 | -1.803 | 0.751 | 1.332 |
| **6** | **C-GB** | 5.021 | 1.676 | 0.027 | 2.996 | 0.003 | 1.734 | 8.308 | 0.893 | 1.120 |
| **7** | **C-HK** | 22.178 | 4.290 | 0.045 | 5.169 | 0.000 | 13.763 | 30.593 | 0.951 | 1.052 |
| **8** | **C-IE** | -9.884 | 2.651 | -0.033 | -3.729 | 0.000 | -15.082 | -4.685 | 0.924 | 1.083 |
| **9** | **C-IT** | -8.006 | 2.808 | -0.026 | -2.851 | 0.004 | -13.514 | -2.498 | 0.851 | 1.176 |
| **10** | **C-JP** | 44.081 | 1.275 | 0.337 | 34.578 | 0.000 | 41.580 | 46.581 | 0.757 | 1.321 |
| **11** | **C-MY** | 20.859 | 6.243 | 0.029 | 3.341 | 0.001 | 8.614 | 33.105 | 0.984 | 1.016 |
| **12** | **C-SE** | -42.942 | 6.257 | -0.059 | -6.863 | 0.000 | -55.215 | -30.669 | 0.980 | 1.021 |
| **13** | **C-TH** | 17.200 | 4.709 | 0.032 | 3.653 | 0.000 | 7.965 | 26.435 | 0.963 | 1.038 |
| **14** | **C-TN** | -11.549 | 3.944 | -0.025 | -2.928 | 0.003 | -19.284 | -3.813 | 0.953 | 1.049 |
| **15** | **C-TW** | 13.011 | 2.242 | 0.051 | 5.804 | 0.000 | 8.614 | 17.409 | 0.929 | 1.077 |
| **16** | **C-VN** | 11.762 | 3.441 | 0.030 | 3.419 | 0.001 | 5.014 | 18.511 | 0.960 | 1.042 |
| **17** | **Q-KNO** | 21.193 | 5.804 | 0.032 | 3.651 | 0.000 | 9.808 | 32.577 | 0.949 | 1.053 |
| **18** | **Q-LAMB** | -63.618 | 2.367 | -0.241 | -26.879 | 0.000 | -68.260 | -58.976 | 0.896 | 1.116 |
| **19** | **Q-OTH1** | -37.141 | 1.787 | -0.203 | -20.785 | 0.000 | -40.645 | -33.636 | 0.759 | 1.318 |
| **20** | **Q-OTH2** | -24.048 | 8.090 | -0.026 | -2.972 | 0.003 | -39.916 | -8.179 | 0.976 | 1.025 |
| **21** | **Q-PLVL1** | -54.838 | 2.924 | -0.177 | -18.756 | 0.000 | -60.573 | -49.103 | 0.812 | 1.231 |
| **22** | **Q-PLVL2** | -59.599 | 5.313 | -0.097 | -11.218 | 0.000 | -70.020 | -49.179 | 0.972 | 1.029 |
| **23** | **Q-SF15** | 4.327 | 1.082 | 0.041 | 4.001 | 0.000 | 2.206 | 6.449 | 0.693 | 1.444 |
| **24** | **Q-SF56** | -11.001 | 2.791 | -0.035 | -3.942 | 0.000 | -16.475 | -5.527 | 0.892 | 1.122 |
| **25** | **Q-US** | 27.670 | 1.536 | 0.179 | 18.014 | 0.000 | 24.657 | 30.683 | 0.727 | 1.376 |
| **26** | **Q-VID** | -60.582 | 1.260 | -0.588 | -48.062 | 0.000 | -63.054 | -58.109 | 0.481 | 2.080 |
| **27** | **Q-VIE** | -32.979 | 1.028 | -0.337 | -32.082 | 0.000 | -34.996 | -30.963 | 0.652 | 1.534 |
| **28** | **Q-VIJ** | -37.282 | 3.055 | -0.107 | -12.205 | 0.000 | -43.273 | -31.291 | 0.944 | 1.060 |
| **29** | **T-19** | -9.553 | 2.933 | -0.030 | -3.257 | 0.001 | -15.306 | -3.800 | 0.868 | 1.152 |
| **30** | **T-22** | -5.025 | 1.286 | -0.035 | -3.909 | 0.000 | -7.547 | -2.504 | 0.918 | 1.089 |
| **31** | **T-48** | 42.386 | 9.816 | 0.037 | 4.318 | 0.000 | 23.133 | 61.638 | 0.994 | 1.006 |

# APPENDIX 5: BATCH SIZE – MULTIPLE REGRESSION MODELS, PINE AND SPRUCE

| PINE AND SPRUCE | | | | | | |
|---|---|---|---|---|---|---|
| ANOVA | | | | | | |
| Model | | Sum of Squares | df | Mean Square | F | Sig. |
| 23 | Regression | 212604284 | 23 | 9243664.535 | 56.233 | 0.000 |
| | Residual | 2374492516 | 14445 | 164381.621 | | |
| | Total | 2587096801 | 14468 | | | |
| PINE | | | | | | |
| ANOVA | | | | | | |
| Model | | Sum of Squares | df | Mean Square | F | Sig. |
| 15 | Regression | 440810896 | 15 | 29387393.061 | 18.605 | 0.000 |
| | Residual | 3332865210 | 2110 | 1579556.972 | | |
| | Total | 3773676106 | 2125 | | | |
| SPRUCE | | | | | | |
| ANOVA | | | | | | |
| Model | | Sum of Squares | df | Mean Square | F | Sig. |
| 8 | Regression | 543575988 | 8 | 67946998.531 | 33.534 | 0.000 |
| | Residual | 3434470154 | 1695 | 2026236.079 | | |
| | Total | 3978046142 | 1703 | | | |

| PINE AND SPRUCE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Coefficients | | | | | | | | | |
| Model | | Unstandardised Coefficients | | Standardised Coefficients | t | Sig. | 95% Confidence Interval for B | | Collinearity Statistics | |
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound | Tolerance | VIF |
| 23 | (Constant) | 183.278 | 10.332 | | 17.739 | 0.000 | 163.026 | 203.529 | | |
| | C-DZ | 259.413 | 22.924 | 0.092 | 11.316 | 0.000 | 214.478 | 304.348 | 0.961 | 1.040 |
| | C-EG | 123.021 | 17.402 | 0.058 | 7.070 | 0.000 | 88.912 | 157.130 | 0.929 | 1.076 |
| | C-ES | –65.395 | 14.808 | –0.037 | –4.416 | 0.000 | –94.421 | –36.370 | 0.921 | 1.086 |
| | C-FI | –93.844 | 7.930 | –0.104 | –11.834 | 0.000 | –109.389 | –78.300 | 0.817 | 1.223 |
| | C-IL | 83.897 | 21.107 | 0.032 | 3.975 | 0.000 | 42.525 | 125.269 | 0.960 | 1.041 |
| | MC16 | 94.715 | 28.420 | 0.027 | 3.333 | 0.001 | 39.008 | 150.422 | 0.965 | 1.036 |
| | MC20 | –33.292 | 7.821 | –0.036 | –4.257 | 0.000 | –48.623 | –17.961 | 0.879 | 1.138 |
| | MC8 | 90.385 | 30.996 | 0.024 | 2.916 | 0.004 | 29.629 | 151.140 | 0.952 | 1.050 |
| | PINE | –45.589 | 8.342 | –0.052 | –5.465 | 0.000 | –61.940 | –29.237 | 0.706 | 1.417 |
| | Q-SF | 85.219 | 9.561 | 0.082 | 8.913 | 0.000 | 66.478 | 103.961 | 0.755 | 1.324 |
| | Q-SIDE | 250.180 | 16.030 | 0.137 | 15.607 | 0.000 | 218.759 | 281.601 | 0.829 | 1.206 |
| | Q-STGR | 290.829 | 33.706 | 0.073 | 8.628 | 0.000 | 224.760 | 356.898 | 0.892 | 1.121 |
| | Q-V | 48.369 | 8.775 | 0.047 | 5.512 | 0.000 | 31.169 | 65.569 | 0.867 | 1.153 |
| | S-FUR | 101.290 | 31.753 | 0.026 | 3.190 | 0.001 | 39.049 | 163.531 | 0.970 | 1.030 |
| | S-STGR | 155.981 | 29.373 | 0.045 | 5.310 | 0.000 | 98.406 | 213.557 | 0.904 | 1.107 |
| | T-22 | 95.346 | 15.620 | 0.053 | 6.104 | 0.000 | 64.728 | 125.964 | 0.841 | 1.189 |
| | T-32 | –33.174 | 12.221 | –0.022 | –2.715 | 0.007 | –57.129 | –9.220 | 0.951 | 1.051 |
| | T-50 | 54.246 | 8.619 | 0.053 | 6.294 | 0.000 | 37.351 | 71.141 | 0.906 | 1.103 |
| | W-100 | 74.261 | 9.269 | 0.072 | 8.012 | 0.000 | 56.092 | 92.430 | 0.790 | 1.266 |
| | W-175 | –56.085 | 11.711 | –0.040 | –4.789 | 0.000 | –79.039 | –33.130 | 0.907 | 1.103 |
| | W-200 | –38.750 | 10.852 | –0.030 | –3.571 | 0.000 | –60.021 | –17.479 | 0.882 | 1.133 |
| | W-225 | –41.539 | 12.686 | –0.028 | –3.275 | 0.001 | –66.405 | –16.674 | 0.898 | 1.113 |
| | WEST | –39.928 | 7.269 | –0.047 | –5.493 | 0.000 | –54.175 | –25.680 | 0.862 | 1.160 |
| PINE | | | | | | | | | | |
| Coefficients | | | | | | | | | | |
| Model | | Unstandardised Coefficients | | Standardised Coefficients | t | Sig. | 95% Confidence Interval for B | | Collinearity Statistics | |
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound | Tolerance | VIF |
| 15 | (Constant) | –81.829 | 50.419 | | –1.623 | 0.105 | –180.706 | 17.047 | | |
| | C-DZ | 714.183 | 147.939 | 0.103 | 4.828 | 0.000 | 424.061 | 1004.305 | 0.926 | 1.080 |
| | C-EG | 235.609 | 87.387 | 0.057 | 2.696 | 0.007 | 64.235 | 406.982 | 0.925 | 1.081 |
| | C-GB | 654.203 | 93.018 | 0.148 | 7.033 | 0.000 | 471.787 | 836.620 | 0.949 | 1.054 |
| | C-MA | 1534.632 | 245.482 | 0.129 | 6.252 | 0.000 | 1053.220 | 2016.043 | 0.983 | 1.017 |
| | C-SA | 559.492 | 170.070 | 0.069 | 3.290 | 0.001 | 225.971 | 893.014 | 0.952 | 1.050 |
| | C-TN | 524.797 | 147.060 | 0.074 | 3.569 | 0.000 | 236.400 | 813.195 | 0.972 | 1.029 |
| | Q-LAMA | 1570.094 | 421.958 | 0.077 | 3.721 | 0.000 | 742.597 | 2397.591 | 0.990 | 1.010 |
| | Q-PLVL1 | 1657.112 | 229.415 | 0.154 | 7.223 | 0.000 | 1207.208 | 2107.015 | 0.924 | 1.083 |
| | Q-SFMB | 768.249 | 266.612 | 0.060 | 2.882 | 0.004 | 245.399 | 1291.098 | 0.977 | 1.024 |
| | Q-V | 315.334 | 76.275 | 0.089 | 4.134 | 0.000 | 165.751 | 464.916 | 0.894 | 1.118 |
| | Q-VA | 640.523 | 210.898 | 0.064 | 3.037 | 0.002 | 226.934 | 1054.112 | 0.952 | 1.051 |
| | Q-VIE | 310.102 | 72.268 | 0.092 | 4.291 | 0.000 | 168.378 | 451.827 | 0.912 | 1.096 |
| | T-50 | 344.423 | 65.263 | 0.111 | 5.277 | 0.000 | 216.437 | 472.409 | 0.945 | 1.058 |
| | W-100 | 400.793 | 74.845 | 0.119 | 5.355 | 0.000 | 254.016 | 547.570 | 0.849 | 1.178 |
| | W-150 | 205.896 | 69.388 | 0.063 | 2.967 | 0.003 | 69.821 | 341.971 | 0.917 | 1.090 |
| SPRUCE | | | | | | | | | | |
| Coefficients | | | | | | | | | | |
| Model | | Unstandardised Coefficients | | Standardised Coefficients | t | Sig. | 95% Confidence Interval for B | | Collinearity Statistics | |
| | | B | Std. Error | Beta | | | Lower Bound | Upper Bound | Tolerance | VIF |
| 8 | (Constant) | 124.293 | 46.971 | | 2.646 | 0.008 | 32.165 | 216.420 | | |
| | C-DE | 1221.038 | 154.839 | 0.194 | 7.886 | 0.000 | 917.342 | 1524.734 | 0.843 | 1.187 |
| | C-FR | 373.864 | 109.562 | 0.079 | 3.412 | 0.001 | 158.973 | 588.755 | 0.944 | 1.059 |
| | C-JP | 513.474 | 119.651 | 0.101 | 4.291 | 0.000 | 278.795 | 748.154 | 0.911 | 1.098 |
| | C-NL | 407.276 | 109.503 | 0.087 | 3.719 | 0.000 | 192.500 | 622.052 | 0.941 | 1.063 |
| | MC16 | –1033.144 | 311.466 | –0.080 | –3.317 | 0.001 | –1644.042 | –422.246 | 0.883 | 1.133 |
| | Q-LAMA | 1060.251 | 312.495 | 0.078 | 3.393 | 0.001 | 447.335 | 1673.167 | 0.955 | 1.047 |
| | Q-PLVL1 | 2648.279 | 272.316 | 0.220 | 9.725 | 0.000 | 2114.167 | 3182.391 | 0.992 | 1.008 |
| | Q-SF15 | 791.977 | 94.262 | 0.193 | 8.402 | 0.000 | 607.094 | 976.860 | 0.966 | 1.035 |

# APPENDIX 6: PRODUCT STANDARDS AND NORMS FOR CONIFEROUS SAWNWOOD

1. SFS 5878. 2000. INSTA 142. Sahatavaran visuaalisen lujuuslajittelun Pohjoismaiset säännöt. Nordic visual strength grading rules for timber. 2000–10–02. (In Finnish) 1st Edition.
2. SFS-EN 336. 2003. Structural timber. Sizes, permitted deviation.
3. SFS-EN 338. 2003. Structural timber. Strength classes.
4. SFS-EN 384. 2004. Structural timber. Determination of characteristic values of mechanical properties and density.
5. SFS-EN 385. 2001. Finger jointed structural timber. Performance requirements and minimum production requirements.
6. SFS-EN 518. 1995. Rakennesahatavara. Lajittelu. Visuaalisille lujuuslajittelustandardeille asetetut vaatimukset. Structural timber. Grading. Requirements for visual strength grading standards. 1995–08–28. Publ. 1997–12–01. (In Finnish) 1st Edition.
7. SFS-EN 519. 1995. Rakennesahatavara. Lajittelu. Koneellisesti lujuuslajitellulle puutavaralle ja lajittelukoneille asetetut vaatimukset. Structural timber. Grading. Requirements for machine strength graded timber and grading machines. 1995–08–28. publ. 1997–12–01. (In Finnish) 1st Edition.
8. SFS-EN 844–1. 1996. Round and sawn timber. Terminology. Part 1: General terms common to round timber and sawn timber.
9. SFS-EN 844–2. 1997. Pyöreä puutavara ja sahatavara. Sanasto. Osa 2: Pyöreän puutavaran yleiset ammattisanat. Round and sawn timber. Terminology. Part 2: General terms relating to round timber. 1997–12–01 (In Finnish) 1st Edition.
10. SFS-EN 844–3. 1995. Round and sawn timber. Terminology. Part 3: General terms relating to sawn timber.
11. SFS-EN 844–4. 1997. Pyöreä puutavara ja sahatavara. Sanasto. Osa 4: Kosteuspitoisuutta koskevat ammattisanat. Round and sawn timber. Terminology. Part 4: Terms relating to structure content. 1997–12–01 (In Finnish) 1st Edition.
12. SFS-EN 844–5. 1997. Pyöreä puutavara ja sahatavara. Sanasto. Osa 5: Pyöreän puutavaran mittoja koskevat ammattisanat. Round and sawn timber. Terminology. Part 5: Terms relating to dimensions of round timber. 1997–12–01 (In Finnish) 1st Edition.
13. SFS-EN 844–6. 1997. Pyöreä puutavara ja sahatavara. Sanasto. Osa 6: Sahatavaran mittoja koskevat ammattisanat. Round and sawn timber. Terminology. Part 6: Terms relating to dimensions of sawn timber. 1997–12–01 (In Finnish) 1st Edition.
14. SFS-EN 844–7. 1997. Pyöreä puutavara ja sahatavara. Sanasto. Osa 7: Puun anatomista rakennetta koskevat ammattisanat. Round and sawn timber. Terminology. Part 7: Terms relating to anatomical structure of timber. 1997–12–01 (In Finnish) 1st Edition.
15. SFS-EN 844–8. 1997. Pyöreä puutavara ja sahatavara. Sanasto. Osa 8: Pyöreän puutavaran ominaisuuksia koskevat ammattisanat. Round and sawn timber. Terminology. Part 8: Terms relating to features of round timber. 1997–12–01 (In Finnish) 1st Edition.
16. SFS-EN 844–9. 1997. Pyöreä puutavara ja sahatavara. Sanasto. Osa 9: Sahatavaran ominaisuuksia koskevat ammattisanat. Round and sawn timber. Terminology. Part 9: Terms relating to features of sawn timber. 1997–12–01 (In Finnish) 1st Edition.
17. SFS-EN 844–10. 1998. Round and sawn timber. Terminology. Part 10: Terms relating to stain and fungal attack.
18. SFS-EN 844–11. 1998. Round and sawn timber. Terminology. Part 11: Terms relating to degrade by insects.
19. SFS-EN 844–12. 2001. Round and sawn timber. Terminology. Part 12: Additional terms and general index. 1st Edition.
20. SFS-EN 942. 1996. Timber in joinery. General classification of timber quality.
21. SFS-EN 1309–1. 1997. Pyöreä puutavara ja sahatavara. Menetelmä kokojen mittaamiseksi. Osa 1: Sahatavara. Round and sawn timber. Method of measurement of dimensions. Part 1: Sawn timber. 1997–12–01 (In Finnish) 1st Edition.
22. SFS-EN 1310. 1997. Pyöreä puutavara ja sahatavara. Menetelmä ominaisuuksien mittaamiseksi. Round and sawn timber. Method of measurement of features. 1997–12–01 (In Finnish) 1st Edition.
23. SFS-EN 1311. 1997. Pyöreä puutavara ja sahatavara. Menetelmä biologisten vikojen mittaamiseksi. Round and sawn timber. Method of measurement of biological degrade. 1997–12–01 (In Finnish) 1st Edition.
24. SFS-EN 1312. 1997. Pyöreä puutavara ja sahatavara. Sahatavaraerän tilavuuden määritys. Round and sawn timber. Determination of the batch volume of sawn timber. 1997–12–01 (In Finnish) 1st Edition.
25. SFS-EN 1313–1. 1997. Pyöreä puutavara ja sahatavara. Sallitut poikkeamat ja suositut koot. Osa 1: Havupuusahatavara. Round and sawn timber. Permitted deviations and preferred sizes. Part 1: Softwood sawn timber. 1997–12–01 (In Finnish) 1st Edition.
26. SFS-EN 1313–1/A1. 1999. Round and sawn timber. Permitted deviations and preferred sizes. Part 1: Softwood sawn timber.
27. SFS-EN 1315–2. 1998. Dimensional classification. Part 2: Softwood round timber.
28. SFS-EN 1438. 1999. Symbols for timber and wood-based products.
29. SFS-EN 1611–1/A1. 2002. Sawn timber. Appearance grading of softwoods. Part 1: European spruces, firs, pines, Douglas fir and larches.
30. SFS-EN 1611–1. 2000. Sawn timber. Appearance grading of softwoods. Part 1: European spruces, firs, pines and Douglas firs.
31. SFS-EN 1912. 1998. Rakennesahatavara. Lujuusluokat. Visuaalisten laatuluokkien ja puulajien määritys. Structural timber. Strength classes. Assignment of visual grades and species. 1998–12–21, Julk./publ. 2001–05–21 (In Finnish). 1st Edition.
32. SFS-EN 12246. 1999. Quality classification of timber used in pallets and packaging.
33. SFS-EN 12248. 1999. Sawn timber used in industrial packaging. Permitted deviations and preferential sizes.
34. SFS-EN 12249. 1999. Sawn timber used in pallets. Permitted deviations and guidelines for dimensions.
35. SFS-EN 13183–1. 2002. Moisture content of a piece of sawn timber. Part 1: Determination by oven dry method.
36. SFS-EN 13183–2. 2002. Moisture content of a piece of sawn timber. Part 2: Estimation by electrical resistance method.
37. SFS-EN 13556. 2003. Round and sawn timber. Nomenclature of timbers used in Europe.
38. SFS-EN 14251. 2004. Structural round timber. Test methods.
39. SFS-ENV 1927–1. 1999. Qualitative classification of softwood round timber. Part 1: Spruces and firs.
40. SFS-ENV 1927–2. 1999. Qualitative classification of softwood round timber. Part 2: Pines.
41. SFS-ENV 12169. 2000. Criteria for the assessment of conformity of a lot of sawn timber. 10 pp. SFS–ENV 14464. 2002. Sawn timber. Method for assessment of case-hardening.

# APPENDIX 7: TABLES FOR DIMENSION, LENGTH, MOISTURE CONTENT AND USER SEGMENT ANALYSES

## CASE UK AND LARGE PINE CSW DIMENSIONS

**Table 100. The development of sales distribution of the most important Finnish pine CSW dimensions to the UK in 1995–2000. The thickness classes in the sample are accurate. For example, 19 mm includes only thicknesses of 19 mm.**

| PINE CSW | YEARS | | | | | | | LINEAR REGRESSION | | |
|---|---|---|---|---|---|---|---|---|---|---|
| THICKNESS MM | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | Average | R-squared | Year *p*-value | Significant change |
| **19 mm** | 4.4% | 6.0% | 5.6% | 5.0% | 4.3% | 4.2% | 4.8% | 0.228 | 0.338 | No |
| **25 mm** | 16.5% | 16.4% | 15.6% | 15.6% | 15.6% | 16.6% | 16.0% | 0.042 | 0.698 | No |
| **32 mm** | 2.3% | 2.9% | 2.7% | 4.0% | 4.9% | 5.8% | 4.1% | 0.924 | 0.002 | Yes |
| **38 mm** | 15.5% | 15.6% | 15.0% | 14.1% | 13.8% | 14.9% | 14.7% | 0.463 | 0.137 | No |
| **50 mm** | 38.1% | 41.4% | 43.3% | 40.6% | 40.3% | 39.2% | 40.4% | 0.000 | 0.978 | No |
| **63 mm** | 12.3% | 8.7% | 8.9% | 9.9% | 8.8% | 7.6% | 9.2% | 0.542 | 0.095 | No |
| **75 mm** | 10.1% | 8.3% | 8.2% | 8.9% | 8.3% | 7.8% | 8.5% | 0.502 | 0.115 | No |
| **Other** | 0.8% | 0.7% | 0.7% | 1.9% | 4.0% | 3.9% | 2.3% | 0.813 | 0.014 | Yes |
| **SAMPLE, $m^3$** | 200,308 | 244,526 | 204,243 | 319,502 | 383,216 | 368,437 | 1,720,232 | | | |

## LENGTH APPROACH

**Table 101. Length approach ($m^3$). Sample, year 2000. Thicknesses 25 mm and under comprise sides boards, other are centre boards.**

| Length cm | All sawnwood in sample, $m^3$ | Side boards, $m^3$ | Centre boards, $m^3$ | Pine, $m^3$ | Spruce, $m^3$ | All sawnwood in sample, % | Side boards, % | Centre boards, % | Pine, % | Spruce, % |
|---|---|---|---|---|---|---|---|---|---|---|
| **180** | 36.23 | 34.82 | 1.41 | 36.18 | 0.05 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| **210** | 223.65 | 147.52 | 76.13 | 150.94 | 72.71 | 0.0% | 0.1% | 0.0% | 0.1% | 0.0% |
| **240** | 1,023.19 | 888.25 | 134.94 | 990.51 | 32.68 | 0.2% | 0.6% | 0.0% | 0.4% | 0.0% |
| **270** | 4,403.97 | 3,331.82 | 1,072.15 | 3,761.32 | 642.65 | 0.9% | 2.2% | 0.3% | 1.4% | 0.3% |
| **300** | 11,388.39 | 7,045.11 | 4,343.28 | 8,691.94 | 2,696.45 | 2.4% | 4.6% | 1.3% | 3.3% | 1.3% |
| **330** | 20,888.44 | 11,816.17 | 9,072.27 | 14,199.35 | 6,689.09 | 4.4% | 7.8% | 2.8% | 5.3% | 3.2% |
| **360** | 33,664.17 | 17,293.73 | 16,370.44 | 21,480.54 | 12,183.63 | 7.0% | 11.4% | 5.0% | 8.0% | 5.8% |
| **390** | 57,179.48 | 23,738.13 | 33,441.35 | 39,720.05 | 17,459.43 | 11.9% | 15.6% | 10.2% | 14.9% | 8.2% |
| **420** | 89,946.36 | 25,812.91 | 64,133.45 | 58,494.51 | 31,451.85 | 18.8% | 17.0% | 19.6% | 21.9% | 14.9% |
| **450** | 77,684.49 | 21,159.61 | 56,524.88 | 40,497.64 | 37,186.85 | 16.2% | 13.9% | 17.3% | 15.2% | 17.6% |
| **480** | 71,288.12 | 1,9704.3 | 51,583.82 | 35,166.85 | 36,121.27 | 14.9% | 13.0% | 15.8% | 13.2% | 17.1% |
| **510** | 52,723.38 | 10,134.95 | 42,588.43 | 21,895.35 | 30,828.03 | 11.0% | 6.7% | 13.0% | 8.2% | 14.6% |
| **540** | 49,168.38 | 8,683.16 | 40,485.22 | 22,109.34 | 27,059.04 | 10.3% | 5.7% | 12.4% | 8.3% | 12.8% |
| **570** | 4,722.96 | 1,339.37 | 3,383.59 | 0.26 | 4,722.7 | 1.0% | 0.9% | 1.0% | 0.0% | 2.2% |
| **600** | 4,511.49 | 968.35 | 3,543.14 | 0 | 4,511.49 | 0.9% | 0.6% | 1.1% | 0.0% | 2.1% |
| **$m^3$ total** | 478,852.7 | 152,098.2 | 326,754.5 | 267,194.8 | 211,657.9 | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

## CONNECTION BETWEEN END MOISTURE CONTENTS AND USER SEGMENTS

**Table 102. The end moisture content classes and user segments in 1995–2000. The MC classes are: 6–[6,7];8–]7,9];10–]9,11];12–]11,13];14–]13,15];16–]15,17];18–]17,19];20–]19,21];30–]21,30]; Green–]30,unlimited]. Green includes all end MC above 30% but not 30% (WPDB).**

| PINE | Segment | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| MC | Distribution | Furniture | Joinery | Planing | Strength Grading | Total with segment and MC information, $m^3$ | % | MC total, $m^3$ | % |
| 8 | 4% | 17% | 0% | 3% | 0% | 47,348 | 4.3% | 47,748 | 0.7% |
| 10 | 3% | 7% | 1% | 4% | 0% | 29,684 | 2.7% | 49,026 | 0.8% |
| 12 | 3% | 2% | 11% | 0% | 13% | 32,240 | 3.0% | 43,333 | 0.7% |
| 14 | 0% | 0% | 1% | 0% | 0% | 4,959 | 0.5% | 6,830 | 0.1% |
| 16 | 1% | 0% | 12% | 1% | 0% | 18,595 | 1.7% | 20,520 | 0.3% |
| 18 | 62% | 53% | 67% | 68% | 87% | 677,195 | 62.1% | 5,872,443 | 90.7% |
| 20 | 26% | 7% | 7% | 17% | 0% | 256,314 | 23.5% | 256,495 | 4.0% |
| 30 | 0% | 0% | 0% | 0% | 0% | 0 | 0.0% | 134 | 0.0% |
| Green | 2% | 13% | 0% | 6% | 0% | 23,529 | 2.2% | 178,262 | 2.8% |
| Total | 100% | 100% | 100% | 100% | 100% | 1,089,864 | 100% | 6,474,790 | 100% |
| Sample, $m^3$ | 932,919 | 46,059 | 58,063 | 47,857 | 4,965 | | | | |
| SPRUCE | Segment | | | | | | | | |
| MC | Distribution | Furniture | Joinery | Planing | Strength Grading | Total with segment and MC information, $m^3$ | | MC total, $m^3$ | % |
| 6 | 0% | 0% | 0% | 0% | 0% | 0 | 0.0% | 307 | 0.0% |
| 8 | 0% | 19% | 0% | 0% | 0% | 2,129 | 0.2% | 2,880 | 0.0% |
| 10 | 0% | 12% | 0% | 1% | 0% | 4,043 | 0.5% | 4,590 | 0.1% |
| 12 | 1% | 0% | 0% | 0% | 0% | 4,102 | 0.5% | 17,239 | 0.3% |
| 14 | 1% | 2% | 0% | 0% | 3% | 6,980 | 0.8% | 125,562 | 2.0% |
| 16 | 1% | 0% | 0% | 19% | 0% | 33,995 | 3.9% | 130,930 | 2.1% |
| 18 | 53% | 1% | 53% | 48% | 97% | 480,071 | 55.7% | 5,635,768 | 90.1% |
| 20 | 44% | 37% | 47% | 31% | 0% | 326,803 | 37.9% | 326,803 | 5.2% |
| Green | 0% | 29% | 0% | 0% | 0% | 4,039 | 0.5% | 8,676 | 0.1% |
| Other | 0% | 0% | 0% | 0% | 0% | 26 | 0.0% | 26 | 0.0% |
| Total | 100% | 100% | 100% | 100% | 100% | 862,187 | 100% | 6,252,780 | 100% |
| Sample, $m^3$ | 618,568 | 8,816 | 6,045 | 154,626 | 74,133 | | | | |

## QUALITY APPROACH – CSW QUALITY CLASS DISTRIBUTIONS

**Table 103. The quality class development for pine and spruce 1995–2000 and linear regression which indicates significant changes 1995–2000.**

| | | | | | | | | LINREG | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Quality class | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | R-squared | *p*-value | Significant change |
| Pine | U/S | 18% | 16% | 16% | 17% | 17% | 17% | 0.005 | 0.894 | No |
| | V | 36% | 36% | 36% | 33% | 31% | 30% | 0.882 | 0.005 | Yes |
| | VI | 31% | 31% | 29% | 27% | 26% | 26% | 0.922 | 0.002 | Yes |
| | SF | 3% | 5% | 7% | 11% | 12% | 11% | 0.877 | 0.006 | Yes |
| | OTHER | 13% | 12% | 11% | 13% | 14% | 15% | 0.463 | 0.137 | No |
| | $m^3$ | 760,714 | 1,040,388 | 1,408,887 | 2,128,101 | 2,227,353 | 2,306,641 | | | |
| | Quality class | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | | | |
| Spruce | U/S | 12% | 12% | 11% | 9% | 9% | 9% | 0.852 | 0.009 | Yes |
| | V | 15% | 16% | 15% | 11% | 11% | 11% | 0.754 | 0.025 | Yes |
| | VI | 18% | 20% | 17% | 14% | 14% | 14% | 0.731 | 0.030 | Yes |
| | SF | 43% | 40% | 41% | 51% | 51% | 48% | 0.536 | 0.098 | No |
| | OTHER | 12% | 12% | 16% | 14% | 16% | 19% | 0.785 | 0.019 | Yes |
| | $m^3$ | 1,023,669 | 992,421 | 1,288,083 | 2,019,541 | 2,058,318 | 1,968,162 | | | |

# APPENDIX 8: FORM FOR TESTING IMPORTANCE OF PROPOSITIONS

IMPORTANCE OF PROPOSITIONS DATE: _____________ NAME _______________________________________

I ask you kindly to evaluate the importance of proposition to the Finnish sawmilling industry with the scale: 1 = not important, 5 = very important. The evaluation areas are the following: 1) Profitability, 2) Efficiency and cost competitiveness, 3) Research and development, 4) Strategic development, 5) Sales promotion.

| No | Proposition | Profitability | Efficiency and cost competitiveness | Research and development | Strategic development | Sales promotion |
|---|---|---|---|---|---|---|
| **1** | Changes in sawnwood consumption can be found in Finland during the time periods between 1961 and 2002. It is possible that the CSW consumption in Finland in 1961–1996 was significantly different from the CSW consumption in the years 1997–2002 and 1961–2002. | | | | | |
| **2** | For sawnwood produced in Finland in 2000, sawnwood trade was concentrated on main dimensions. Simultaneously, the number of dimensions was large. The Pareto principle assumption and its 20–80 rule applied to sawnwood dimensions. | | | | | |
| **3** | The importance of large pine dimensions, as concerns sawnwood exported from Finland, decreased in the UK markets due to thickness approach between 1995 and 2000. | | | | | |
| **4** | For sawnwood delivered from Finland, dimensions had big differences specific to country and species of sawnwood between 1995 and 2000. The dimensions of pine and spruce differed by country. | | | | | |
| **5** | There was a market trend towards smaller batch sizes in sawnwood delivered from Finland between 1995 and 2000. | | | | | |
| **6** | Differences of length between pine and spruce sawnwood delivered from Finland were relatively small in 2000. | | | | | |
| **7** | The development of end moisture content and quality distribution remained rather stable for both pine and spruce in the Finnish sawmilling industry in the years 1995–2000. | | | | | |
| **8** | A logical sawnwood price system can be found for a set of sawnwood dimensions and species in Finland in 2000. In this system, a specific pine dimension of 50 x 150 mm (or close to this) set a basis price, and the prices of other dimensions could be derived from the basis price. Both pine and spruce pricing used the basis price system but it was more dominant with pine. | | | | | |
| **9** | In the predominant quality classes (U/S, V, VI), a small number of special lots was priced differently in Finland in 2000, with a few lower and higher price classes. | | | | | |
| **10** | Sawnwood supply distributions consisted primarily of the supply of standardised sawnwood in Finland in 2000. The number of special products was still small. Sawnwood supply can be estimated with both logistic and linear regression analyses. | | | | | |
| **11** | Sawnwood supply can be analysed by end moisture contents as well as batch sizes and prices. It is possible to create logistic and linear regression analyses for sawnwood supply distributions with the database approach. | | | | | |
| **12** | A country's geographical area can be assessed as a factor for coniferous sawnwood consumption in Europe in 1999. | | | | | |
| **13** | Sawmills had not completed their user segmenting strategies in Finland in the years 1998–2000. They used a user segment system in their sales but still divided most of their production into the distribution segment as a general segment instead of more specified joinery, furniture, planing and strength grading segments. | | | | | |

## HELSINKI UNIVERSITY OF TECHNOLOGY, LABORATORY OF WOOD TECHNOLOGY REPORTS

83. Koskela, K.
Koesuunnittelun perusmenetelmiä. 2000.

84. Pulkkinen, P., Hanhijärvi, A., Rohumaa, A., Sundman, S., Hyttinen, P., Sokka, K., Paajanen, T.
Viilun kuivaus – Puumateriaalin ja kuivausprosessin vaikutukset tuoteominaisuuksiin. 2000.

85. Pelkonen, T., Rohumaa, A., Honkanen, J., Pulkkinen, P., Kairi, M., Paajanen, T.
Liimausolosuhteiden vaikutus lamellihirren liimasauman ominaisuuksiin. 2001.

86. Honkanen, J., Kotilahti, T., Paajanen, T.
Puutuotteiden pinnankarheuden määrittäminen. 2001.

87. Pennanen, J.
Puun rakenteen, kosteuden ja lämpötilan vaikutus taipuisuuteen. Kokeellinen tutkimus. 2001.

88. Vuorilehto, J.
Size Control of Sawn Timber by Optical Means in Breakdown Saw Machines. 2001.

89. Vahtikari, K., Ala-Laurinaho, A., Paajanen, T.
Puutuoteteollisuuden työympäristökartoitus. 2001.

90. Paajanen, T., Kotilahti, T., Vahtikari, K., Hirvensalo, R.
PuuSuomi –toimintaohjelman arviointi 2003. 2004.

91. Kivi, O., Soljamo, K., Haapio, A., Paajanen, T.
Huonekalun ympäristöseloste. 2004.

92. Paajanen, T., Kotilahti, T., Hirvensalo, R.
Keski-Suomen puutuotealan toimialatyö – Toteutus ja työn suuntaus. 2004.

93. Holmijoki, O.
Sahateollisuus ja puutuoteteollisuuden toimintaympäristö – Mallintaminen ja esimerkkejä vuorovaikutusten analysoinnista. 2005.

94. Salovaara, J.
Puurakentamisen kilpailukyky kaupunkimaisessa pientalorakentamisessa. 2005.

95. Kairi, M.
Interaction of R&D and Business Development in the Wood Products Industry, Case Kerto®- Laminated Veneer Lumber (LVL). 2005.

96. Virtanen, J.
Analysing sawnwood supply distribution in Finnish sawmilling industry with database approach. 2005.

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