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AJS

Decision Support Tools for Wood Supply and Stock Control in a Modern Softwood Sawmill

Alexandre Macé
16e promotion FIF
2004-2008

Stage de Mars à Août 2008, réalisé au sein de A&J Scott Ltd.
Mémoire de fin d'étude, Septembre 2008

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FICHE SIGNALÉTIQUE D'UN TRAVAIL D'ÉLÈVE DE LA FIF

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Nom du responsable : Neil Campbell
Fonction : Forestry Director

Nom du correspondant ENGREF (pour un stage long) : Yves Ehrhart

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ABSTRACT

The UK's wood industries massively invested over the last twenty years and they are now extremely competitive. But competition rhymes with a good organisation. A & S cott, a sawmill processing homegrown timber, encounters difficulties to control the round wood stock level. This is mainly due to a lack of production planning and a poor data flow between production staff and timber procurement staff. This thesis presents an analysis of the wood supply chain of the sawmill, aiming to highlight its strengths and weaknesses. Then guidance support tools are proposed in order to improve the stock level management, helping the decision-makers in their choices.

RESUME

L'industrie du bois au Royaume Uni a investi de manière considérable durant les vingt dernières années, et est maintenant extrêmement compétitive. Mais la compétitivité requiert une bonne organisation. A&J Scott est une scierie transformant du bois produit localement. Cette compagnie rencontre des difficultés pour gérer son stock, principalement du fait du manque de communication interne entre la partie production et les service chargé de l'approvisionnement, et de l'absence de planification de la production. Dans un premier temps,ce mémoire présente une analyse de la chaîne d'approvisionnement en bois à la scierie, visant à mettre en évidence ses points forts et ses points faibles. Dans un second temps, des outils aidant les responsables dans leur choix pour la gestion du stock, sont proposés.

Acknowledgments

This placement gave me the opportunity to meet very nice and helpful people, within A&J Scott, who contribute to my project. That is why I would like to thank the whole staff I worked with. First of all, I would like to express my sincere gratitude to my supervisor and forestry Director, Neil Campbell, and to Geordie Nicholson for their usual happiness and for working in good spirit. Both largely helped me to understand many points composing my thesis. They also enabled me to spend time with other companies in the forest sector which gave me a wider point of view about forestry in the UK.

I am also grateful to the office staff of AJS, even I cannot mention all of them, and more particularly to Gail Cowan for dealing with the administrative process of my stay in England. Thanks to Richard Tate for the help he gave me working on Excel and for the nice time I spent chatting in his office. I would like to send him a few words: good luck in the future to deal with VBA!

Finally, I would like also to thank Yves Ehrhart for his support and for supervising my placement from the ENGREF in France. He found the time to visit me in England and helped with the directions chosen during my placement.

Alexandre Macé

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Table of abbreviations

AJS: A & J Scott Limited
DBH: diameter at breast height
FC: Forestry Commission
LTC: long-term contract
GVW: gross vehicle weight
RS: roadside
WGS: woodland grant scheme

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Introduction

Currently in the UK, the yearly timber production is only of about 9 millions cubic metres wood raw material equivalent. The home grown timber production represents about 20% of the country consumption. This is still a little percentage, though the forest industries have massively invested to increase their production capacity. Now that the UK wood processing sector is as modern as in the other European countries, it can handle the whole timber production. Professionals of the forest sector even already predict a shortage of home-grown timber in the future, processing capacity overtaking the production on the island. Although there is currently largely enough timber to supply the demand, wood industry already tries to anticipate the oncoming gap, steadying their wood supply chain

Timber procurement to sawmill is a complex process which comprises purchasing, then harvesting, extraction to road side, haulage to the mill, as well as management and planning of theses activities. Since quality of inbound sawlogs is decisive for the output of sawn timber, procurement is a basic strategic business process. Improving timber procurement management has become more and more important with the increasing competition to fulfil customer's demand. The sawmill must react very quickly to demand, so do raw timber supply to the sawmill. In order to meet customer's demand, it implies to produce a wide range of sawn products which are requested, but also products with non requested dimensions, with a lower attractiveness on the market. It is capital to supply the sawmill with the most adequate log specifications in order to reduce as much as possible the loss of raw material and so of money.

Improving timber supply management as well as reducing costs induce to process the timber from the stump to the yard is an important issue for the sawmill, especially with the current market situation which push up raw material prices and does not stop reducing sawmill's margin on the final product.

This thesis is the result of the placement at the end of the last year of the forest engineer education. My training period took place within a medium size sawmill in the county of Northumberland, England. The initial requirements of the company concerning my role were not clearly announced. Therefore the core of the undertaken study will be specified later in the paper. However, the initial wish of the company was that I was there as an external eye in order to analyse the wood supply function. What are the potential improvements that could be done in order to improve the wood supply chain management?

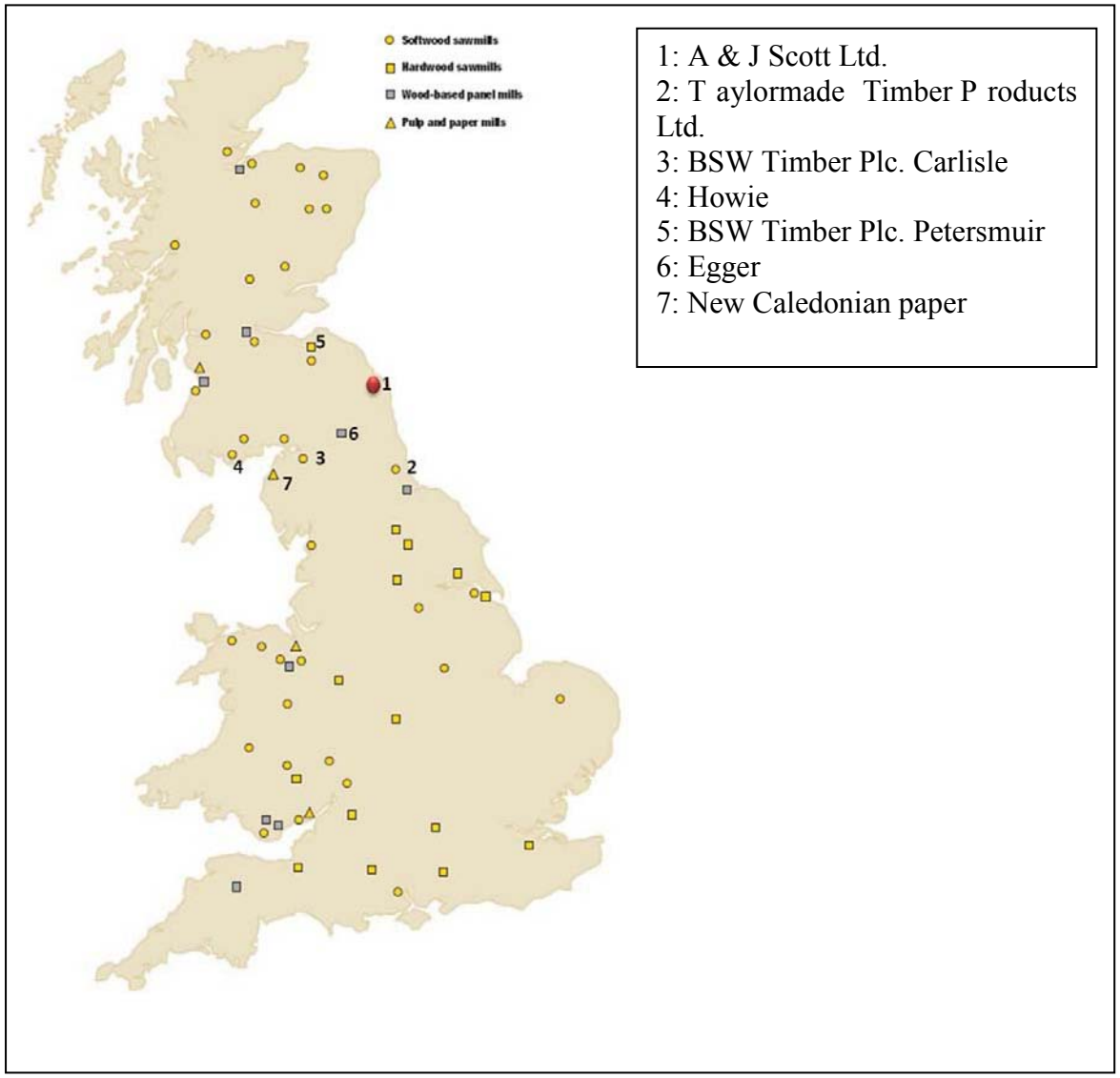
First, this thesis will present A & J Scott, the sawmill where the study was carried out during the placement period. It will gives information about the local context, some indications to better understand which market it targets and thus what are the products needed. This will be completed with a quick snap shot of the UK's wood industry and the current timber market situation, as well as forecasts. Then I will analyse the different steps composing the wood supply chain. This second part will try to highlight what the strengths and the weaknesses of the supply chain are. Finally, the last part of the thesis will be dedicated to study more in depth the control of the stock, which is one weak point emphasized in the previous part. Guidance support tools, aiming to simply the decision making task, will be presented and then the efficiency of theses tools will be discussed.

1. Background

1.1.A&J Scott

A & J Scott is a family owned home grown sawmill and timber merchant. It was founded in 1960 by the father of the present managing director, Andrew Scott. The company mainly buys and contract harvests spruce timber at assorted lengths to comply with different customer's demands; it is one of the country's most flexible timber merchants. About 90 % of the business is made up of softwood timber sawmilling, and the remaining 10 % are dedicated to deal hardwood timber, the activity on which the company was founded.

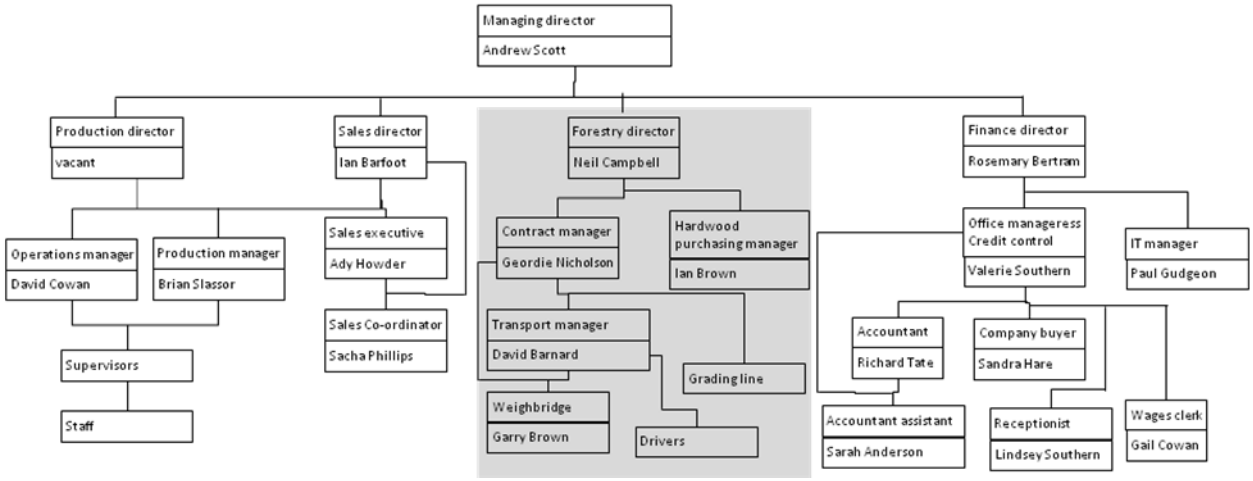
Figure 1: major forest products processing mills which use domestic timber. Forestry industry council. 1998



AJS is located in north of England in the county of Northumberland, close to the Scottish Borders. The forest activities weigh significantly in the local economy. Medium to big size wood industries are implanted next to the border as described on the map above where the principal wood processing industries have been highlighted. Some of them stand as A & J

Scott's customers for round wood, but they are of course possible competitors either for purchasing of raw material or for marketing the ended products.

Figure 2: AJS management tree. 2008.



1.1.1. The mill

Private UK-based round timber merchant A & J Scott has increased its sawn wood production by almost 100% over the past year having up graded and consolidated its Northumberland facilities. Until the last year, AJS had been processing about 1,000 t/week of raw material, through two separate mills: one for small-to-medium logs diameters, and one for medium-to-large logs diameters. In late 2005, the company decided to rationalise this system and contracted Danish sawmill supplier Broadbaek Co to provide a turn-key operation that could process the full range of logs Scott was buying in. Even though the mil is still in commissioning phase, it processes now about 2,500 t /week of round wood. Fully commissioned, the mill would be able to process over 3,000 t/week. This mill was called mill 7 because it is the seventh sawmill built by the Scott family.

Processing using only one mill for the all range of logs saves on overheads and the facility also operates now with just ten dedicated employees, which saves on labour.
The mill consists of a complete log grading facility with butt reducer, debarker, 3D scanning, and sorting into 40 bins. Mill 7 is designed to process logs the lengths of which ranges between 2.4 and 4.9 meters and diameters ranging from 16 cm-top to 50 cm-butt end diameter.
The mill components are as follows:
Log deck, step feeder model 5/5 with 20 strokes/minutes, 3D scanning from Microtec, and an automatic log rotation with the Rotolog R550
Saw line with BCO600 chipper canter machine, four BCO4-500 R3-L2 arbour saws with five moveable blade sets and merry-go-round cutting
Profiling with "S"-type singulator, board turner, BCO 800/60 edger, and set down operation
Tray sorting line with 10 trays for side boards from edging and profiling lines with single-piece BCO Speed Feeder
Layer cross-cutting and stacking line for side boards with a BCO 5/100 multi-heads cross-cutting saw, stacking facility with programmable hold back arms for brick stacking, without sticks, and eight automatic stick cassettes. Capacity for 120 boards or 12 layers/minute

Layer cross-cutting line and stacking line for main item with BCO 4/100 multi-heads cross-cutting saw, stacking facility with forks for brick stacking, without sticks, and nine automatic cassettes. Capacity for 120 boards or 12 layers/minute.

1.1.2. Products

AJS is positioned on the fencing market and produces boards of all range of dimensions depending on orders. There are no standard products; therefore that is not possible to detail what products are sawn by AJS.

AJS' products are labelled "FSC mixed sources — Product group from well-managed forests and other controlled sources". In the UK, FSC label is largely represented compared to PEFC; few woodland owners or management companies are certified PEFC, and therefore, retail stores' demands target mainly FSC certified products. Not buying 100 % of certified timber implies that AJS cannot display FSC pure label on its products and also that the non FSC-certified timber sources to be controlled in recognition of FSC policy.

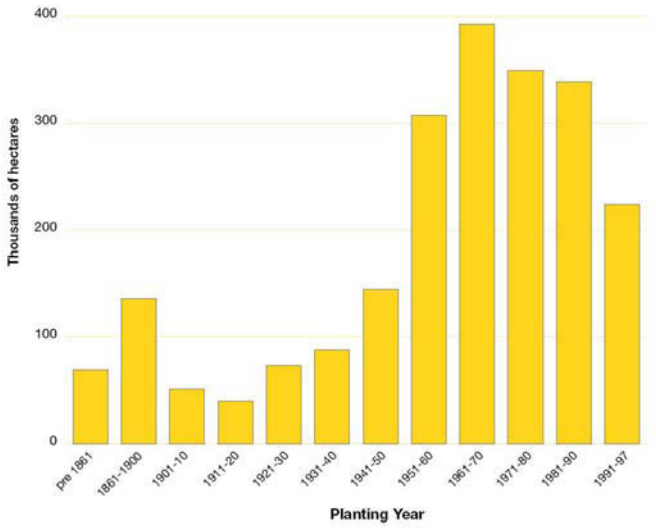
1.2.Some data about the UK's forest-wood industry

1.2.1. The UK forestry

The United Kingdom is a country where forestry industry is very young compared to other European countries. In fact, the UK forest cover was really poor by the end of the First World War with only 4 % of tree cover. In the past, most of the country was covered by natural forest but centuries of clearance for agriculture, warships, industry and housing depleted it to this level.

After the Second World War, the Forestry Commission (FC) sets up strict regulations for felling trees and created grant packages that largely contributed to raise the forest cover to almost 12 %. The total land area in the UK is 24.2 million of hectares and the forest area represents 2.8 million ha (FAO, 2005). Though, the UK remains one of the least forested countries in Europe. In comparison, French forest area is 15.5 million ha, which represents 28 % of the total area. The grant schemes developed by the Forestry Commission have been at there height from 1968 to 1988 and thus most of current forest in the UK were planted during this period.

Figure 3: distribution of the planted forests by age. Forestry industry Council. 1998.



Forest cover having risen thanks to massive planting helped by the woodland grant scheme (WGS), forest main function was production. Although timber production is the main target, professional foresters, both in public and private sector, aim now to integrate conservation aspects along wood production for the industry. This evolution tries to balance the various functions of the forest, providing wildlife habitats, and recreation areas for the public where possible. Besides multi-purpose forest management being personal initiative, the Forestry Commission ensures it, allocating government's grants and controlling the felling of trees. Since early planted areas are approaching to harvesting, opportunities are arising to redesign the UK's forests, using lessons learnt over the last 80 years of pioneering commercial forestry.

Though softwood forests represent about 58 % of the total wooded area, UK grown softwood production is 95 % of the wood production in this country (FC, 2007).

Table 1: main commercial tree species grown in Britain. — Forestry industry council of Great Britain

Species	Possible yield m^3/ha	Average yield m^3/ha/y	Age of thirst thinning	Age of felling	Approximate % forest area
Scots pine *Pinus sylvestris* L.	4 -14	9	21-40	55-75	13
Corsican pine *Pinus nigra var. maritime (Ait.) Melville.*	6-20	13	18-33	45-60	2
Lodgepole pine *Pinus contorta*	4-14	7	19-40	50-60	7
European larch *Larix decidua Mill.*	4-14	8	18-32	45-55	2
Japanese larch *Larix kaempferi Carr.*	4-16	9	14-26	45-55	2
Douglas fir *Pseudotsuga menziesii Franc.*	8-24	14	16-25	45-60	2
Norway spruce *Picea abies (L.) Karst.*	6-22	12	20-35	50-70	6
Sitka spruce *Picea sitchensis Carr.*	6-24	13	18-33	40-60	28

Main production-oriented forests have been planted by man over the last century mainly in Scotland and North of England. Therefore the biggest timber production as well as the major wood industries is concentrated there.

During the last twenty years, thinning was not a valuable operation for the woodland owners. Because the products coming out from a thinning are small round wood, there is almost one unique market: pulp industries and panels industries. At this time the price those industries bought the small round wood did not even cover the cost of the labour. Besides, the gain, in term of final product quality, was not enough substantial to make the thinning worth. Forest in Great Britain was seen more like an investment rather than a multifunctional site.

Therefore it is assumed that any operation done in the forest had to be lucrative, or at least generating a future gain

As a consequence, many of the stands which were planted during the planting period were not thinned. Besides, even more unusual, this was a common practice in the State's forest managed by the Forestry Commission. This is really remarkable in Kielder forest, managed by the FC, which is said to be the largest man-made forest in the UK. Depending on the area in this forest (there is always exception), it is common to find unthinned stands. Since the normal plantation density was two meters by three meters, it is obvious that those stands are constituted with high and thin stems, the volume per hectare of which sometimes reaches more than 700 m^3 / ha. Sitka spruce stands, the yield class of which may be quite important (Table 1), are harvested every 40 years, and it is frequent seeing clear fell of stands of which the average DBH is 25 cm, even less. Therefore, an important part of wood industries supply, like AJS, is with round wood from such stands, and so of lower quality.

The UK spruce market, both species considered, splits the wood produces in two different qualities: **green** logs and **red** logs. The quality grades used to sell timber is different and a lot less elaborated than the European grades based on several criterions. Actually, the round wood grading system consists in few criterions which are straightness and nodes. There used to be a clear definition of allowance for those criterions using quantifiable factors. However, the grading is not as strict as it used to be years ago. In the forest sector, as well as in the wood processing sector, grading is done by sight assessment. Anyway, given the quality of home grown timber, it does not need to be as accurate as it is required in hardwood, the difference of value being not that important. Green quality may be described as being logs which are straight, with not a strong taper, not too many branch, no big branches and no big opened nods.

1.3. The UK wood industry

In 2005 the UK used 44.6 million of cubic metres wood raw material equivalent (FC, 2006). The production in the country is only of 8.6 million cubic metres WRME. However The UK exports 16.5 million of cubic metres WRME. This gives an apparent consumption of 44.6 million cubic metres. A huge part of the timber used in the UK is imported and this makes it one of the largest European markets for the forest products.

The United Kingdom produces 11.4 million cubic metres overbark standing per year (FC, 2007). The timber production does not cease to increase and should reach a peak of around 16 million cubic metres in 2025 (Forestry industry council, 1998). The production will then decrease due to the decline of planting in the early 1970s. Home grown timber is now more abundant than ever. So the wood industry invested massively to modernise their processing chain and to increase their production capacity too. Since the middle of the 1980s, £1.6 billion has been invested in the processing sector. As a result the UK has now one of the most modern wood processing industries in Europe.

Sawmilling benefited from big investments as well as wood-based panels pulp and paper industries. British mills are now to the same standard as the ones in Scandinavia or North America. Sawmilling is the high value sector within the UK forest industry. Current forecasts indicate that sawn softwood self-sufficiency should reach 30% by 2025.

Table 2: estimated number of sawmills sawing British grown timber. 1997.

Production (sawn m3/y)	England	Wales	Scotland	GB Total
Under 1,000	132	16	47	195
1;000 to 9,999	105	13	35	153
10,000 to 24,999	10	0	9	19
Over 25,000	8	5	10	23
Total	255	34	101	390

1.4. Context of the study

The major investment realised by AJS to build this new mill aims to increase considerably the production. Fully commissioned, the mill should be able to product 1,500 sawn cubic metres per week, based on a 10 hour-per-day run, 5 days a week (30 sawn cubic meters per hour). However, after more than two years of commissioning, the mill has never reached such productivity. Regularly different breakdowns, of gravity more or less important, strike the mill and so strongly decrease the production. During the months of June and July 2008, an important breakdown happened and made the second chipper canter out of order. As a consequence, the mill processed only 1,500 tonnes per week Broadbaek, the sawmill designer company; send its engineers many times in order to reconfigure the weakest points but in vain; there is always new problems or old one which were supposed to be fixed. Those abnormal problems should be solved one day and then the mill would required a lot more round wood to feed it at its highest capacity.

Because of problems encountered by the mill, AJS' board thinks about setting up a double shift in order to fulfil current orders in due time. This alternative solution consists in two eight-hour shift which should permit to reach the production needed. Therefore there would be a greater need of round timber too, compared to the current situation. This double shift measure could be maintained later, even though the mill is fully commissioned, in order to take benefits of a favourable market. 2007 was a really good year for the company when sawn timber market was going up, however AJS did not have the opportunity to catch wider order book be cause of failure in the mill. That means that the need of round wood to be supplied would even be greater than 3,000 tonnes per week.

Those variations of round wood quantity needed cause obviously inherent difficulties to plan the wood supply at all scale. Because of likely breakdown, the supply may need to be knocked down suddenly; one day and the following day may require different amounts. Considering that the production may almost vary from the simple to the double, this assumes to get also a flexible wood supply chain and which would be extremely reactive.

2. AJS' timber procurement analysis

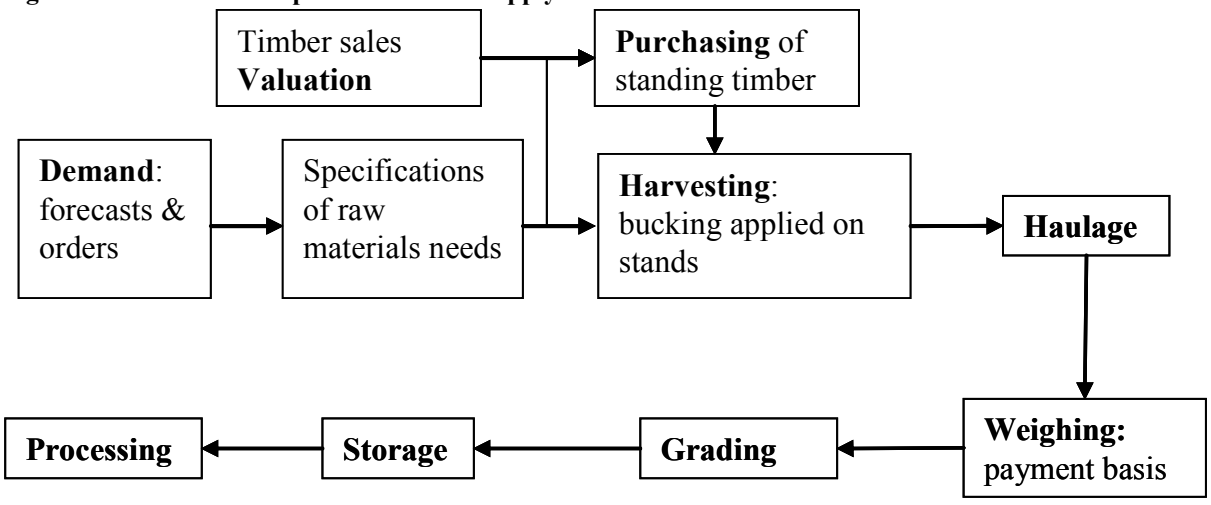
2.1. Methodology

The first stage of my placement within the AJS Company aimed to study the whole wood supply chain and its management. In order to do so, I undertook a timber procurement analysis. On the first hand, it helps to understand the wood supply chain, giving an overall view of AJS' activities and to discover how far the company is involved into its own wood supply. On the second hand, it highlights potential dysfunctions into the processing chain that would worth to be more deeply studied furthermore

I gathered as much as data as I could about wood procurement in order to cover all its steps (Figure 4): purchasing, harvesting, haulage, yard management and planning of the whole supply chain. Many medium size companies keep generally lots of data but not using them to analyse their business usefully. Collecting data assumes then to filter what is useful and what is not. The main data source was the weighbridge of the sawmill where all wagons go through; this is the check point for wood brought to the yard. This is a strategic point for the sawmill but also for all previous steps of the supply chain because in most of the cases timber is sold by weight, therefore woodlands owners are paid on the basis of the tonnage going through the weighbridge. Weighbridge files stock daily data of every load of round wood timber coming to the yard, which serve to establish invoices. This system is quite particular when compared to the usual practice in France. As a consequence, the UK's wood industries are not as limited as some abroad regarding their standing or roadside timber stock. This is a saving of money which can be invested somewhere else.

Those data were compiled from January 2006 to April 2008 in an Excel data base. A standardisation work was done. All the hardwood loads data were erased because they were not concerned by this study. Then data were cross-referenced with data concerning harvesting operations carried out by A&J Scott. This ended up with matching each load with a standing price and harvesting rate applied for standing timber jobs. This data base constitutes the source of figures and graphs presented in the following sections of the preliminary wood supply chain analysis.

Figure 4: the different steps of AJS' wood supply chain.



Besides the weighbridge data collected, other sources were used through this analysis. The software running the grading line stores daily data of the each batch. So it gives accurate information about all the graded logs (diameter, length, species, quantity and volume).

2.2. The timber supply staff

AJS' forestry director, Neil Campbell, is a former head forest manager, who has worked for almost all his carrier with Scottish woodlands, one of the main forest companies doing both management and timber harvesting and marketing. This detail takes its importance for public relation that can be decisive in this field, as well as for getting knowledge to approach and understand very well how timber market prices fluctuate.

Geordie Nicholson is the contract manager. He supervises the harvesting sequence, following the stocks level both in the yard and on each logging site. He manages daily the contractor lorries as well as the AJS' transport logistic along with David Barnard.

The complexity of timber procurement management is due to variables such as heterogeneous raw material, the fragmented supplier structure and the characteristics of those suppliers, the dependence on local supply, and the keen competition on raw material market (K. HELSTAD, 2006). Sawlog is a heterogeneous raw material which implies that it cannot be manufactured to a particular specification; instead it is possible to select logs with the most desirable range of properties. Sawmill's timber procurement department has to deal with timber quality and dimensions which both vary with procurement regions, forest stands an the individual tree. However, they can make decisions about species, lengths and diameters dimensions of the supplied sawlogs. The managerial task of timber procurement is to set choices that will optimise the incoming flow of sawlogs in a given market situation with respect of sawmill production technology, internal stocks and current stock of order (K. HELSTAD, 2006).

Principally, there are five origins for sawlogs to supply the sawmill as follows:

- timber harvested in sawmill's owned forest (which is quite marginal in most of the case),
- imports,
- delivered timber,
- roadside timber for sale,
- standing timber for sale

2.3. Timber purchasing

2.3.1. Timber sales system

FC sales are notified on a special website. The interested buyers have access to all lots for sale, both for standing timber and roadside timber.

Standing timber data available with the Forestry Commission are, among others, the average tree volume (with sometimes the tariff number selected to calculate it) for each compartment composing the sale, the average DBH, the sale method which is generally at weight, the total volume as well as the tonnage for the lot, the location with enclosed maps. The working period, generally around six months, and the sale date are also notified.

Roadside timber data are changed in consequence. The Forestry Commission make out the product qualities; green logs and red logs are separated before the sale.

When a sale interests AJS, the bid is to be submitted on the FC's website by electronic tender before the sale date. The bid system is a "simultaneous, first price and sealed bid" which means that all lots are presented for bidding at the same time, the winner pays his own bid price and the bids are confidential and cannot be viewed by anyone other than the bidder prior to closure and winners and winning prices are not published following the sale.

Actually, though neither the winner nor the winning price is published by the Forestry Commission, it is possible to gather some information about the sale for those who bid for it. After the allocation of the lot, the FC will not gave details if it is not asked, but the bidder can

call them and will know how many bidders participated at the sale, his rank among all of them, and get a rough idea of how far was his offer from the winning price (i.e. few pence or one pound or more). Therefore, it happens to AJS to bid for lots which do not interest them because there is enough wood to supply the mill at that time, in order to assess the current market. This may be quite handy for both standing timber and roadside timber sale.

Private sector sales, allocated by tender, are sent to the AJS forestry department. When forests managers, or sometimes directly forest owners, want to sell timber, they usually target all the wood industries and private sector forest companies getting harvesting activities, so that playing them off against each other and getting a competitive price for their lot. AJS forestry department is sent information about private sector sales which will occur for the following period, each company giving their own field-collected data as simple indication for customers. Those data accuracy and number can vary strongly depending on companies

Besides the tender sales, private sector forest companies propose also negotiated- price timber which is usually at lower price. In this case, the knowledge of an opportunity works through the relation network of the forestry department. Therefore, it is really important to strengthen the relationship between AJS and its suppliers in order to be notified when a sale is to happen. Somehow, a weak relationship would lead the company in losing a supplier which could be useful for next events.

2.3.2. Valuation of the lot to sale

After looking at in details all the new coupes to sale — it is necessary to follow the FC sales about every month — and determining which sales' products may interest the mill, a valuation of it is to be carried out.

To assess the offer that AJS can do for the lot, the forestry department goes on site to sample the stand. Trees are sampled for DBH so that to confirm or sap the stand data given by the forest manager. It is necessary to re-assess the DBH because depending on which forest manager did the sample, it can be very reliable as it can be wrong when the sample was too light. Top height as well as timber height are data collected on site. For some lots, it is sometimes necessary to differentiate species, diameter ranges, or thinned and unthinned stands.

Data are processed to get the average tree's DBH which is used to evaluate the average tree's volume. References for timber measurement in the UK are available in the Forestry Commission booklet N° 39 entitled *Forest mensuration handbook*. The average tree's volume is calculated with two different methods as follows:
Volume table: the top height is used to determine the tariff number to use, then looking up in the volume table matching the tariff number with one input data (DBH), the average tree volume is obtained.

The assessment of volume from length and taper:

Taper: δ
DBH: D
Mid-diameter: Dm
H: timber height

$$\delta = \frac{(D - Dm)}{\left(\frac{H}{2} - 1.3\right)}$$

$$V = \frac{\pi}{4} \times H \times \left[D - \delta \times \left(\frac{H}{2} - 1.3 \right) \right]^2$$

The taper selected depends on the stands; for Sitka and Norway spruce it varies between 1:90 and 1:110 generally, which correspond for the last one to a drop-off of 1cm on the diameter in 1.10 m length. When it is possible, the taper is checked on site on felled tree, often windblown.

A breakdown is done for the lot, or for each subpart of the lot when differences are expected, so that to get the percentage of the total volume that each product represents. The different products considered, describe in the Table 3, directly influence on the stand costing. Buying standing timber assumes that the assessment of lots is the most accurate possible, especially for the percentage of products that will be marketed because, being the lowest value products, they are the decisive elements to make an offer. The green and red sawlogs make up the material cut in the sawmill and so are retrieved to yard. Round fencing materials, bars and some pallet logs (small diameter, short length) are marketed to other wood industries. These latter being the lowest value products, they are the decisive elements to make an offer.

Table 3: specifications of the products from the breakdown.

Category			Top diameter (max)	Top diameter (min)	AJS material used	Indicative average delivered price (April 2008)
Sawlogs	Green logs	Up to 16 cm	NA	16 cm	Yes	£43/t
	Red logs	sleepers	NA	30 cm	Yes	£40/t
		Up to 22 cm	NA	22 cm	Yes	£40/t
		Up to 16 cm	22 cm	16 cm	Yes	£40/t
	Bars	1.9 m length	19 cm	14 cm	No	£30/t
Round fencing materials	Jump poles	3 m length	15 cm	10 cm	No	£36/t
	Stakes (or posts)	1.7 m length	12 cm	7.5 cm	No	£36/t
Small round wood	Chipwood or pulpwood	Between 2.7 and 3 m length	NA	NA	No	£24/t

Once the assessment of the quality and the breakdown is done, the forestry department needs to make an offer for the lot. The calculation of the offer is done as follows:

$$Offer = \frac{\sum_{i=1}^{n} (GP_i \times 0.95 - LR_i - HR_i) \times W_i}{\sum_{i=1}^{n} W_i}$$

With:

n: number of different products in the breakdown;
GP_i: gross sale price for the product i (delivered price not including VAT);
LR_i: logging rate for the product i;
HR_i: haulage rate for the product i;
W_i: weigh for the product i.

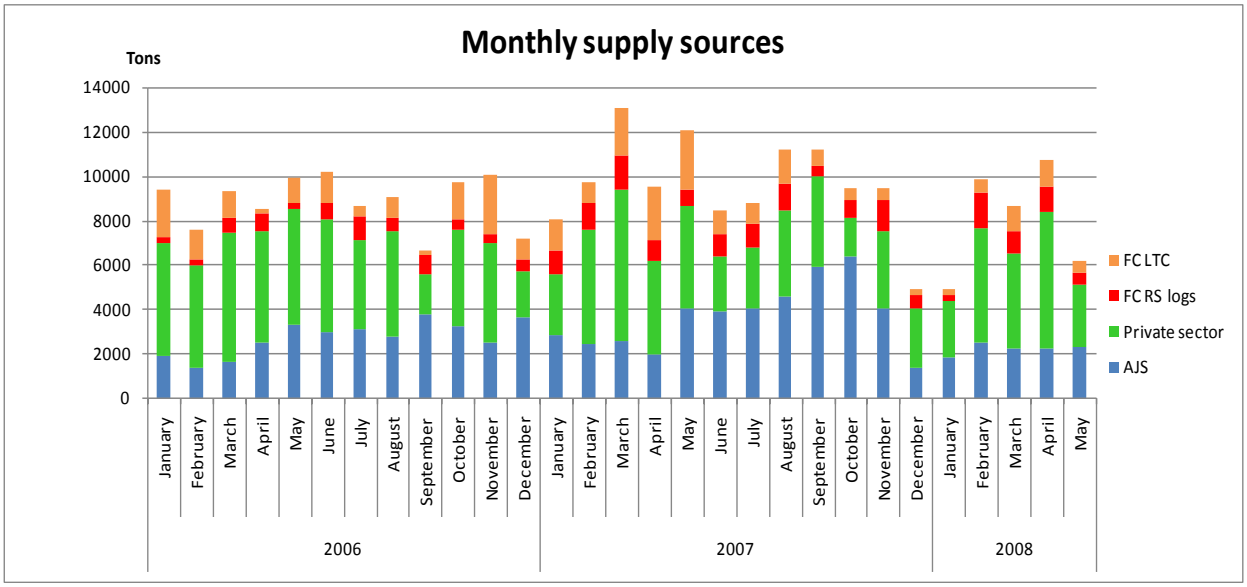
Generally the logging rate is the same for all the products but in some case chipwood is paid differently. The factor of 0.95 applied to the gross price corresponds to the 5% margin retained by the forestry department. The margin may slightly vary depending on the job characteristics. It is supposed to cover the fees inherent to the monitoring of the harvesting sequence.

2.3.3. AJS' wood suppliers

The sawmill buys its round wood from three sources: private sector forestry companies, the UK Forestry Commission (FC), and crops harvested by itself from both private and FC stands. The latter provides Scott's with the flexibility to respond any supply shortfall or to produce any unusual sizes demanded by the mill.

In average along 2007 year, AJS bought 38 % of its raw material to private sector companies, 24% to the FC and 38 % of crops harvested by itself. Purchasing timber from as many sources as possible helps to reduce the risk should it encounter problems with one of the supply sources.

Figure 5: repartition of different round wood supply sources.



Sale methods vary according to sources, but are either tender, or negotiation. Auction had been used for FC standing timber sales, but is not used any more, preferring tenders.

Allocation modes vary also depending on sources of supply. AJS buys as well roadside timber from private sector forestry companies and FC, as delivered-to-the-mill timber. Timber harvested by AJS itself is bought standing. Table 4 sums up the different way round wood can be bought to supply the mill.

AJS has got an agreement with the Forestry Commission called long-term contract (LTC). This contract ensures AJS to be sold determinate weight of raw material each year. LTC are signed for a one-year period (April to March) and the prices for all categories of raw materials are agreed at this moment so that they follow the market prices. The sawmill's current LTC is for 15,000 t/year in total. Companies getting a LTC with the Forestry Commission, like AJS, have got a really good advantage on the others, because prices agreed in contracts are much cheaper than the ones generally obtained then tenders.

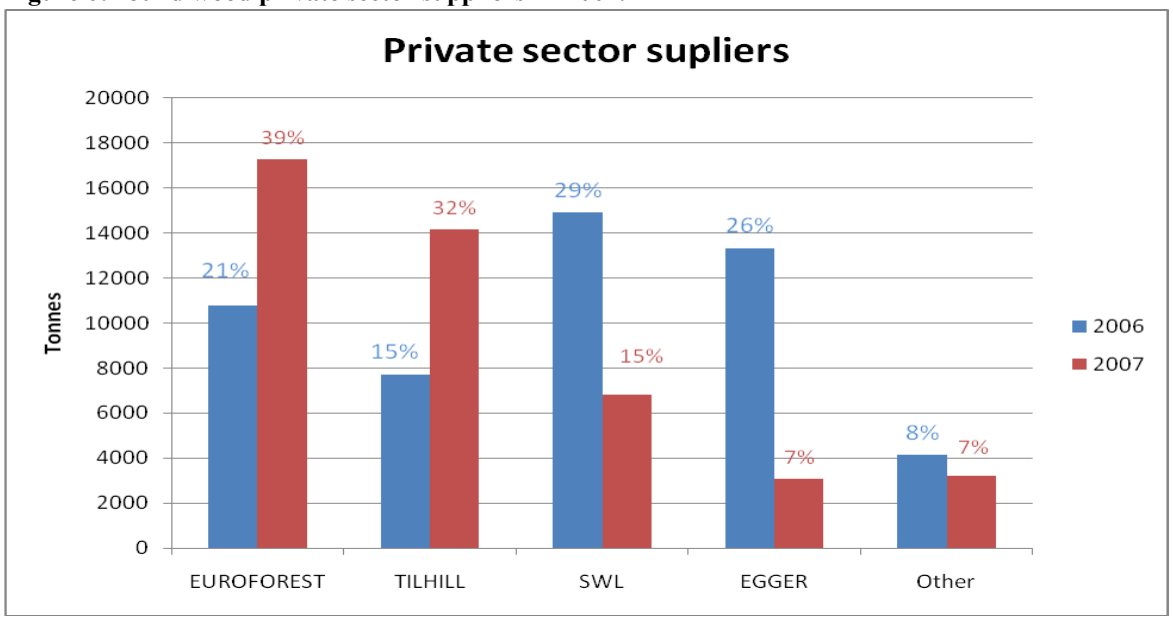
Table 4: the different sources of round wood supply for AJS.

Allocation mode	Supplier	Sale mode	Harvesting	Haulage
standing	FC	Tender	AJS	AJS
	Private sector	Tender	Supplier	AJS
Roadside	FC	Tender	Supplier	AJS
	Private sector	Negotiation	Supplier	AJS
Delivered to the mill	FC	tender	Supplier	Supplier
LTC	FC	negotiation	Supplier	AJS

AJS is working with over thirty different round wood private sector suppliers, but the fourth main suppliers weigh for more than 90 % of private sector supplied timber. Those main suppliers are Euroforest (39 %), Tilhill (31 %), Scottish Woodlands Limited (15 %) and Egger (7 %).

Euroforest Ltd is a timber merchant company operating on all the UK's territory. Tilhill forestry, which belongs to UPM Kymmene group and Scottish Woodlands Limited are forest manager and timber merchant companies. Both are the biggest UK's woodlands managers

Figure 6: round wood private sector suppliers — 2007.



Even though no official declaration was made by the Forestry Commission, LTCs are likely to end by the end of 2011; FC wants more competition to be played, thus, the whole timbers

will be sold by tender. Historically, long term contract were set up in 1998. The Forestry Commission evaluates the yearly timber production in the UK. This evaluation was done considering that a lot of timber would arrive on the market, including timber from the islands in Scotland. FC decided so to sell 70% of its timber through long term contracts. But the facts are those timbers are far too expensive to harvest. Consequently, a huge quantity of woodlands are managed more conservation and amenity oriented. Besides, the development and the massive investments of the wood industry, as described in the paragraph 2.3, has largely increase the timber procesing capacity in the country. The Forestry Commission plans now to reduce the quantity of timber sold by LTC little by little.

Euroforest and Tilhill have a very special status with the Forestry Commission compared with the remaining wood industries or forestry companies. They have got a LTC to harvest standing timber. In some way they market timber of their LTC on behalf of the Forestry Commission, taking a commission on the sale. Standing timber price depends on who is buying it, which means that the FC could be paid on two different price bases for timber coming from the same lot if the sawlogs are sold to two or more customers. For the moment, buying wood from those big harvesting company is very cost-interesting. The LTC for standing timber should be one of the first thing knocked back by the FC. This will have important consequences on the timber market, especially for Euroforest. Indeed, the latter company has only its harvesting activities not like Tilhill which manages woodlands too. Thereby, with the end of standing timber LTC, Euroforest will face big price competition on the open market and it would struggle beating offers from wood industries. Wood processing companies can compensate a higher raw material price with the sale of their ended products which cannot be done by a company like Euroforest. If it happens so, then AJS' supply sources are likely to change. How should AJS orientate its sourcing, to prepare this change? The answer will be detailed in further paragraph.

2.4. Harvesting

AJS deals with harvesting operations for the standing timber contracts it buys (currently circa 40% of the total). The company used to get its own forestry machinery and this activity almost kept occupied a dozen of people at itself. Harvesting activity was given up in the company about twelve years ago. The decreasing opportunities of buying hardwood were hugely responsible. But the massive mechanisation in the softwood harvesting has led the company to do some choices, giving up its own forestry machinery and its wood cutters.

Nowadays, AJS buys standing timber parcels and harvest them through contractors. Those ones may also use subcontractors when their own staff and machines are all busy elsewhere. Thus AJS has always contracted the same harvesting companies since some years.

Table 5: AJS' main harvesting contractors. 2007.

Contractor's name	Quantity	Overall %
John Blacklock	18,917 tonnes	43
Ronnie MacVicar	13,608 tonnes	31
Dick Brothers	6,701 tonnes	15
O'Kane	2,269 tonnes	5
E & T Timber Harvesting	1,024 tonnes	2
Other contractors	1,808 tonnes	4

As shown in the table above, five major harvesting contractors are used to work with AJS. Those figures come from 2007 and may slightly change from one year to the next one. Actually, some contractors may be more or less job-seeking. In general, those contractors and their staff entirely satisfy the AJS' forestry department. So the company keeps on working with those ones and strengthening a trustful relationship. It tries to give them regular work to each of these depending on their availability. Of course the size of the harvesting contractor companies are different which explains a part of the difference of quantity worked over the year. Besides, some are more specialised in cutting small parcels with hardwood inside or big logs which need a hand cutter. In the Table 5 the field named "other contractors" group eight of them whom some are only hand cutters working mainly in hardwood.

AJS' own harvesting operations enable flexibility for the company in term of wood supply. Though the contract manager spends much time to watch over the harvesting sequence, AJS' own jobs produce log specifications other do not. Indeed, the private sector and the Forestry Commission only produce usual length that can be marketed elsewhere in case one of their customers desists, whereas it is possible to produce less common length such as 3.2 and 3.5. Besides, contracting directly the harvesting allows changing the specification instructions given to the operator relatively quickly. Whether the mill suddenly needs so many tonnes of one product which was not produce among the current active contracts, a simple phone call make the harvester operator change of specification. If the forwarder is already on site, the first load can come out on roadside about two or three days after. Then the logs are ready to be hauled and can be brought to the yard the very same day or the next one.

2.5. Haulage

2.5.1. Legislation

Timber haulage lorries mainly used in the UK are articulated lorries with six axles in total; three axles for the lorry as well as for the trailer. According to the UK law for loading vehicles, the gross vehicle weight (GVW) permitted for this type of truck is 44 tonnes, but under certain conditions: The second main timber haulage lorry type is a rigid lorry and draw bar with six axles in total. The conditions and the GWV are detailed in the table below for both lorry types.

Timber haulage in the UK is one of the higher in comparison with its main competitors (Scandinavian countries). The main reasons of that are higher fuel prices, heavier tax burden and lower gross vehicles weights. In Finland GVW authorised is 60 tonnes which is 45% more than the one in Great Britain. Thus the average payload is 41 tonnes when it is only about 26 tonnes in the UK. In same conditions for mileage, e.g. 65 -mile distance, road transportation cost 6.43 £/t whilst it is 3.43 £/t in Finland (HÖGNÄS, 2001).

Table 6: legislation for usual timber lorries.

Lorry type	GVW	Conditions	Shape
5 or 6 axles artic.	44 tonnes Conditions 1) and 2)	1) If the driving axles, if it is not a steering axle, has twin tyres and road friendly suspension, or each driving axle is fitted with twin tyres and the maximum weight for each axle does not exceed 9500kg; 2) Distance between the rear axle of the motor vehicle and the front axle of the trailer is not less than 3 m. 2) If the trailer is being used for combined transport.	
6 axles draw-bar	44 tonnes Conditions 1), 2) and 3)		

2.5.2. Lorry fleet

AJS gets its own timber haulage lorry fleet which is composed currently of seven lorries described in the following table.

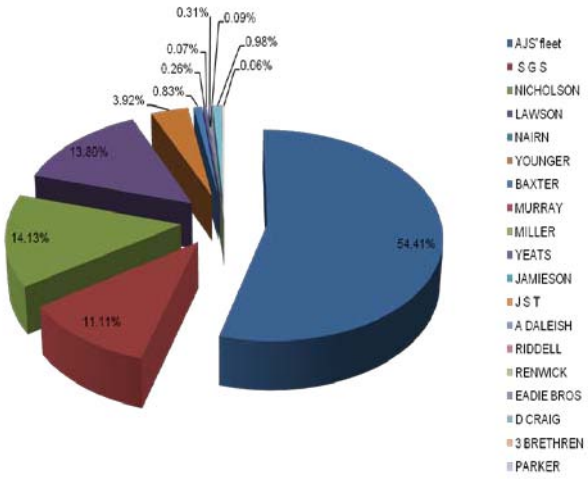
Table 7: AJS' current lorry fleet

Registration	Type	Crane model	Tare weight (tonnes)	GVW (tonnes)	Maximum payload (tonnes)
M22 OAK	Draw bar combination	Loglift 96s	17.7	44	26.3
M33 OAK	Draw-bar combination	Loglift 96s	17.7	44	26.3
R100 OAK	Articulated	Loglift 240	18.8	38	19.2
Y100 OAK	Articulated	Loglift 96s	19.8	44	24.2
X600 OAK	Articulated	Loglift 96s	14.8	44	29.2
S77 OAK	Articulated	Loglift 96s	18.1	44	25.9
SC07 OAK	Draw bar combination	Epsilon 110 L	18.62	44	25.4

AJS' lorry fleet works almost exclusively for the company. It hauls roadside timber to the yard coming from AJS' harvesting operations and from FC. However, lorries may be used sometimes to haul timber for some estates or even other product. This is necessary keeping lorry drivers busy even though there is no need to supply the mill with more wood In the case of roadside timber coming from AJS' standing timber contracts, AJS haulers operate also delivering marketed products (e.g. round fencing material or chipwood) to AJS' round wood customers.

AJS' fleet ensures until now 54.4% of timber haulage managed directly by the company, that is to say excluding haulage for delivered timber from private sector. On top of that, four others haulage contractors deliver almost all the remainder. AJS' trucks, S.G.S, Nicholson, Lawson, Nairn, and Younger weigh for 93% overall. These figures shown on the pie chart are from 2007. This year, Nicholson does not work anymore and another contractor has taken its place: Yeats. This company developed timber haulage exclusively with flat bed trailers which allow it to get heavier loads due to the lack of loading crane. Although the drivers must wait to the forwarder to get their truck loaded, this system seems to work perfectly and be efficient. Flat bed transportation has got another advantage when timber haulage comes to lack, when times are hard, contractors may then diversify easily the kind of merchandise they haul.

Figure 7: AJS' timber haulage breakdown. 2007.



AJS also owns three flat bed trailers that can be towed by two of their trucks. Those are dropped on harvesting sites and loaded as and when the forwarder comes to the stacking area; instead of unloading timber onto the pile it is done directly on the trailer. Thus the drivers just need to bring there a second empty flat bed and haul the loaded one to its destination. That is handy for the company to own flat beds to haul also other products than round wood. During my placement, in June, the mill encountered an important breakdown causing damage to the second chipper canter in the mill 7. Due to the impossibility to fix it for a month, the mill was only able to saw logs of which top diameter was greater than 20 cm to make a double pass on the first chipper worth. Besides the constraints for top diameter, the mill drastically decreases the production; the latter dropped from 1,200 to 750 swan cubic meters per week. Of course this combines with over stocking in the yard has a direct influence on the weekly supply of round wood; instead of bringing 2,700 tonnes to the yard it was only necessary to supply 1,500 tonnes per week even less sometimes. Then it is hard keeping busy AJS lorry drivers with at least two loads a day to try keeping this activity profitable. The company had to cut off supply with haulage contractors, working almost exclusively for them in normal times, for a week or so. When keeping a whole fleet of trucks creates difficulties, management of the team becomes truly a brainteaser.

2.5.3. Haulage management

As notified previously in the subpart about the wood supply staff, Geordie Nicholson manages haulage daily, giving to each haulers the sites where to go, the destination (e.g.. AJS' yard) as well as the specifications of the raw materials (e.g.. 3.7 m length spruce logs). Even though it takes a lot of time, managing daily timber haulage daily allows more flexibility for the raw materials retrieved to the yard to match with the specifications needed by the mill to fulfil orders of the day. Of course managing timber haulage as it is done assumes that orders to fulfil are known by Geordie Nicholson but more important that production planning is known as well.

Wagons arriving to the yard are generally unloaded onto the grading line so that the logs are directly graded. When the grading line feeder is full, the alternative is to unload the wagons in the ungraded yard. This is avoided as much as possible because this generates more handling cost. Graded stock is located next to the mill whereas ungraded stock is further. Moving timber from the ungraded stock to the grading line needs many round trips with the machines. Therefore, sawlogs specifications which are brought to the yard are as much as possible logs which will be saw in the next days. This is necessary to target the specifications needed in order not to increase the yard stock of ungraded.

From an accountancy point of view, the lorry fleet is not differentiated inside the company which means that it does not work like a normal haulage contractor company. So their main goal is not to make benefits. Two consequences result of that. First, this may slightly biased the haulage cost used when making an offer to buy round wood. Secondly, not considering enough seriously the need to make money results with a really poor benefit. The real efficiency of the lorry fleet is not reveal through accountancy figures. Taking the lorry fleet trips done in 2007 allows getting the amount of virtual money they would win, based on haulage rate applied for each trip. Once deducting the drivers' salary and fixed costs associated, it results with the figures shown in the table below.

Table 8: lorry fleet profits. 2007.

Registration	Profits (£)
M22 OAK	19544
M33 OAK	15669
NK53 DWV	4540
R100 OAK	6153
S77 OAK	-303
X600OAK	3265
Y100 OAK	1332
Total	50198

2.5.4. Weight policy

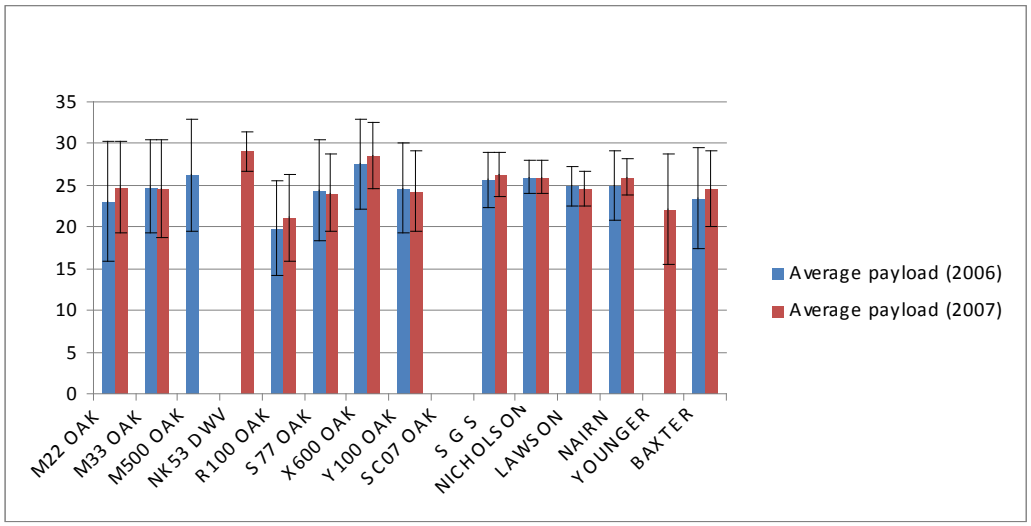
Gross vehicle weight has always been an issue in timber haulage. In the UK, main actors concerned by timber haulage gathered and produced a code of practice to set up the frame of timber road transportation. Timber haulage rate being extremely high in the UK, and it keeps on increasing with fuel price raise, it is a common fact that trucks are overloaded in order to maximise each run. However, overloading generate severe damages to normal roads as well as to forest roads, as shown in the following table.

Table 9: relationship of damaging effects to GVW. — Haulage of Round Timber, Code of Practice.

GVW (tonnes)	Damaging effects increase (%)
44	0
46	22
48	47
50	76
52	110
54	149

In the North of England and Scotland it does not happen very often getting GVW control for timber haulage truck, mainly due to short to medium transportation distances of which an important part is realised on secondary road network from the forest to a major road leading towards the wood processing site. So, whatever it is said, there is not the same need to be careful when the fear of the overweight fine is small. There is generally no doubt that the most cost-efficiency way to haul raw material is to maximise the payload to its legal limit. Beardsell (1986) stated that there is a substantial net gain in average payload by eliminating both overloading and underloading.

Figure 8: average payload of timber delivery.



The Figure 7 shows the average payload for the all AJS' lorry fleet as well as for their main haulage contractors. The error bars represents the standard deviation of the payloads and give a good picture of overloading and underloading. Comparing AJS' lorries payloads with the ones of their contractors shows a bigger variation on AJS' loads. This is explained by the dysfunction of the weighing device on some lorries. In order to maximise the average payload, it is necessary to fix on-board electronic scale and that AJS' lorry drivers pay more attention to the weigh of their load.

Monitoring the payload of their lorries will become more and more important now that the Forestry Commission decided to give sanction for overloading. The FC will monitor the payloads for each delivery, written on the haulage ticket it receives. The penalties will be an interdiction of loading for a period depending on the overloading. Consequently, AJS needs to set up a weigh policy, intern to the company, in order to avoid those future sanctions.

2.6. Grading line

Once timber lorries arrive to sawmill, they must be weighed on the weighbridge. This is the check point for every load coming to (e.g. round wood) or leaving (e.g. sawn wood) the yard. After that step, timber is unloaded from the wagon and two possibilities are then offered:
Either timber load specification matches the grading group used at this moment on the grading line and it is unload onto the grading line feeder,
Or it does not and then it is unloaded in another part of the log yard to be added to the so called ungraded stock.

The grading is often considered as out of the timber procurement process which ends up when timber is received, i.e. when wagons go through the weighbridge. However this part is treated in this paper like the last step of the procurement. Indeed, the upstream wood supply chain includes stock management.

The grading line works with only one grading group at once which allows it to grade one or two length specifications. Timber groups (Appendix 1: grading groups characteristics.) are constituted with following length specifications when there are two lengths graded at the same time. Besides, one or two length specifications can be part of the group bordering the main graded lengths on their extremity (up and down). On the grading line, the logs are on a chain feeder, and then the operator turns them back if it is necessary in order to present the butt towards the butt reducer. Then the logs go through the 3D scanner and the debarker. The scan sorts them out in the bins according to their length and their top diameter. The logs which are crooked or got a stronger taper than the limit are rejected as well as the logs the top diameter of which is less than 14 cm or the butt diameter greater than 50 cm, and the shorter or longer lengths. Rejected logs are stocked in the ungraded logs yard. Over sized logs which have a butt diameter greater than 50 cm and the ones top diameter of which is greater than 30 cm but which are tapered or crooked are generally processed through the band mill next to mill 7. For the remainder of rejected logs, they are until no stocked and should be soon sawn with a new saw which is being built.

As an example, the group called group 4 is used to grade logs which are 4.1 m length; 4.1 is the name given to logs issued from this group. There length must be included between 4.05 and 4.24 metres. The final product length is 4.0 m. When grading line works with the group 4, then it grades 4.1 m length but logs belonging to 3.7 m length specifications and 4.3 m length specifications are graded too but just partially (half graded); logs from those bordering specifications are all directed to same bin (one for each specification). Inside a length grading specification, the logs are graded by diameter range grouping them in a two-centimetre difference top diameter bin. The logs which are only half graded are then stock back in the ungraded logs yard on the pile matching their real length specification.

After being graded, logs are stacked per bin number and the whole constitutes the graded stock, i.e. sawlogs ready to go through the mill.

2.7. Timber yard stock

Once round timber is delivered to the mill, it can either be directly graded or stocked in the ungraded yard. Consequently, the mill has available two sources of logs directly on site: one ready to be utilised and the other needing to be graded. Both make up the timber yard stock. Being totally customer oriented, AJS needs to get the round wood specifications needed in stock to fulfil the orders. Because logs are graded by length and by diameter it implies to get quite a massive stock in order to ensure flexibility as great as possible. However, it is important not to get a timber yard stock too huge and with too many currently unused length.

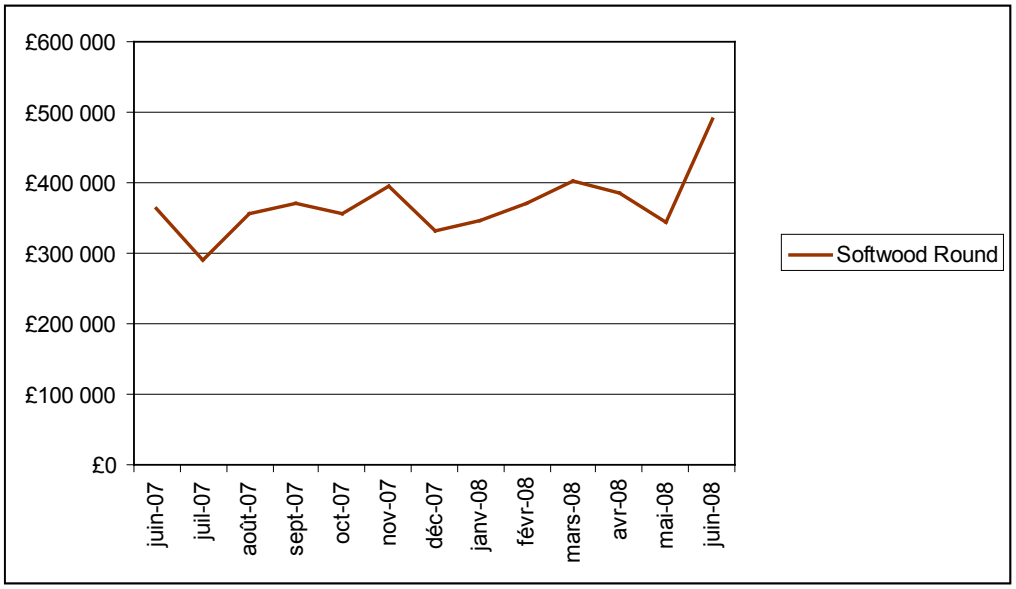
Currently the timber yard stock is taking every last day of the month. Estimation of the tonnage is not something done really accurately but it is always undertaken the same way. This is what matter in order to compare the figure of one month to the previous one. This operation is usually realised by two people walking down the stock piles and it takes roughly two hours. It consists in measuring the length of each of them (by foot), multiplied it by the height of the stack which is estimated and multiplied it by the length of the logs. Then a conversion factor of 0.5 is applied to the total volume of the pile in order to consider the air

space and to convert the cubic metres into tonnes. The 0.5 conversion factor is lower than the one recommended in the measurement handbook of the Forestry Commission which is between 0.65 and 0.7. However, the field experience shows that it works better with a conversion factor of 0.5 than with a bigger one. For the moment, stock taking unit used is the tonne because it is bought so.

The second step of the stock inventory is then the data processing. It takes about half an hour to do it. Regarding products differentiated when stock taking, length specifications of course are considered and diameter categories too. For the latter, only three ranges are made out: 16 to 22 cm top, 22 to 30 cm top and 30 cm and greater. Diameter ranges as used with the grading line are not used for two reasons. Firstly, timber arriving to the mill is generally classified with those categories and secondly an interest of the stock taking is to get its value. Round wood being paid by tonne, it had been decided to keep with it instead of finding the most adequate conversion factor cubic metre/tonne which may hugely vary depending on the season, the species and the location.

The stock value is an important element to consider financially. Indeed, once the timber is stocked in the yard, it has been paid and represents so a massive amount of money tied up. The figure below shows how important the stock value can be, representing the figures over one year. Only round softwood has been graphed on it, excluding round hardwood owned by the company for its timber merchant activity. As well, ended products are not shown. Round softwood represents 40 % in average of the total value of the stock and stays relatively constant (39% for the sawn wood and 21% for the round hardwood).

Figure 9: yard stock value for round softwood. 2008.



Depending on the month, the stock value oscillates between £300,000 and £400,000. The peak, reached in June 2008, is due to special events described further. Financially, this is far too much. There has been since a long time a need to reduce the total stock value and of course the round softwood stock value too. Besides the fact that stock represents a diminution of cash flow for the company, the insurance adds another constraint. AJS' insurance contract stipulates that the total stock value covered is £750,000. And yet, the average total stock value, over June 2007 to June 2008, has been £917,620. Thereby, it is necessary to knock back the stock value of 18%. Reflected in the round softwood stock, this means a decrease of

at least 7%. This figure is the minimum target in order to get back under £750,000 This is considering the distribution of the stock and the fact that not only round softwood stock would be decreased but also the other products (7% for the sawn wood and 4% for the round hardwood).

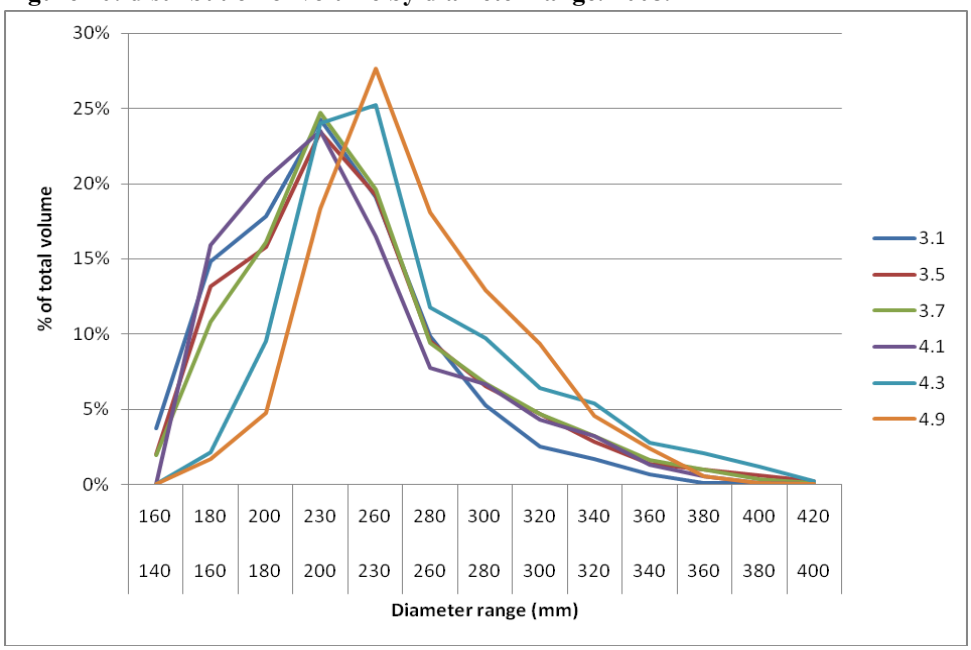
Actually this reasoning is hardly applicable in this case. Even though AJS cut timber on order, there is always the matter of the side boards. When those ones are not sizes ordered by some customers, then they need to be stock until they will. Regarding the round hardwood stock, the way this business works does not allow the same theory. Hardwood need to be bought, stocked and then it is necessary to attract the customers potentially interested. So it is not really possible to reduce its stock value.

2.7.1. Log specifications and diameters available in the yard

First of all, the production staffs complain sometimes that they get short of a certain length. In the best case the operator only swaps for the next bigger diameter range but of same length. Thus there is lower recovery because the quantity of material chipped in the first canter becomes more important.

The operator may have to change of bin number more often when using particular diameter range. Indeed, as shown on the Figure 9, the distribution of volume by diameter range is not constant. The data used in this graph were collected over a three-month period thanks to the grading line files. Though there are some differences between length specifications, the distribution tends to be similar. All the lengths present a peak. For the 3.1, 3.5 and 3.7, the highest percentage of volume is between 20 and 23 cm top diameter. A huge percentage of the volume is concentrated in a narrow diameter scope; 80% of the volume is found between 16 and 28 cm top diameter. For the 4.3 and the 4.9, the distribution slightly moves towards bigger diameter: 23 to 26 cm top diameter; 80% of the volume is distributed among the 18 to 30 cm top diameter categories. Cutting longer logs is only possible on bigger stems in order to keep with a 16 cm top diameter. Because of the feature of the timber available on the market, you cannot control the diameter distribution with the constraint to steady a certain volume of supply. Consequently, the mill should adapt to the diameter of the logs supplied and not to expect to produce the major part of the sawn timber within big diameter logs.

Figure 10: distribution of volume by diameter range. 2008.



But in the worst case the mill is fed with longer logs than necessary which cause a much greater recovery loss. This is one of the disadvantages of the cut-to-length system. A good definition of the log length scope that is supplied must consider both the final sawn products and the easiness to procure the mill with them. About two years ago it was decided to reduce the number of log specifications available in the yard. Some particular lengths were used often enough to be worth to get in stock. It has happened that certain lengths have stayed in the graded timber yard for more than one year. The way the market economy does work nowadays does not tolerate this anymore. Consequently the supply of those lengths, rarely used, was interrupted. This assumes that the company is ready to allow a loss of material due to the length range reduction. The products which were cut with such lengths have now to be sawn from a longer specification as shown in the Table 10.

Table 10: rationalisation of the length range.

Lengths specifications previously supplied (m)	Substitute lengths (m)
2.1	2.5
2.3	
3.3	3.5
4.5	4.9
4.7	

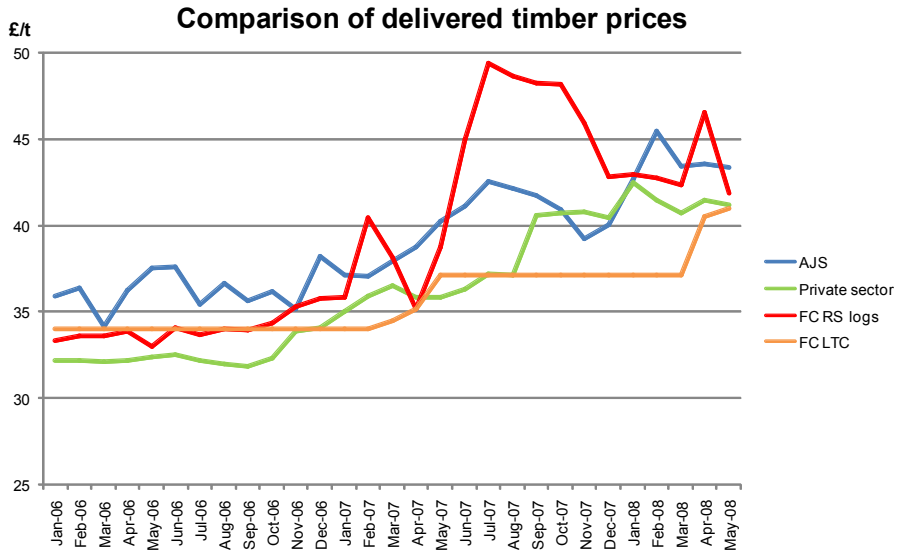
However it may occur sometimes that some of those specifications are cut to fulfil particular orders. It must be a substantial quantity and it cannot be delivered as quickly as other usual lengths. Actually only the 4.5 and 4.7m length are occasionally cut on order in AJS' harvesting operations.

2.8.Round wood supply cost analysis

As explained in the chapter about purchasing of round timber, AJS' supply sources are various in term of origin as well as in term of prices. On the Figure 10, prices were represented from January 2006 to May 2008, so that to compare the different sources of supply once timber arrives at the yard; of course those figures could be updated to nowadays or at least further than May but there no specific need to understand the trend.

Looking at this graph may need to be aware about the axis range which does not start from zero; this is done so that having an easier reading of the graph in consideration of which it creates distortion, increasing the differences between the lines.

Figure 11: delivered timber prices by supply sectors



The timber market evolution is obviously the major element that explains prices fluctuations for all of these supply categories but it is even more important as soon as timber is sold on the opened market. Considered at AJS' scale, timber market fluctuation are caused by general competition on round wood material with other wood industries, more or less local, but having supply areas in common (see AJS' main competitors on the Figure 1). More specifically and somehow included in the previous reason, the fluctuations are caused by the sawn timber market evolution, tightly connected to the housing market. AJS' final products are not directly used for construction but there is a certain relation between the housing market and gardening market; when housing market is going well so do the gardening market. That is why this element worth to be taken into consideration.

The Forestry Commission LTC line is relatively constant because prices are negotiated for a twelve-month period, from April to March of the following year in the case of AJS. However, as it may be noticed on the FC LTC line that there is a small raise in March 2006 and in May 2008 whereas raises should be when negotiation happens in April. These are merely explained by a haulage rate increase of £0.5 to adjust it to the petrol or other costs associated with haulage increase.

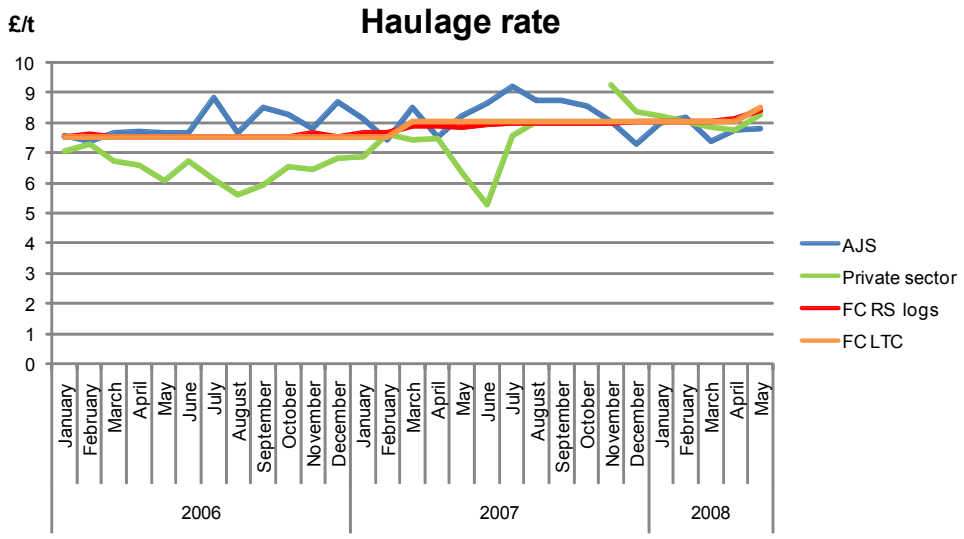
Even though they are from the same origin, FC roadside logs and FC LTC logs were kept separately in this cost analysis because, the sale method is different: FC LTC prices are negotiated whereas FC RS logs are sold by tender. For this reason the two lines corresponding to those FC products are totally different. It is just perchance that they are quite similar from January 2006 to September 2006. In fact, the FC roadside logs sold by tender are more likely subject to a strong competition since they are offered on the opened market. Therefore, prices vary according to the general situation of the timber market. The FC contracts concerns either green or red logs but never both. The FC roadside line includes a mix of green and red logs contracts. Sudden raise of FC roadside price may be explained by a certain proportion, or in totality, at this time of green logs contracts which increase the average at this time.

As previously described, AJS carries out its own harvesting activity through different contractors. On the Figure 10, the line series called "AJS" represents AJS' harvesting

operations. At first glance, AJS' operation appears to result most often in more expensive delivered timber than other supply sources, and this idea would lead obviously to ask what the interest is to maintain the AJS' harvesting operations. AJS' operations are proceeded on standing timber contracts, which like FC roadside logs are sold by tender to the highest bidder, ergo standing timber prices are under competition and so higher. One of the important points needed to be mentioned in order to understand the fact that AJS' operations prices are higher is the quality of the raw material supplied to the mill. Buying standing timber allows AJS to select quality of the timber it purchases. Because there is no specific need for AJS to separate the different quality timber on a job since mill 7 perform with both green and red logs quality, the mix between green and red logs overall AJS' operations is hardly quantifiable. However, this mix must be considered to understand AJS' operations timber is somehow more expensive than the others. Indeed, compared to private sector companies' timber supplied, there is in average £3 to 3.50 of difference between them, but the latter only provides red logs to AJS' sawmill when AJS' harvesting operations produces also green logs.

Previously cited arguments do not fully explain why there is such a difference of prices depending on the origin of supply. Site distances from AJS sawmill may slightly vary. As a direct consequence of the variation of the supply distance, haulage rate gives to us a good picture of this, as shown on Figure 11.

Figure 12: comparison of haulage rate between suppliers



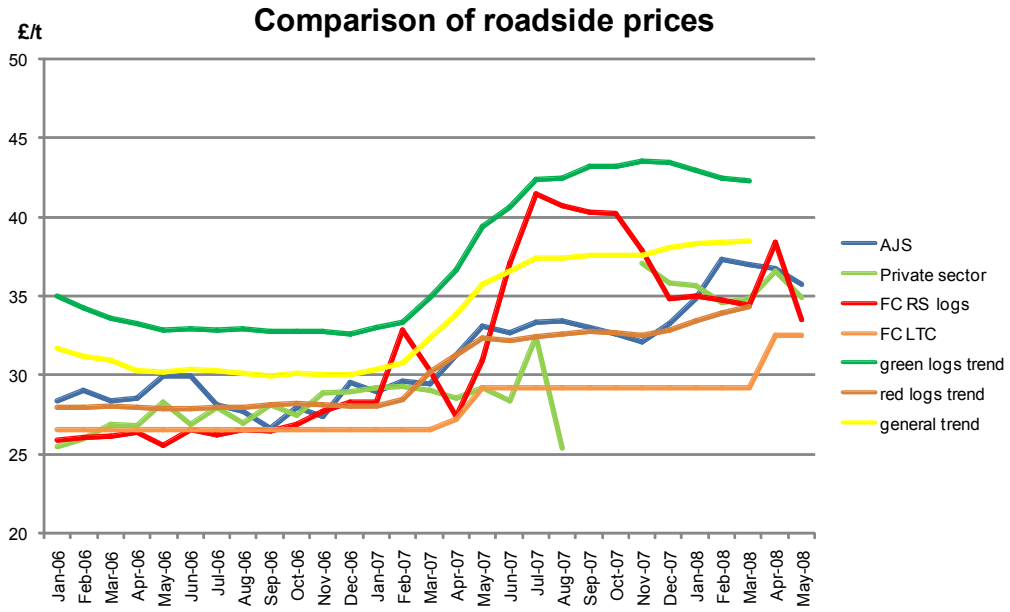
This comparison is done only over the deliveries of timber which were bought either on roadside or standing in the case of AJS' operations, or private sector delivered when data were available, that is to say the few delivery of private sector timber brought by AJS' trucks or trucks contracted by the company. Therefore, those data are to be considered with precaution because the number of samples for the private sector is much smaller than for AJS and the Forestry Commission. For this reason there is a lack of data for the private sector for September and October.

Although this is not always constant, there is a difference of £ 1.30 in average over the studied period between AJS' operations haulage and the private sector haulage In conclusion, AJS' operations are generally located further or in more remote sites than those from which comes the private sector timber. AJS buys standing timber from the Forestry Commission; and from private woodland owners. Though many private woodlands which compose the

standing timber sources for AJS are generally closer to the sawmill than Kielder forest, this represents only a low-level in term of AJS' operations supply. To get bigger contract elsewhere than with the Forestry Commission, AJS is likely to go further like in the Scottish Borders (region in the south-east of Scotland), and so has a more expensive haulage rate. On the graph above FC roadside and FC LTC lines are almost merged because of the predominance of wood supply from Kielder forest which is the quasi unique FC England wood source.

Considering now the price of round wood on roadside, Figure 12, the gap between timber price from AJS' operations and the one from private sector is considerably decreased; this is more visible for 2006 figures. There is a lack of data for the same reasons as in the previous graph. August 2007 point is out of the general trend of private sector because there was only one sample available date for this month.

Figure 13: comparison of roadside timber prices



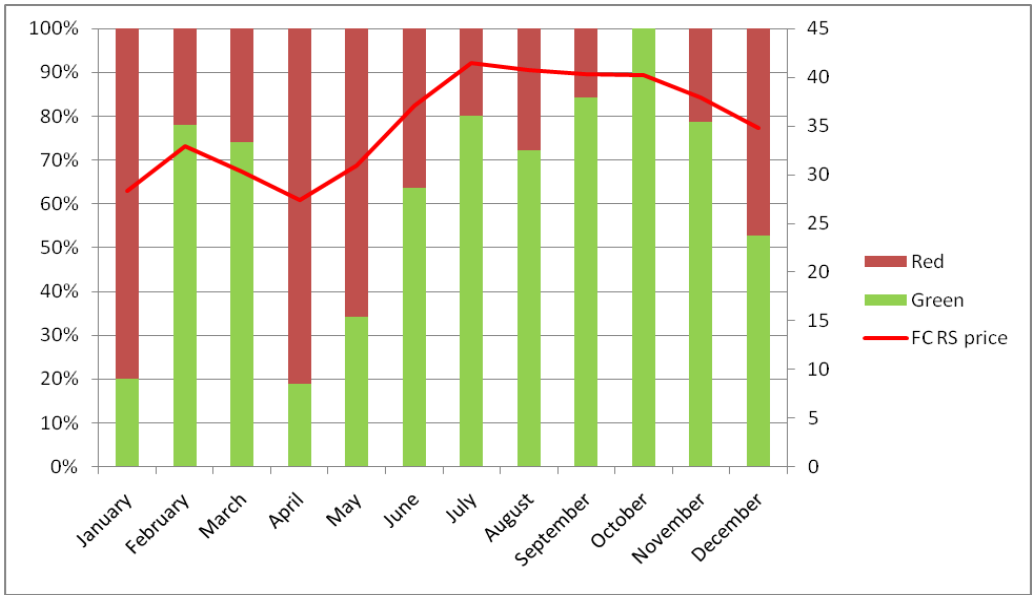
In order to compare to the general timber prices trend, three lines were added on this graph, namely green logs trend, red logs trend and general trend. Those data (FC, Direct production) are average prices calculated over a rolling period of three months; the abscissa of the points composing the trend lines represents the middle month of this period. Figures include despatches of sawlogs and standing timber sales (except the ones sold by lump sum) for England; England rather than Scotland or Great Britain was chosen because the majority of timber supplied to AJS comes from England. Both allocation modes, roadside and standing, are considered thus gives an overall view of the timber opened market.

Although it is somewhat messy to get so many lines on the same graph, this allows the comparison of each AJS' source of supply to the trends for green and red logs. Thereby, first of all, it is to notice that fortunately each price source follows the trends of timber market. Secondly, AJS' operations are closer to the red logs trend than to the general trend even though they provide a good mix of red and green logs. This means that AJS timber supply staff manages to pick up quality timber at lower price.

The quality of raw material supplied highly influences the timber price. AJS operations and the private sector companies supply a mix of timber quality with both green and red logs. It is not possible to monitor accurately which proportion of each quality goes through the mill. Indeed, when harvesting standing timber AJS does not require the forwarder to differentiate green from red logs and to stock them in different piles. However, a rough idea of what is the ratio green/red may be done averaging pre-harvesting data collected when the standing sales were evaluated. Therefore, considering the major contracts that were active over 2007 (Spithope: 5,362 t; Coal Grains: 9,575 t; Over Dalgleish: 13,865 t; Swindown Hill: 3,012 t; Attonburn: 2,097 t; Riccarton: 5,406 t), on a total of 39,310 tonnes of logs brought to the yard, 56% of those were green quality. Of course this figure does not take into account smaller jobs for which a precise breakdown was not available, but it important to keep in mind that in average green logs percentage represents between 50 and 60% of raw material coming from AJS harvesting operations. Regarding the private sector supply, the same problem more or less is encountered; the contracts generally are mixed and therefore include an unknown proportion of green logs.

FC roadside logs can be bought either as red or green logs. Therefore, the FC RS logs line of the chart above represents a monthly average of green and red logs supplied, but it is easier to monitor what proportions of green and red come to the yard thanks to contract number. Thereby, the figure below shows the monthly percentage of green and red logs coming from FC roadside contracts. Superposing the FC RS logs line (same as on Figure 12) on this graph makes easy to understand the variation of FC RS logs supply; price and green quantity clearly evaluate together. The important raise that happened during the summer in 2007 is due to a take off of green logs on the market which accentuate price difference between both qualities.

Figure 14: ratio green/red in the FC roadside supply. 2007.



2.9.Analysis key points

The table below summarize the strengths and weaknesses that I have highlighted in my analysis of the sawmill.

Table 11: strengths and weaknesses resulting from the analysis

	Strengths	Weaknesses
Internal	**Production** **- The sawmill is flexible on the size and type of product to cut** **Wood Supply** **- The sawmill has a good supply network** **- It has its own harvesting operations which provide more flexibility and can produce unusual specifications**	**General** - There is a poor data flow between Wood Supply, Production and Commercial Departments (only ad hoc discussions) - There is too much stock **Production** **- There are frequent machine breakdown within the sawmill** - The mill preferably uses bigger diameters to have a better production which causes constant shortage of those logs **- There is no mid or long term planning of production** **Wood supply** **- Constant changes of the quantity to supply** - No instant overview of the stock (only monthly)
	Opportunities	**Threats**
External	**Commercial** **- There are existing customers for specific products that many other sawmills cannot produce**	**Wood supply** **- Strong variation of the price depending on the supply sources** **Commercial** **- The market of wood is not constant, there are huge variation**

Jointly with my supervisor, it has been decided that the stock control was the current biggest issue for AJS' wood supply management. Improvement of the supply planning and the production planning heads towards the same direction: better stock control. In the next part of the report, you can find the tools I have created to improve what is in bold.

3. Stock control decision support tools

In the following part, I focused more in depth about wood supply planning, trying to highlight important criteria to take into account in the wood supply decision-making process. The aim with those criteria is obviously to provide guidance support tools to the decision-maker. This chapter tackles now the core of the carried out study during the placement.

The managers face new problems in term of wood supply chain. There is an increasingly severe competition in the marketplace, the mill requires tighter specification of raw material quality and the flow of timber must be faster. Researchers have published many studies dealing with wood procurement planning. Lots of them are labelled as decision support systems. Decision support systems (DSS) are a specific class of computerized information systems that support business and organisational decision-making activities. A properly-designed DSS is an interactive software-based system intended to help decision-makers compile useful information from raw data, documents, personal knowledge, and/or business models to identify and solve problems and make decisions (Wikipedia definition of DSS). Wood procurement processes are a promising area for decision support system because there is no formal structure for these operations and decisions deal with human behaviour (HARTSELA, 1997).
Two approaches can be done to study the decision-making process: the mathematical-statistical approach and the human behaviour approach. The first one assume that the decision-makers act rationally, which is seldom entirely true in practice. One reason for managers not applying rationally-based models may be because human decision-making process does not follow rational models (SCHWEDER, 1977). Managers only need and use a small proportion of the information available for good decision-making (CHESTNUT & JACOBY, 1982). Few planning systems really meet the important features of a DSS in term of planning and control of wood procurement. In Finland in the early 1990s, lots of forest departments of large wood industry companies used mathematical optimisation models in their operational planning, but only linear programme. None of the small companies used them (MERILÄIEN & al., 1995). The utilisation of relevant models in wood procurement planning has increased at the enterprise level over the last twenty years. But it has also brought lots of disappointment (ROBAK, 1990). Kallio et al. (1979) stated that only small and repetitive decisions can be fully automated. Decision making remains human tasks where computerised system should only have a support role.

3.1. Current context and stakes

In the wood supply chain management it is essential to control the stock level. As the thesis focus on the upper stream of the chain, the following deals with the stocks of wood raw material. Wood is a heterogeneous material for its mechanical and physical features. Considering that, it makes the supply chain management for wood even more complex than for other materials.

In logistics, in its widest sense, stock control is a major issue for any industry transforming raw material into ended products. In order to ensure the deliveries of raw material that needs the plant, supply chain manager have to control all the steps composing the upper stream. It is only when the whole supply chain is under control that the deliveries may be done according to the real needs of the mill. This is the final goal of logistics management: controlling the stock. The stock is the enemy of accountancy in any kind of processing industry. This is

applicable to the whole supply chain, both upstream and downstream. Raw materials and ended products stocks represent an important amount of money tied up. Thereby the greater the stock level reaches the less the company cash flow is. The latter is a key to keep a company healthy; that is why controlling the stock is such a big issue.

AJS' forestry department is in charge of the round wood supply chain management. As a result of the first part of this report, presenting the whole timber procurement, the weak points which were highlighted were the planning. Actually this is largely due to the lack of planning from the production department. AJS has been lacking of a director of production for the last two years and the former director of production had not achieved production planning. Although there is a strong will from the forestry department, nothing has moved yet. It might be due to by this "long term" vacancy. There is a production manager but it has been in vain, up until now, to make him plan the production more than one day to the next one. The forestry department manages therefore the wood supply without any information coming from the production or very few. Its relative success is due to the experience of the decision-makers. They have succeeded to provide to the mill the raw material specifications needed. However there are some problems inherent to the lack of production planning that are worth to be solved.

3.2.Stumpage and roadside stock control

It is not possible to get the whole length range with all the AJS' wood supply sources. It implies therefore to control also the mix of sources so that to control the stock. For a sawmill like AJS the whole round wood stock is composed from the timber yard stock, the standing timber and the roadside timber stocks. The stumpage and the roadside stocks need to be controlled as much as the yard stock because they have a direct influence on the latter.
As described in the prior part of this report, AJS' timber procurement managers provide round wood to the sawmill from three different suppliers groups. Those are namely, in this report, private sector forest companies, the Forestry Commission and AJS harvesting operations carried out by itself. Between those supply sources, there are fundamentals differences to consider so that to plan wood supply according to their availability, their periodicity and their average price. Therefore, the three supply sources previously cited will be kept separately in the following part.

3.2.1. Financial reasons

Firstly, it is necessary from an accountancy point of view to control the stumpage and the roadside stock for the money it represents. Fortunately most of the round timber is bought by tonnes and paid on a monthly out turn basis. This is somehow linked to the cut-to-length system. So the advantage is to have no drastic limit the back-up of wood supply sources. This is really significantly reflected in the cash flow. Nevertheless AJS buy a certain quantity of standing timber on a lump sum basis. This is only anecdotic with the Forestry Commission but it can be more common with some private sector agents. Although lump sum sales tend to disappear with the forestry market evolution, some old forest managers rather prefer this system to the price by weight. AJS' lump sum contracts essentially concern small areas which are often bought with hardwood marketing as ulterior motive. Notwithstanding, some precautions are worth to be taken in order not to cumulate a too important stumpage reserve bought on a lump sum basis. This is totally different from what is practiced generally in France where the sawmills need to buy the standing stock they need on a lump sum basis. Because of this financial difficulty small or medium sawmill can be in bankrupt.

Secondly, when buying round wood, both standing and roadside, the decision-makers should carefully consider the supply sources. The results from the cost analysis, which were described in a prior paragraph, have shown some non negligible delivered price differences. Thus the purchasing should be targeted based on those indicators. What the accountancy department wants to avoid is to get a too expensive invoice for round wood at the end of the month. That is for cash flow reasons too. Obviously there are some factors that cannot be controlled at all such as market trends and the variation of volume required. However, the decision-makers may control the origins of the supply. Indeed, the monthly average delivered price derived directly from the mix of sources. Considering only the contracts on a monthly out turn basis, all of them do not present the same interests of payment facilities. From an accountancy point of view some sources present great facilities some do not, as shown in the table below.

Table 12: the different payment facilities given by the suppliers

Suppliers	Payment facilities
Forestry Commission	30 days after the collection date
Euroforest	Net monthly
Tihill	Net monthly
SWL	90 days after the invoice date
Egger	Net monthly
Other	30 days after the invoice date

So the Forestry Commission contracts, both at stumpage and roadside, require the payment by the end of the following 30 days after the wood being loaded.

Of course there is the unanswered question related to the quality of the raw material supplied. Currently, though it is not an accurate figure, the average proportion of green logs might be somewhere between 50 and 60%. The more the green logs proportion is the higher the monthly average price is.

3.2.2. Availability of round timber

The long term contract with the Forestry Commission ensure to AJS a constant delivery of 15,000 tonnes yearly, with completion to some points; this is what we could call the only constant among the wood supply process. Besides the LTC, the Forestry Commission presents the opportunity for AJS to buy either roadside timber or standing timber during tender sales. Those FC tender sales occur normally four times a year for each forest district, gathering roadside and standing timber sales at the same moment. Considering this point, it appears important that the decision-maker does not miss those FC events happening each year. In the AJS' case, actually there are not just four FC sales events but eight. Indeed, AJS' supply scope enlarges upon two FC forest districts which are Kielder forest district (FC England) and Scottish Borders forest district. Besides FC sales events, there are opportunities of buying standing timber from private owned forests often through their forest managers. Opportunities of standing timber from private owned forest are not predictable, neither in term of frequency nor in term of volume.

Regarding roadside and delivered timber negotiated with private sector forest companies, two cases need to be made out. First, a certain part of the volume supplied is dealt according to different opportunities coming up but which concern generally small volume each time. Even though overall year it happens several deals can be made with on of theses agents, supply is not insured to be continuous. Those private sector agents are generally forest consultancy

companies of small sizes, which are gathered as "others" in figure representing private sector suppliers. The major private sector suppliers are Euroforest Ltd., UPM-Tilhill, Scottish woodlands Ltd. and Egger (UK).

3.2.3. Possible orientation of the round wood purchasing

The three or four biggest private sector suppliers are obviously a major target. Relationship between AJS and those companies needs to be strengthened to secure an important percentage of the round wood supply. Currently, there are already good relationships with Euroforest, Tilhill and Scottish woodlands; however Egger should not be put aside. In fact, though they cut off the supply to AJS during the last months, Egger forestry harvests a huge quantity of timber each year the quality of which corresponds to AJS needs. With the expected end of the long term contract accorded by the Forestry Commission, the private sector represents a good opportunity to replace the volume obtained through this contract.

According to the timber market fluctuation, round wood prices change very quickly. It is not reasonable buying timber, both standing and at roadside, more than six months or so in advance. Otherwise, the price paid for round wood and the one sawn timber is sold are never in phase. Whether it is impossible cutting timber which has been priced to the current market, it is necessary to synchronise those as much as possible. The private sector supply offers a better flexibility in term of payment and timber can be re-negotiated more easily, whereas the Forestry Commission strengthens its policy for contract extension.

The FC keeps the possibility to resell the roadside timber which has not been uplifted six weeks after the end of the contract. The timber is paid by the initial winner of the sale and then sold a second time. In case a customer wants to give a timber contract, he has to pay the difference of price it will be resold. This is a hard point to deal with for AJS when the quantity needed is drastically knocked back. Thus it put AJS in an uncomfortable situation where it needs to bring expensive timber; which is not wanted, and to reduce private sector supply whereas it is cheap timber. Therefore, limiting the FC roadside contracts avoids such problems regarding the weekly wood supply sources breakdown.

3.3. Wood supply planning

3.3.1. Study of AJS' customers

A&J Scott Ltd is a sawmill the sale policy of which is largely customer-oriented. Therefore it is absolutely necessary to understand well what the expectations of its customers are in order to know what type of raw material is needed.

Observing the products references catalogue of the company gives you an idea of the wide range of products AJS produces. Only considering sawn wood and none of the on-site added value products which could be called by the generic term of gates, AJS has about 4,500 items referenced in its database. The range includes products that are always sawn and also products that are not ordered anymore, and for some of them, they may have been ordered once. Besides the three dimensions (length, width and depth) composing the product characteristics, another component increases the number total of products specification. Indeed, AJS proposes sawn products with more value-added selling timber which receive a wood protection treatment (TANATONE® and TANALISED E®). Then there are 250 pressure treated products references of which dimensions superposed with others untreated sawn timber. However, all of them are not sawn every year; out of those 4,500 references, only 1300 were used in 2007, which still remain a wide pallet of finished sawn products.

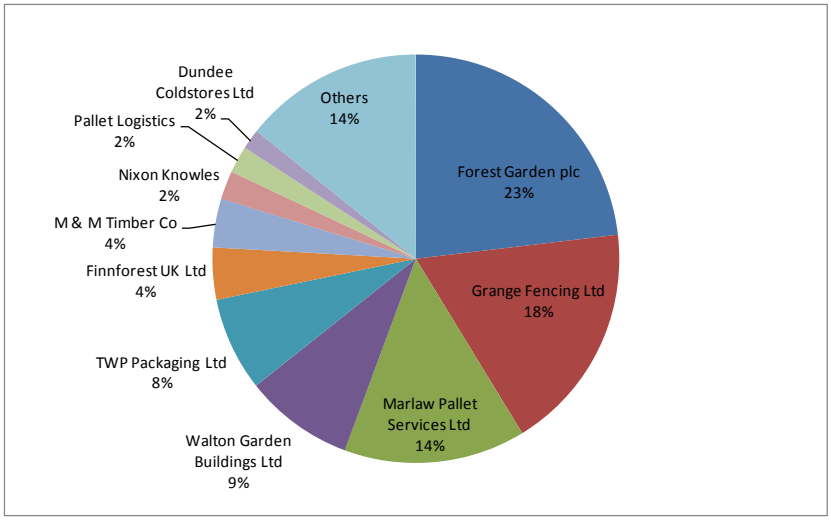
From the point of view of wood supply management, it is interesting and useful for the decision-maker that he understand which products characteristics are required to feed the sawmill. Hence, according to AJS' policy where sawlogs specifications are dictated by orders book, study customers' orders with regards to volume, specifications of products, frequency.

In the following part, only customers' aspects related to squared timber will be discussed. All orders, productions, etc., regarding to gates production will be kept aside for two reasons. First of all, gates and fences orders just represent only around 860 cubic meters, which is hollow compared with the 55,200 cubic meters that represent the annually sawn wood orders. Besides, gate building implies many different sawn wood components not always easy to determinate as having been processed several times in some cases. In the same way, customers for round wood, both softwood and hardwood, and for by-products inherent in sawmilling process were excluded.

3.3.1.1. Who are the main customers?

In 2007, AJS has dealt with no less than 80 customers. Among those customers, it is possible to make out three types of behaviour. The first type of customer is the one which orders weighty volume each month and makes up the core of the customers of the company. The second type refers to clients ordering from time to time but quite regularly. To finish off, the third type of client is composed of customers, qualified by "strangers", which buy sawn wood very sporadically or even just once. The two last types have not been considered as being really important for the purpose of this short customer's analysis. I have focused on the core of customers to understand their behaviour.

Figure 15: AJS' main customers, 2007.



On the Figure 1, the top ten of customers of the year 2007 were represented separately and the remainder are gathered under the label "Others". The top ten counts for 86 % of the total orders and taking just the five first allows considering about the three quarter of AJS sawn wood contracts. The core of AJS customers is equivalent to the top-five customers, namely: Forest Garden Plc., Grange Fencing Ltd., Marlaw Pallet Services Ltd., Walton Garden Building Ltd., and TWP Packaging Ltd. Those five major customers count for about 70% of the total sawn volume sold.

3.3.1.2. Core-customers' habits

Now that the customers which have the biggest weigh in AJS business are identified, it is necessary to understand what their characteristics are and how they may influence AJS' decisions and the orientation of the company.

Table 13: top-five customers' orders quantity — 2007.

Customer	Average quantity ordered monthly (sawn m3)	Coefficient of variation (%)
Forest Garden Plc.	1064.0	41
Grange Fencing Ltd.	834.9	17
Marlaw Pallet Services Ltd.	663.4	64
Walton Garden Buildings Ltd.	398.5	36
TWP Packaging Ltd.	341.8	43

Table 14: top-five customers' orders diversity — 2007.

Customer	Total of different dimensions ordered in the year	Average number of different dimensions ordered monthly	Coefficient of variation (%)
Forest Garden Plc.	128	49	29
Grange Fencing Ltd.	97	34	27
Marlaw Pallet Services Ltd.	177	30	50
Walton Garden Buildings Ltd.	103	28	48
TWP Packaging Ltd.	97	12	86
Top five	582	160	24

The tables above highlight the great variation into the quantity that the top-five customers ordered in 2007. In the Table 12 the coefficient of variation is extremely important for four of them and one is moderate when compared to the others, so the volume ordered monthly by each of the customers varies massively from one month to the other. The Table 13 shows how wide the ordered products scope is. The top-five customers order lots of different dimensions not only within a month but also from one month to the other (Appendix 1: product specifications and quantity ordered by Forest Garden Plc. in 2007.). Considering the main customers all together does not really change the trend. It has to be noticed that those different customers order different products to each other.

In summary, the customers' habits appear very variable. Even the core customers' orders do not allow determining what the constant main products are. Therefore it is impossible to use the core customers to extrapolate the composition of the stock core in term of specifications. The stock needs to have a relative quick turn over whilst matching the specific requirements of the mill.

3.3.2. Interest of wood supply planning

Wood supply is one of the major factors influencing the stock level; this represents the input in the stock, whereas the output is the mill intake. In order to control the stock level it is therefore necessary to control wood supply and its characteristics. Indeed, whether the timber brought to the yard is not used in the short term then it stays stocked in the graded yard for a while, occupying room where could be stocked other logs specifications required by the sawmill and besides this timber represents money tied up.

Controlling the stock level assumes to work with a just-in-time supply system as much as possible. Ideally, none required length specifications for the mill to fulfil its order book should not be retrieved to the yard. This would result in a short-term rotation of the stock with consequently the possibility to largely decrease the stock level. So that timber specifications brought to the yard match with the mill need, it is necessary to base wood supply on the order book.

Orders are stored in a data base and it is possible to follow so and when what are the current orders which remain to fulfil. The idea was thus to create a computer tool which would convert out standing orders into raw material equivalent as it is used by the mill, i.e. length and diameter range.

Out standing orders data contain the code of the product ordered, the initial quantity, the remaining quantity and the sawn volume the latter represents, the order date, plus some eventual details. The part code specific to each product is composed with letters and numbers giving the dimension of the final product: SU2400X150X150 represents a untreated softwood product of which dimension are 2400 mm of length, 150 mm of width and 150 mm of depth.

3.3.3. Basis of the programme and processing

The first step to build this tool consisted in creating a spreadsheet which stores final product length and associates to the latter the length of the logs that would be used by the mill. The difficulties reside in the fact that a certain final product may be cut either in a log the length of which is close enough to the sawn product or the operator may also decide to pick up a longer log so that to cross-cut the sawn timber in two, three or four pieces at the end of the chain and thus to get several final products from one log. In order to associate log length to the length of the final product, the choice of reducing as much as possible the loss of material was made. The logs used by the mill come from the different bins of the grading line and, as prior mentioned in the part dealing with the grading line, the logs in a bin gather different lengths range established in the grading line software (Appendix 1) There is therefore a loss of material induce by difference of length between the log and the final product or its multiple when there are cross-cuts at the end.

A VBA code has been developed to calculate for each final product length the difference between each log length specifications available in the yard and the different multiples of the first one. Then it associates to the final product length the log length for which the difference was the lowest. The results are given in the Appendix 2. Ordered product the length of which is smaller than 700 mm are processed recycling, i.e. re-working side boards and so on.

To associate diameters to each part code, it has been chosen to break it down only in three categories, namely 16 -22, 22 -30 and 30 +. Those categories represent the ones which are generally used on harvesting operations. The instructions given to the harvester and to the forwarder are to make out 16 cm to 22 cm top from 22 cm top and more. Actually the differentiation of 30 cm plus is only made for sleepers (2.5 and 2.7 m length). However, those three diameter range have been selected because they split the diameter scope handily. Both 16+ cm and 22+ cm, and sometimes 30+ cm are the data given generally for each load coming to the yard .According to the cutting patterns the centre block gets sides of circa 135 mm for a log of 22 cm of diameter and circa 195 mm for a log of 30 cm of diameter. Besides, final products the width of which is greater than 67.5 mm and less than 96 mm get their width

double; therefore it is necessary to double the product width to find the associate diameter range.

A spreadsheet named *Part codes* looks up the diameter range and the log length used for each product code both in *Length* and *Width* spreadsheets. Those data may be updated whenever it needs to. For example the company may take an order of products of which dimensions have never been cut so far, and it has to be input in this *Part codes* data base to enable the conversion of this order into raw material equivalent. The user only has to write properly the code corresponding to the new product, its dimensions and to extend the formula contained in the upper row to look up the length and the diameter range.

To calculate the volume of wood raw material equivalent corresponding to each order the conversion factor value used by default is 2.5. This corresponds to the average value of recovery. The recovery varies a lot depending on the final products dimensions and the cutting pattern used but average of 40% for the real recovery has been calculated during prior tests.

Besides those sheets, the excel file *Wood supply planning* has got the *OS orders* sheet to receive the order book data. A button was added in the sheet *Form* to make the user run the conversion. This button is linked to a VBA code (Appendix 3) which does the following operations:
Looks up the part code of the ordered product in the *Part codes* sheet and returns the source product, i.e. the optimised log length and the diameter range concatenated;
Gives the volume of wood raw material equivalent corresponding to the order;
Sums up the volume of round wood per source product and presents it sorted by source in *Wood supply* sheet.

Whether a product has not got its part code already referenced then a message box would appear on the screen to warn the user. The message notice to user at what row is located the un-referenced order so that he can find it back. When such a case happens, the message will only make a pause in the programme until the user click the ok button on it. The orders concerned the will not be considered in the calculations. They will not be included therefore in the result. An unreferenced item may have two different causes. The first one is simply that the dimensions of the final products are ordered for the very first time. Then the user may need to add the product code to the *Part code* sheet as notified above, after what he may start again the programme. The other cause may be the product is not just sawn wood but value-added product such gates and panels. For those products it is not possible to convert the sawn wood used to make them into wood raw material equivalent. Indeed, gates and other value-added products of the same type are built using different wood dimensions. However those products only represent a small percentage of AJS activities (circa 1.5% of the sawn volume). Thus the user may either erase the raw of this order or let it; the result will not change insofar.

When pasting the order book data, the user has the opportunity to plan weekly the supply before to start the programme. He may allocate to each order the week number when it should be fulfilled. This can be done either for the whole out standing orders or just partially. The programme will then give the result detailed per week number. When no information is given by the user for the date of some orders they are gathered in a unique group. The interest of planning weekly the orders will be dealt more in depth in the following discussion part.

3.3.4. Using manipulations

Few manipulations need to be done by the user to get the result wanted. First, he has to open the excel file named *Wood supply planning*. Then he might copy the out standing orders from the order book and paste it in the sheet *OS orders*, right in the upper left corner. To get the result, he has to click on the *Form* sheet and to click on the button saying "Convert orders into raw material equivalent". That is it, and the result appears in the *Wood supply* sheet as shown in the Table 14.

A brief user guide has been written to go with this tool. The manipulations needed to run stay as simpler as possible, so the guide is (Appendix 4). The aim when building such a tool is obviously to enlarge the scope of people who could use it. Thereby, everyone who is IT literate should be able to use the wood supply planning tool following the user guide steps. All the calculations and the use of formula are done thanks to the VBA code linked to the button in *Form* sheet.

Table 15: wood supply based on the order book.

Week	Source	m3
Summary	2.5 16-22	80
Summary	2.5 22-30	335
Summary	2.5 30+	382
Summary	2.7 16-22	4
Summary	2.7 22-30	58
Summary	2.7 30+	624
Summary	2.8 22-30	23
Summary	3.1 16-22	86
Summary	3.1 22-30	120
Summary	3.2 22-30	515
Summary	3.5 16-22	77
Summary	3.5 22-30	17
Summary	3.5 30+	2
Summary	3.7 16-22	539
Summary	3.7 22-30	438
Summary	4.1 16-22	7
Summary	4.3 16-22	218
Summary	4.3 22-30	34
Summary	4.5 16-22	132
Summary	4.5 22-30	23
Summary	4.7 16-22	45
Summary	4.7 22-30	19
Summary	RECYLE 16 - 22	30
Summary	RECYLE 22 - 30	1

3.3.5. Discussion

A presentation of the wood supply planning tool has been given to the staff involved in the wood supply. This was short but it aims to make the tool known and to be sure that using it

was as simple as thought. It resulted that using the wood supply tool is definitely accessible for the people who will use it.

Geordie Nicholson is the one who is the most interested by the results because he plans the quantity and the specifications of the timber which is supplied to the mill. The wood supply in the strict sense of the word, i.e. the logistics, is planned daily. The difficulty resides in deciding what the good mix of lengths is. As prior notified, there is a huge lack of planning for the production part. It is barely if the orders that will be dealt the following day are known. It is therefore extremely tough to plan too for the wood supply decision-makers. Geordie Nicholson has used that tools for several consecutive weeks and gave me his first impression. The figures given by the wood supply planning tool are helpful to guide him to plan timber deliveries. However, it has remained so far only a guide and does not provide the full information that would be ideally required. In order to make it fully operative the week number allocation must be done.

Finally although this tool provides helpful data for the wood supply planning, the initial problem remains. The purpose of improving the wood supply is obviously to provide the raw material that the mill needs. But in order to provide the better log lengths mix to the mill, at the right time, the decision-makers must get the full data required to do their choice. Yet the missing data are the production planning. This is a kind of vicious circle. Because there is no production planning the delivered timber is not of the right length specification sometimes. Thus the operator in the mill decides to use another log length to fulfil the remainder of the order when the most appropriate length comes to lack. We have come back to the initial reason pushing to improve wood supply. As soon as there will be a longer term production planning, this tool will be really more efficient and more helpful for the decision-makers. Because the user has already the choice to type the date planned for each order, this decision support tool is ready for when it will happen.

Assuming there is an efficient production plan, another problem may cause eventual difference between the wood supply plan and the mill intake. When an order is being dealt with, it may occasionally be combined with another order. If two orders get the same width and thick but the length differs then both product may be processed in once picking up a longer log. Because this is not predictable, it has not been considered when building the wood supply planning tool. The mill operator would have to select the same length as the one planned in order to optimize the benefits that could bring this tool. Per se, this would not impose upon the operator lots of constraints.

Besides he also watches over the active standing timber contract. So he has to decide too what are the logs specifications that will be cut.

3.4. Cutting pattern optimiser

3.4.1. Problems coming up with the cutting patterns

Currently the software which runs with the main line of the mill is RM patterns. This one stores the multitude of cutting patterns created for each product dimensions. During a run, the mill can only use one and only one cutting pattern at once. Cutting patterns are designed for one products and one diameter category corresponding with the bin sorting. Therefore when the operator selects the cutting pattern he will use, the logs going through are all from the same length specification and the same diameter range. The same pattern is applied to all the logs of the run. The software does not include any cutting pattern optimisation linked to the

scanner. Even though the drastic grading line sorting breaks down the log diameter between 16 cm and 42 cm into 12 groups (or 13 for the shortest), recovery optimisation is only possible by group and not by log unit. That assumes that the optimisation can be done for the smaller diameter of the group to be ensured to get the main products out of the log.

In order to fully understand what the possibilities are in term of cutting pattern creation, it is necessary to quickly describe the process in the mill. At the entrance of the chain, the 3D scanner pictures the log and gives the information to the log turner which present the log the best way. The log goes through the first chipper canter and then directly through the four-arber saw. The latter is composed of four saws placed onto a telescopic axle. There is one axle on each side which allows to get up to seven cuts. The two first gaps between the first, the second and the third saw on the axle are fixed. It may be changed in order to cut side boards matching with orders. The change of the spacer however takes a couple of hours of work with three people so it is done only about once a week. The four-arber saws the vertical side boards of the cant and split the centre block if needed. It can cut up to three of them on each side depending on the number of centre block set up. Then two possibilities are offered depending on the cutting pattern selected. Either there is one unique centre block or there are several (up to three). In the first case, the cant is directed towards a second chipper canter and then goes through the multi-rip saw. Two profiled boards (horizontal side boards) are cut. If there are two or more centre blocks cut, then there is a second pass. The cant is redirected towards the first chipper canter. A double pass is usually applied only on logs of a certain diameter (not less than 23 cm top).
When the current cutting patterns were created, and it was still the case until now, no particular attention was taken regarding the maximisation of the recovery. It is the call of the operator to create them and to try to get a good recovery. By experience he knows well which log specification and which bin to use to cut the ordered product. But he has got the whole responsibility until know about recovery while he must deal with two major constraints. On one side he must ensure a certain percentage of recovery to keep the process profitable. Until now, he only have his own experience because there is absolutely no guide telling him what would be the best cutting patterns he should use. On the other hand, he is under pressure with the graded logs available in the yard. That is to say that he may wish to use logs from a certain bin but this one is not always available or there are anyway not enough timber to fill the order. That is why he needs sometimes to cut the ordered products with the wrong length. When the right length is available it happens very often to get short of the desired diameter range. He has then to drop of one diameter size (up or down) to go on.

Changing of bin implies to change of cutting pattern in the software; this operation does take only a couple of minutes to operator. Very often, dropping of diameter range modifies the number of boards produced from the centre block. Because the saws from the multi-rip need to be re-adjusted, this makes another loss of time. The downtime caused by the reconfiguring of the multi-rip is of ten to fifteen minutes. Because the mill does not have the possibility to cut the same raw material for a long run, a lot of downtime are caused, and so a loss of money.

Because the cutting pattern software does not include the optimisation of the recovery, the operator designs them based on his own experience. Even though there work quite well, the recovery on certain cutting patterns is not always the best it could be. In order to help him in his choice, I created a programme giving all the possibilities of cutting patterns for a specific ended product. As a first thought, this part of the work may seem to be out of the issue of stock control. Actually, it has different purposes and that why it is highlighted in this report.

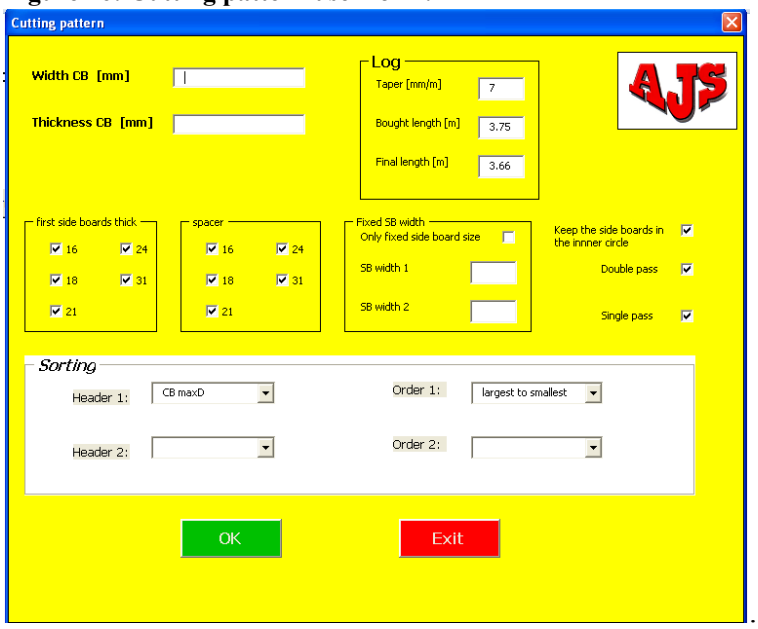
Obviously it will help the operator in his choice to create the best appropriate pattern, but it will also, in a second time, provide an efficient tool to get rid of certain diameter ranges stocked in the yard. Indeed, the biggest logs are usually selected because they give a better recovery. So keeping in mind that the mill is often reluctant to cut some diameter ranges, this programme guides the operator to utilise "none desired" sizes. However it appears that for some dimensions of ended product that a smallest log will give a better recovery for the main centre block than a bigger log while still providing a total recovery acceptable.

3.4.2. Structure of the programme

The programme has been written in VBA. It proposes different options to the user. Those choices the user can do are similar to the one in the cutting pattern software running in the mill. Depending on the user's need, the latter may want to have only specific results. To launch the programme, the user need to open the Excel file, named in this case *Cutting pattern.xls*. This file contains two spreadsheets: *form* and *cutting pattern.* The first one only has the button which will launch the user form, and the second sheet is where the result appears.

The user form provides a friendly interface and makes the utilisation easier (Figure 15). Only really basic IT knowledge is required to use this programme as it almost consists into opening an Excel file. Once the form opened, the user need to type few information depending on his request:
Section of the main sawn product: width and thickness
In the "first side boards width" frame, five choices are available. The choices given to the user stand for the standard thickness of side boards cut in the mill. They give the width of the side boards taken either by the four-arber blade which can slide onto the axle or the profiled board. Several choices can be done.
In the frame named "spacer", the user sets up the fixed width between the first three blades of the four-arber. As for the first side boards, the user can choose to let several possibilities.
In the "Fixed SB width", the user has the opportunity to select up to two specific widths of side boards. The interest of this option is whether side boards must be cut to fulfil an order known. The user needs to check the "Only fixed side boards width" box to activate this option.
In the "Log" frame, the user may type information about the log input into the mill to give a more accurate result. The way to enter those data was traced from the cutting pattern software.
A checkbox lets the user decide whether he wants the side boards to be contained in the inner circle or in the outer circle.
Two checkboxes allow the user to select either a single pass or a double pass process or both.
It is possible to sort the result selecting the field wanted in the "Sorting" frame.

Figure 16: Cutting pattern user form.



Once the user has made his choice, press the button "OK" runs the programme strictly speaking. The VBA code executed when clicking on OK is described in the Appendix 10 in the private subroutine calls "CmdOK_click".

The programme calculates for a given main product, typed by the user, the different cutting patterns that could be created and the associated recovery. It tests the different possibilities offered when creating a cutting pattern in the appropriate software. First, for the centre block, it establishes what the highest number of boards that can be contained in the inner circle is. The process is reiterated for a number of cants between one and three. Then it determines the best solution to choose in order to maximise the recovery of the side boards for a centre block pattern given. If the user checks several thicknesses possible for the side boards it will calculate all the combinations that can be done while respecting the process constraints; e.g. maximum number of vertical side boards depending on the number of cants. In case the user selected fixed width for the side boards, the programme then works almost the same trying to maximise the recovery for those side board dimensions. For a side board thickness given, it picks up among the selection the largest width it can instead of taking the real widest one that can fit until touching one of the circle. It is possible a maximum of two side board width but the programme will test the possibilities for the double of one of them. Five millimetres are added when doubling the width to take into account the future rework.

3.4.3. Application

A meeting has been organised inside the company aiming to discuss around improving cutting patterns initially. Different interested people attended to this meeting: the finance director, the sales director, the operation manager, the operator of the mill, the rework manager, the round softwood supply manager and I. It gathered such a broad scope of people because actually all the activities of those ones gravitate around cutting pattern, directly or indirectly.

Different people mean different interests, everybody wanting to improve concerning himself first. That is what quickly came out at the beginning of this master class. So one may want to

reduce as much as possible the production of side boards when another wants to increase the total recovery from the sawlogs. The mill, like every other sawmill, prefers cutting bigger diameter and longer logs rather than small ones. This is even more accentuated in the case of AJS because of the multiple downtimes unfortunately. The mill utilises bigger material in order to catch up with the production objectives in term of volume It was necessary to re-focus on the fact that timber is a very heterogeneous material. Though it may be wished to have such characteristics of timber in the ideal situation, the reality is often slightly different. This is not efficient, neither productive, to discuss in depth what would be the ideal situation when knowing that it will never happen.

Because of the British grown timber characteristics and forestry applied on the crops, it is really unlikely getting exclusively big diameter logs in quantity needed. As reminded in the Figure 9, all the logs brought to the yard follow the same trend of distribution. This input is almost like totally fixed. Once keeping in mind the distribution of diameters, this gives the objectives in term of target for the cutting pattern. Although the results of the comparison give often big logs with a better recovery, it is not always realistic to define the top cutting patterns for each product in those ranges of diameter. Doing like this will not solve any of the initial problems but on the paper. Choosing a cutting pattern for a big diameter logs implies getting a small volume ordered otherwise the operator is likely to drop very quickly and many times from on bin to the next one.

The programme I created may be used however to determine for example what could be the best three cutting patterns (diameter of the log, centre block and side boards). Indeed, with all the possibilities before the eyes decision making is largely simplified.

3.5. Yard stock control decision support system

3.5.1. Interest

As stated in the third part of the report, analysing wood supply to AJS' sawmill, stock taking used to be done each month the last working day. This operation needs two men to get it easier to assess and takes two hours walking through the log yard and measuring each stack of timber, after that forty five minutes are spent typing data on an excel spreadsheet and checking them. Although stock taking is a good opportunities to have a look where the stock level is, what the available specifications are, this operations is also slightly fastidious and repetitive.

The aim of this support tool is to reduce the time needed to take the stock and as far as possible to make it the most accurate. The yard stock control decision support system is built using available data from prior quoted sources. Indeed, AJS' scope of data allows controlling the quantity of sawlogs being retrieved to the yard thanks weighbridge delivery tickets. Controlling the volume of wood graded through the grading line is possible thanks spreadsheets created automatically by the grading line software to store daily logs throughput. A third source of data is necessary to build this system which would give the sawmill intake, detailed by length and diameter range. Those data are summed up in an excel spreadsheet too, giving information about the date, the cutting pattern used and the volume of logs cut during that run. Cutting patterns includes logs specifications used, exactly as what is needed to get similar information from the three sources.

A minor difficulty using those data is that they are stored with different spreadsheet presentation and different period. The weighbridge data are stored with daily table within a weekly sheet, whereas the grading line software creates and store the data daily. Regarding the mill intake data, they are summed up weekly on a new sheet in an Excel file. In order to enable the use of those data, they need to be processed before. Because the operations required to make the content of those data more homogeneous are repetitive and time-taking, I opted to simplify them using macro mode on Excel. Thereby, the manipulations that the user needs to do are largely reduce and there is an important gain of time. The function of the tool is detail in the Appendix 5, and three VBA codes, running the data processing of each one of the three data sources, are presented in the Appendix 6, Appendix 7 and Appendix 8.

Once the user has done the operations needed to process the data, each source data are gathered in one table (weighbridge, grading line and mill intake) presenting the total volume, by length and diameter given. Then the stock is calculated according to the following equations:

$$GS_{l,d} = GS^0_{l,d} + GL_{l,d} - MI_{l,d}$$
$$US_{l,d} = US^0_{l,d} - GL_{l,d} + W_{l,d}$$

With:

$GS^0_{l,d}$: initial graded stock for the length l and the diameter d

$GS_{l,d}$: graded stock for the length l and the diameter d;

$US^0_{l,d}$: initial ungraded stock for the length l and the diameter d

$US_{l,d}$: ungraded stock for the length l and the diameter d;

$GL_{l,d}$: grading line throughput for the length l and the diameter d;

$MI_{l,d}$: mill intake for the length l and the diameter d;

$W_{l,d}$: weighbridge throughput for the length l and the diameter d.

The stock is split into graded and ungraded, which gives a better view of what is ready to be used by the mil. The breakdown considers the usual lengths cut by the mill, but also some more exceptional. Thereby, the programme should be able to deal with most of the situation. Regarding the diameters, they are gathered by ranges classically used when stock taking: 16 to 22 cm top diameter, 22 to 30 cm top diameter and 30 cm and plus top diameter.

3.5.2. Discussion

The yard stock control decision support system, as I entitled it, is not actually a real DSS. It only uses the macro and programming with Visual Basic Editor. However, it results in something similar. The user interface is not as friendly as it could be with any other software. This would probably need to be improved. The difficulties to do so remain that different operations are handled by the programme, but not only within the same Excel file. It compiles and processes data located in extra folders, chosen by the user. Understanding my very new experience in programming with VBA explains why I have been limited.

Principle operations are automated and the user only needs to follow the instructions appearing before his eyes on the screen. Though, errors are possible caused by the mill intake data. Those data are summed up manually in a weekly spreadsheet and the name of the sheet is typed manually too. The problem starts here. In fact, when the user follows the instruction

to select the mill intake data, he must type the period he wants with a starting date and one for the end. Then the VBA code calculates what the corresponding weeks are. Normally they match with the name of the sheets in the mill intake file. In the case the sheet name is type slightly differently, this generates an error and unable the data processing. The only way to figure out the problem is by typing the proper name of the sheet. In order to avoid such a problem, the mill supervisor updating the file only need to type the sheet name cautiously.

This tool works perfectly in theory but it encounters few difficulties until now. Besides the error that can appear as explained above, another problem makes this programme unusable for the moment. The length specifications given by the mill intake data are very often wrong. The reason of this error is relatively simple. On each batch in the mill, the operator selects the cutting pattern. This latter may be set up for several lengths. Often the operator does not pay attention selecting the length because it does change anything in the final product really cut on the main line. However, the length selected is the one recorded by the computer. Thereby, it ends up with the wrong length associated to the real volume scanned at this entrance. Consequently, the whole results for the graded stock are totally biased. The operator needs to select the right length in order to get accurate data.

I have corrected the mill intake data, approximating the original log length thanks to the ended products lengths. This is not possible in the programme to substitute the lengths in the mill intake data by the ones of the ended products. In fact, sawn products are cross-cut at the end of the main line and the initial log length can be guessed only assuming that it was the best suiting length which was used. Nevertheless, it appears that correcting the length for the mill intake solves all the problems. After cross-referencing the figures obtained through the yard stock control tool with the on-field stock taking figures, results are closed enough. Some differences remain between each specification and diameter range, but they are acceptable. Besides, it is necessary to remember that the on-field stock taking does not pretend to be extremely accurate whereas data used in this programme are real calculation. Indeed, the grading line data, regarding the length and the diameter, come from the 3D scanner and can be considered reliable so. The mill gets also its scanner, just before the first chipper canter, which gives normally an accurate volume. . Therefore, graded stock data are extremely accurate.

In order to get the figures of the ungraded stock, it implies to convert the unit either from the weighbridge data or from the grading line; the first one being by weight whereas the other being by volume. In the stock control tool, weighbridge data are converted into volume unit, applying a constant factor of 1.1 m^3/t. Of course, this factor actually changes depending on the species, the origin of the product, the season, the weather conditions, etc…However this is considered as an average value for sitka spruce. AJS processing mainly the latter species, that is why the value of 1.1 was selected.

Finally, there are some constraints in order to make this tool running properly but the problems highlighted can be solved easily. The yard stock control tool gives an accurate picture of the stock and that can be done whenever the decision-maker desires it. He just needs to have a previous stock inventory and access to the different source of data for the period from the last inventory to the date wanted.

Conclusion

The analysis, undertaken during the first stage of my placement, allows highlighting the strengths and the weaknesses of AJS' business. With the current context of timber procurement in the UK in mind, it appears that AJS has a strong wood supply chain with a good and steady network of different supply sources: the Forestry Commission, the private sector forest companies and AJS' own harvesting activities.

However, future changes within the supply sources, especially with the likely end of Forestry Commission long term contract, forces its staff to plan to a longer term. The different round timber prices influence importantly the breakdown of the supply between each source. Besides, the payment facilities condition the preferable choices of sources. Thus, AJS should keep, and even strengthen its relationships with the major private sector companies (Euroforest, Tilhill, Scottish woodlands and Egger forestry), whilst reducing the purchase of roadside timber with the FC. The latter provides less payment facilities, prices generally higher and less flexibility regarding the completion to uplift the timber. With that in mind, it should be possible to keep on ensuring the supply of the quantity needed and it would bring more flexibility to it but also from an accountant point of view.

Flexibility is the key of the wood supply to the mill. In fact, AJS is a medium-size sawmill which encounters several difficulties. Since the new mill has been built, it is still commissioning after two years and its production is far from what was expected. Production varying a lot, so the volume supplied do. Contrary to many other of its competitors, AJS' business is totally customer-oriented. The wood supply management needs to consider the production level in order not to stock too much. Currently, there are rarely long runs with the same log specification because it gets quickly short of it. On one hand, wood supply is hold for responsible of the lack of the specifications desired. But on the other hand, decision-makers struggle planning the wood supply because of the very poor data flow between the production staff and the timber procurement staff. This is a kind of vicious circle, and both end with a relative high stock level.

During my placement, I identified several weak points which tend to keep a high stock level. The core problem I highlighted is the lack of production planning. This problem generates other problems, all connected to each other. I proposed three different tools in order to try to solve some of them. All of them are based on VBA codes and works under Excel. They present useful data helping the decision-maker in his choices.

Firstly, the timber procurement staff struggle in planning the wood supply. Ideally, he wood brought to the yard should match as close as possible to the orders cut. Therefore, the wood supply planning tool uses the order book data and converts them into round wood equivalent. There is an opportunity to ripen the result combining the production plan with the order book. For the moment this tool provides a rough guide of the raw material needed to fulfil the orders, but without any real deadline.

Secondly, there is a stock picture only at the end of each month. In order to improve the wood supply planning tool, an instant picture would be a plus. Since the company stores a lot of information throughout the supply and production chain, all the data needed to follow the stock level are already there. They just needed to be organised and presented on an easy way in order to simplify their use. That is what the yard stock control tool enables the decision

maker to do. Unfortunately, its function is not yet as simple as it should do because of mild problems. However, few efforts are required in order to avoid the latter ones.

Finally, the third decision support tool presented in the report deals with the cutting pattern. This tools starts to tackle the production organisation. It can be seen as multi-functional for the moment. First it helps the operator choosing the most appropriate log specification to fulfil an order. It might be used with the picture of the logs available in the yard in mind. This tool is now currently used in the sawmill. According to the people using it, this tool is really a useful guide. Besides, there are already future applications that are planned with the cutting pattern tool. The next step will be of course to set up a production planning, which was one of the biggest problems. The cutting pattern tool is expected, in this next step, to help in determining the cutting pattern which will be used to cut the products ordered. So it would be possible to establish a list of the top three best cutting patterns, for example, for each product and to store it in a database. Thereby, it would result in an improvement of the wood supply planning tool which data currently used for the conversion are not always accurate.

In conclusion, the decision support tools proposed in this thesis result in improving the stock control but also will help for the next step, production planning, which influences on the sock level too.

References

BEARDSELL, M.G. — Decreasing the cost of hauling timber through increased payload. — PhD dissertation, Virginia Polytechnic Institute and State Univ. — 1986, Blacksburg. — 133 p.

CHESTNUT R.W., JACOBY J. — Behavioural process research: concept and application in consumer decision making. In: Decision making: an interdisciplinary inquiry. — Boston, 1982. — Kent Publishing.

FAO. — Global forest resources assessment. — 2005
Available on the internet the 14/06/08 at:
http://www.fao.org/forestry/32089/en/gbr/

FORESTRY COMMISSION. — Direct production, despatch unit prices
Available on the internet the 29/05/08 at:
http://www.forestry.gov.uk/pdf/Despatch_Values_Apr08.pdf/$FILE/Despatch_Values_Apr08.pdf

FORESTRY COMMISSION. — Forest mensuration handbook, FC booklet nº 39. — London, 1975

FORESTRY COMMISSION. — Forestry facts and figures. — 2007
Available on the internet the 28/04/08 at:
http://www.forestry.gov.uk/pdf/fcfs207.pdf

HARTSELA P. — Decision Support Systems in Wood Procurement. A Review. — *Silva Fennica*, issue 31, n°2, p.215-223. — 1997.

HÖGNÄS T. — A Comparison of Timber Haulage in Great Britain and Finland. — Forestry Publications of Metsähallitus 39. — Vantaa, 2001. — 29 p.

KALLIO M., MANNINEN J., SALMI T., SALO S. — Computer-aided decision making in forestry. — Folia Forestalia 757.

MERILÄIEN A., SIKANEN L., HARTSELA P. — Puunhankinnan suunnittelujärjestelmät suomalaisissa puunhankintaorganisaatioissa. — Folia Forestalia 1995(1), p. 35-49. — 1995.

ROBAK E.W. — OR in forest operations: new environments, tools and approaches. — IUFRO XIX world congress Divison 3. — Montreal, 1990. — p. 9-19.

ROUNDWOOD HAULAGE WORKING PARTY. — Road Haulage of Round Timber, Code of practice. — FC, 2003
Available on the internet the 28/04/08 at:
http://www.ukfpa.co.uk/pdfs/CODE_OF_PRACTICE_2003.pdf

SCWEDER R.A. — Likeness and likelihood in everyday thought: marginal thinking in judgments about personality. Current Anthropometry 18. — 1977.

WIKIPEDIA. — Definition of Decision support system (DSS).
Available on the internet the 02/08/08 at:
http://en.wikipedia.org/wiki/Decision_support_system

Table of appendixes

Appendix 1: grading groups characteristics.

Group 1 Copy ofNEW 2.50 AND POST/SLPR										
Diameter		Length			Taper	Crock		Sorting to		
from	to	from	to	Final	limit	allowed	limit	1. box	2.box	Remarks
420	600	2.65	3.04	2.60	50	10	15	32		
400	420	2.65	3.04	2.60	15	5	7	31		
400	420	2.45	2.64	2.40	18	5	7	16		
380	400	2.65	3.04	2.60	23	5	7	30		
380	400	2.45	2.64	2.40	23	5	7	15		
360	380	2.65	3.04	2.60	28	5	7	29		
360	380	2.45	2.64	2.40	28	5	7	14		
340	360	2.65	3.04	2.60	38	5	7	28		
340	360	2.45	2.64	2.40	38	5	7	13		
320	340	2.75	3.04	2.70	38	5	7	27		
320	340	2.45	2.74	2.40	38	5	7	12		
300	320	2.75	3.04	2.70	38	5	7	26		
300	320	2.45	2.74	2.40	38	5	7	11		
280	300	2.75	3.04	2.70	38	5	7	25		
280	300	2.45	2.74	2.40	38	5	7	10		
260	280	2.75	3.04	2.70	40	5	7	24		
260	280	2.45	2.74	2.40	40	5	7	9		
240	260	2.75	3.04	2.70	40	5	7	23		
240	260	2.45	2.74	2.40	40	5	7	8		
220	240	2.75	3.04	2.70	40	5	7	22		
220	240	2.45	2.74	2.40	40	5	7	7		
200	220	2.75	3.04	2.70	40	5	7	21		
200	220	2.45	2.74	2.40	40	5	7	6		
180	200	2.75	3.04	2.70	40	5	7	20		
180	200	2.45	2.74	2.40	40	5	7	5		
160	180	2.75	3.04	2.70	40	5	7	19		
160	180	2.45	2.74	2.40	40	5	7	4		
140	600	2.30	2.44	2.20	50	5	7	17		
140	160	2.75	3.04	2.70	40	5	7	18		
140	160	2.45	2.74	2.40	40	5	7	3		

Group 11 sleepers timber										
Diameter		Length			Taper	Crock		Sorting to		
from	to	from	to	Final	limit	allowed	limit	1. box	2.box	Remarks
420	440	2.65	2.90	2.60	5	5	5	23		
400	420	2.65	2.90	2.60	15	5	7	21		
400	420	2.45	2.65	2.40	18	5	7	39		
380	400	2.65	2.90	2.60	25	5	7	20		
380	400	2.45	2.65	2.40	25	5	7	18		
360	380	2.65	2.90	2.60	30	5	7	17		
360	380	2.45	2.65	2.40	30	5	7	16		
340	360	2.65	2.90	2.60	40	5	7	15		
340	360	2.45	2.65	2.40	40	5	7	13		
320	340	2.65	2.90	2.60	40	5	7	12		
320	340	2.45	2.65	2.40	50	5	7	11		
300	320	2.65	2.90	2.60	50	5	7	10		
300	320	2.45	2.65	2.40	50	5	7	9		
280	300	2.65	2.90	2.60	50	5	7	7		
280	300	2.45	2.64	2.40	30	5	7	6		
260	280	2.65	2.90	2.60	50	5	7	5		
260	280	2.45	2.65	2.40	50	5	7	4		
240	260	2.65	2.90	2.60	50	5	7	3		
240	260	2.45	2.65	2.40	50	5	7	38		

Group 2 Copy of NEW 3.05 to 3.44 AND 3.45 to 3.69										
Diameter		Length			Taper	Crock		Sorting to		
from	to	from	to	Final	limit	allowed	limit	1. box	2.box	Remarks
400	420	3.45	3.69	3.40	10	5	7	28		
400	420	3.05	3.44	3.00	10	5	7	15		
380	400	3.45	3.69	3.40	15	5	7	27		
380	400	3.05	3.44	3.00	10	5	7	14		
360	380	3.45	3.69	3.40	20	5	7	26		
360	380	3.05	3.44	3.00	10	5	7	13		
340	360	3.45	3.69	3.40	20	5	7	25		
340	360	3.05	3.44	3.00	20	5	7	12		
320	340	3.45	3.69	3.40	30	5	7	24		
320	340	3.05	3.44	3.00	35	5	7	11		
300	320	3.45	3.69	3.40	35	5	7	23		
300	320	3.05	3.44	3.00	35	5	7	10		
280	300	3.45	3.69	3.40	35	5	7	22		
280	300	3.05	3.44	3.00	35	5	7	9		
260	280	3.45	3.69	3.40	35	5	7	21		
260	280	3.05	3.44	3.00	35	5	7	8		
230	260	3.45	3.69	3.40	30	5	7	20		
230	260	3.05	3.44	3.00	35	5	7	7		
200	230	3.45	3.69	3.40	35	5	7	19		
200	230	3.05	3.44	3.00	35	5	7	6		
180	200	3.45	3.69	3.40	35	5	7	18		
180	200	3.05	3.44	3.00	35	5	7	5		
160	420	2.65	3.05	2.60	30	5	7	30		
160	180	3.45	3.69	3.40	35	5	7	17		
160	180	3.05	3.44	3.00	35	5	7	4		
140	160	3.45	3.69	3.40	35	1	2	16		
140	160	3.05	3.44	3.00	35	5	7	3		

Group 3 Copy of NEW 3.70 to 4.04 AND 3.45 to 3.69										
Diameter		Length			Taper	Crock		Sorting to		
from	to	from	to	Final	limit	allowed	limit	1. box	2.box	Remarks
400	420	3.70	4.04	3.66	10	5	7	15		
400	420	3.45	3.69	3.40	10	5	7	28		
380	400	3.70	4.04	3.66	15	5	7	14		
380	400	3.45	3.69	3.40	15	5	7	27		
360	380	3.70	4.04	3.66	20	5	7	13		
360	380	3.45	3.69	3.40	20	5	7	26		
340	360	3.70	4.04	3.66	20	5	7	12		
340	360	3.45	3.69	3.40	20	5	7	25		
320	340	3.70	4.04	3.66	30	5	7	11		
320	340	3.45	3.69	3.40	30	5	7	24		
300	320	3.70	4.04	3.66	35	5	7	10		
300	320	3.45	3.69	3.40	35	5	7	23		
280	300	3.70	4.04	3.66	35	5	7	9		
280	300	3.45	3.69	3.40	35	5	7	22		
260	280	3.70	4.04	3.66	35	5	7	8		
260	280	3.45	3.69	3.40	35	5	7	21		
230	260	3.70	4.04	3.66	30	5	7	7		
230	260	3.45	3.69	3.40	30	5	7	20		
200	230	3.70	4.04	3.66	35	5	7	6		
200	230	3.45	3.69	3.40	35	5	7	19		
180	200	3.70	4.04	3.66	35	5	7	5		
180	200	3.45	3.69	3.40	35	5	7	18		
160	180	3.70	4.04	3.66	35	5	7	4		
160	180	3.45	3.69	3.40	35	5	7	17		
140	160	3.70	4.04	3.66	35	1	2	3		
140	160	3.45	3.69	3.40	35	1	2	16		

Group 4: 4.05 to 4.24										
Diameter		Length			Taper	Crock		Sorting to		
from	to	from	to	Final	limit	allowed	limit	1. box	2.box	Remarks
400	420	4.05	4.24	4.00	30	5	7	15		
380	400	4.05	4.24	4.00	30	5	7	14		
360	380	4.05	4.24	4.00	30	5	7	13		
340	360	4.05	4.24	4.00	30	5	7	12		
320	340	4.05	4.24	4.00	30	5	7	11		
300	320	4.05	4.24	4.00	30	5	7	10		
280	300	4.05	4.24	4.00	30	5	7	9		
260	280	4.05	4.24	4.00	30	5	7	8		
230	260	4.05	4.24	4.00	30	5	7	7		
200	230	4.05	4.24	4.00	30	5	7	6		
180	200	4.05	4.24	4.00	30	5	7	5		
160	180	4.05	4.24	4.00	30	5	7	4		
140	420	4.25	4.45	4.10	30	5	7	16		
140	420	3.70	4.05	3.60	30	5	7	3		

Group 5 Copy of NEW 4.25 to 4.44										
Diameter		Length			Taper	Crock		Sorting to		
from	to	from	to	Final	limit	allowed	limit	1. box	2.box	Remarks
400	420	4.25	4.44	4.20	30	5	7	15		
380	400	4.25	4.44	4.20	30	5	7	14		
360	380	4.25	4.44	4.20	30	5	7	13		
340	360	4.25	4.44	4.20	30	5	7	12		
320	340	4.25	4.44	4.20	30	5	7	11		
300	320	4.25	4.44	4.20	30	5	7	10		
280	300	4.25	4.44	4.20	30	5	7	9		
260	280	4.25	4.44	4.20	30	5	7	8		
230	260	4.25	4.44	4.20	30	5	7	7		
200	230	4.25	4.44	4.20	30	5	7	6		
180	200	4.25	4.44	4.20	30	5	7	5		
160	180	4.25	4.44	4.20	30	5	7	4		
140	420	4.45	4.65	4.30	30	5	7	16		
140	420	4.05	4.25	4.00	30	5	7	3		

Group 6 Copy of NEW 4.45 to 4.64										
Diameter		Length			Taper	Crock		Sorting to		
from	to	from	to	Final	limit	allowed	limit	1. box	2.box	Remarks
400	420	4.45	4.64	4.40	30	5	7	15		
380	400	4.45	4.64	4.40	30	5	7	14		
360	380	4.45	4.64	4.40	30	5	7	13		
340	360	4.45	4.64	4.40	30	5	7	12		
320	340	4.45	4.64	4.40	30	5	7	11		
300	320	4.45	4.64	4.40	30	5	7	10		
280	300	4.45	4.64	4.40	30	5	7	9		
260	280	4.45	4.64	4.40	30	5	7	8		
230	260	4.45	4.64	4.40	30	5	7	7		
200	230	4.45	4.64	4.40	30	5	7	6		
180	200	4.45	4.64	4.40	20	5	7	5		
160	180	4.45	4.64	4.40	30	5	7	4		
140	420	4.65	4.85	4.60	30	5	7	16		
140	420	4.25	4.45	4.10	30	5	7	3		

Group 7 Copy of NEW 4.65 to 4.84										
Diameter		Length			Taper	Crock		Sorting to		
from	to	from	to	Final	limit	allowed	limit	1. box	2.box	Remarks
400	420	4.65	4.84	4.60	30	5	7	15		
380	400	4.65	4.84	4.60	30	5	7	14		
360	380	4.65	4.84	4.60	30	5	7	13		
340	360	4.65	4.84	4.60	30	5	7	12		
320	340	4.65	4.84	4.60	30	5	7	11		
300	320	4.65	4.84	4.60	30	5	7	10		
280	300	4.65	4.84	4.60	30	5	7	9		
260	280	4.65	4.84	4.60	30	5	7	8		
230	260	4.65	4.84	4.60	30	5	7	7		
200	230	4.65	4.84	4.60	30	5	7	6		
180	200	4.65	4.84	4.60	30	5	7	5		
160	180	4.65	4.84	4.60	30	5	7	4		
140	420	4.85	4.98	4.80	30	5	7	16		
140	420	4.45	4.65	4.30	30	5	7	3		

Group 8 Copy of NEW 4.85 to 4.98										
Diameter		Length			Taper	Crock		Sorting to		
from	to	from	to	Pinal	limit	allowed	limit	1. box	2.box	Remarks
400	420	4.85	4.98	4.80	5	5	7	15		
380	400	4.85	4.98	4.80	10	5	7	14		
360	380	4.85	4.98	4.80	10	5	7	13		
340	360	4.85	4.98	4.80	15	5	7	12		
320	340	4.85	4.98	4.80	15	5	7	11		
300	320	4.85	4.98	4.80	20	5	7	10		
280	300	4.85	4.98	4.80	25	5	7	9		
260	280	4.85	4.98	4.80	30	5	7	8		
230	260	4.85	4.98	4.80	30	5	7	7		
200	230	4.85	4.98	4.80	30	5	7	6		
180	200	4.85	4.98	4.80	30	5	7	5		
160	180	4.85	4.98	4.80	30	5	7	4		
140	420	4.65	4.85	4.60	30	5	7	3		

Appendix 2: product specifications and quantity ordered by Forest Garden Plc. in 2007.

Product	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07	Nov-07	Dec-07	Grand Tota
SAWN U/T 1828 X 40 X 15 CAPPIN	265.15	416.78	496.30	370.17	312.59	370.17	441.46	222.10	222.10	315.33	348.23	27.42	3807.82
SAWN U/T 2400 X 100 X 100	217.80	234.30	118.80	59.40	131.22	166.68	209.34	580.62	188.10	417.96	302.28	250.80	2877.30
SAWN U/T 1762 X 31 X 15.5	39.58		205.10	194.30	568.52	507.35	305.85	219.49		25.19	176.31	21.59	2263.28
SAWN U/T 1828 X 36 X 18		342.04	550.81	324.27	155.47	133.26	137.70	75.51					1719.07
SAWN U/T 1722 X 31 X 15.5			189.89	214.51	116.05	200.44	298.91	203.96		28.13	133.63	31.65	1417.17
SAWN U/T 1417 X 31 X 15.5	75.24	31.83	46.30	89.70	8.68	162.05	231.50			69.45	211.24	52.09	978.07
SAWN U/T 1624 X 28 X 28	11.46	126.05	87.85	112.55	124.14	66.84	89.76	85.94	97.40	118.41	15.28	13.37	949.06
SAWN U/T 3000 X 200 X 100 SQ	127.88	53.63	325.88	24.75					33.00	115.50	132.00		812.63
SAWN U/T 1500 X 75 X 75	171.28	66.45	106.46	164.40	91.25	147.61	6.64	0.00					754.10
SAWN U/T 1746 X 31 X 15.5	14.26		96.27	96.27	153.32	178.28	121.23			24.96	60.61		745.20
SAWN U/T 1828 X 050 X 018 CAP	34.55	140.22	118.27	74.03	54.29	74.03	98.71	54.29	22.21	14.81			685.43
SAWN U/T 1728 X 28 X 28	24.39	60.96	60.96	64.96	79.25	81.29	14.22	52.84	54.87	79.25	14.22	14.22	601.44
SAWN U/T 2400 X 245 X 120		59.27	156.64	50.80						176.40	153.82		596.94
SAWN U/T 1636 X 28 X 28 1 ANG	11.54	48.10	53.87	98.12	30.78	32.71	69.26	38.48	44.25	71.19	13.47	13.47	525.23
SAWN U/T 3000 X 75 X 75	12.40	90.07	35.44	172.08	134.20	73.83	2.70						520.72
SAWN U/T 3000 X 150 X 22 G/B	22.28	120.78	71.28	62.35	48.31	94.97			17.57	14.63	28.86	25.39	506.41
SAWN U/T 1810 X 31 X 15.5			96.10		96.10	99.80		92.41		22.18	62.84	22.18	491.60
SAWN U/T 0900X68X16 GROOVE R/T	29.52	28.20	18.80	79.90	39.95	21.15	61.10	57.86	61.10	39.95	25.85	7.05	470.45
SAWN U/T 1505 X 31 X 15.5	52.25	18.44		94.73	95.28	49.17	27.66			46.10	82.98		466.61
SAWN U/T 1660 X 45 X 15	27.45	63.87	53.78	77.31	13.45	26.89	67.23	20.17	36.98	77.31			464.45
SAWN U/T 1441 X 31 X 15.5	29.43		29.43		58.85	153.02				88.28	38.26	38.26	435.52
SAWN U/T 2700 X 75 X 75	37.21		94.88	59.80			53.16	64.85		33.30	14.88	27.91	385.99
SAWN U/T 2400 X 45 X 28	55.19				101.19	15.12	72.58	5.41	32.66	39.52	34.63	17.77	374.06
SAWN U/T 2400 X 150 X 47					109.98		100.12	33.71		38.41	73.77		356.00
SAWN U/T 1300 X 245 X 120	45.86		50.45	151.35	9.17						22.93	45.86	325.63
SAWN U/T 1500 X 50 X 50		79.11	25.89	33.38	35.10	20.62	55.88	14.78		21.77	18.75	18.75	324.03
SAWN U/T 2100 X 100 X 100	28.88	2.89	14.44	23.10	117.18	23.84	46.20	28.88			14.44	17.33	317.15
SAWN GRN 2400 X 75 X 75	17.45	20.25	39.89	33.58	36.48	33.82	32.67	18.63	12.05	22.98	23.05	8.47	299.33
SAWN U/T 3000X75X75 7 NOTCHES	22.74		48.14	24.76	22.15		42.82		17.63		80.49	37.88	296.62
SAWN U/T 1219 2EX 125 X 19	14.83	15.59			65.93	29.86	86.84		13.93		27.85	30.24	285.06
SAWN U/T 2700 X 100 X 100	14.85		111.38	51.98	29.70		44.55					14.85	267.30
SAWN U/T 1828 X 72 X 22 GROOVE	10.13	15.20	25.92	32.72	32.48	20.27	35.47	36.72	20.27	15.20	5.07	15.20	264.65
SAWN U/T 1800 X 100 X 100	116.33				43.97					36.50	27.81	39.60	264.20
SAWN U/T 3658 X 087 X 038		19.65	56.39		49.89	57.44			62.10	0.00		16.39	261.85
SAWN U/T 1110 X 31 X 15.5		11.33		54.40	40.80	79.42	11.33			27.20	27.20		251.69
SAWN U/T 1527 X 28 X 28	7.18	12.57	12.57	52.08	50.28	25.14	3.59	14.37	25.14	25.14	10.77		238.84
SAWN U/T 1452 X 28 X 28		13.66	29.03	52.93	27.32	20.49	17.08	18.78		13.66	13.66		206.61
SAWN U/T 0615 X 28 X 28 2 ANG	20.97	13.74	13.02	41.22	26.04		26.76	14.46	22.42	26.28			204.92
SAWN U/T 1762 X 32 X 16			172.63										172.63
SAWN U/T 1135 X 28 X 28	22.69	13.35	13.35	26.70	13.35	13.35	13.35	13.35	24.03	13.35			166.85
SAWN U/T 1828 X 44 X 15.5					63.58		97.24						160.82
SAWN U/T 3000 X 75 X 50	18.73		25.26	25.93					16.88		34.26	27.84	148.89
SAWN U/T 1855 X 28 X 28	2.18	28.36		26.18	17.45	13.09		13.09	26.18	13.09			139.61
SAWN U/T 1828 X 75 X 35 BRS							48.37	43.46			29.01	13.32	134.15
SAWN U/T 1810 X 32 X 16			19.69	106.34									126.03
SAWN U/T 1200 X 75 X 75	45.56		17.77		32.87						22.98		119.19
SAWN U/T 0730 X 70 X 08 1 ANG	10.02	4.29	13.88	15.61	12.22		14.31	7.15	13.92	25.75			117.15
SAWN U/T 1828 X 35 X 17											48.94	61.18	110.13
SAWN U/T 2420 X 125 X 015					107.09								107.09
SAWN U/T 1820 X 28 X 28		12.84	12.84	25.68		12.84	12.84	12.84	4.28	12.84			107.02
SAWN U/T 1200 X 31 X 15.5				39.21	29.41	12.92				7.35	14.70		103.59
SAWN U/T 1286 X 28 X 28 2 ANG	7.56		15.12	10.59	13.61	16.64		13.61		24.20			101.33
SAWN U/T 1134 X 32 X 16			59.25	29.61									88.86
SAWN U/T 1828 X 44 X 16			88.48										88.48
SAWN U/T 1800 2EX 100 X 22 FEB							84.14						84.14
SAWN U/T 2038 X 60 X 36								63.06	19.61				82.67
SAWN U/T 1422 X 050 X 030			16.00	-0.01	26.37		26.58			12.66			81.61
SAWN U/T 1828 X 95 X 18				34.11	35.56					11.52			81.19
SAWN U/T 1545 X 28 X 28 1 ANG	3.63		12.72	12.72	29.07		9.08		12.72				79.94
SAWN U/T 1828X050X018 FLAT CAP											34.55	39.48	74.03
SAWN U/T 1470 X 28 X 28 1 ANG		12.10	3.46	20.74		13.83	8.64				13.83		72.61
SAWN U/T 2400 X 50 X 50					72.48								72.48
SAWN U/T 1660 X 28 X 15	5.23	18.82	6.27		16.73		12.55		12.55				72.15
SAWN U/T 0900 X 125 X 18		12.28	41.76	17.49									71.53
SAWN U/T 1828 X 75 X 08		7.68	27.74	22.05	13.98								71.45
SAWN U/T 0805 X 31 X 15.5			1.64		19.73	8.22				26.30	14.80		70.69
SAWN U/T 1417 X 32 X 16			41.75	24.67									66.42
SAWN U/T 0640 X 28 X 28			12.79	12.79	12.04	14.30			13.55				65.48
SAWN U/T 1763 X 028 X 028				63.58									63.58
SAWN U/T 1828 X 040 X 015 CAP											63.07		63.07
SAWN U/T 2440X75X34 NOTCHED					32.35		15.71	14.93					63.00
SAWN U/T 1244 X 28 X 28	2.93			13.17	11.70	8.78				24.87			61.44
SAWN U/T 1746 X 32 X 16			60.79										60.79
SAWN U/T 1982 X 125 X 08				13.64	16.05		12.13			16.05			57.87
SAWN U/T 1784 X 45 X 28						37.09	13.49			6.74			57.32
SAWN U/T 0658 X 28 X 28			7.74	13.93			12.38			13.93			47.98
SAWN U/T 2105 X 60 X 36							45.79						45.79
SAWN U/T 2400X75X75 NOTCHED				24.54		20.05							44.58
SAWN U/T 0594 X 28 X 28	11.18			11.88			11.18			9.78			44.01
SAWN U/T 1441 X 32 X 16			37.63	6.27									43.90
SAWN U/T 0805 X 32 X 16			31.53	12.26									43.79
SAWN U/T 1828 X 050 X 030							15.79	27.15					42.94
SAWN U/T 3000 X 100 X 100											41.25		41.25
SAWN U/T 1251 X 28 X 28 1 ANG				13.24	13.24					14.71			41.19
SAWN U/T 0832 X 31 X 15.5	1.70		13.59		11.89					13.59			40.78
SAWN GRN 3658 X 087 X 038							40.66						40.66
SAWN U/T 1636 X 28 X 28	13.47			26.94									40.40
SAWN U/T 1110 X 32 X 16			38.65										38.65
SAWN U/T 1616 X 028 X 028				38.01									38.01
SAWN U/T 1290 X 45 X 15			10.45	10.45				13.58					34.48
SAWN U/T 1525 X 060 X 036							32.86						32.86
SAWN U/T 0744 X 28 X 28				13.12	14.00	5.25							32.37
SAWN U/T 0303 X 35 X 17	8.11				9.46	2.70					4.73	6.76	31.78
SAWN U/T 1270 X 28 X 28 2 ANG			13.44			16.43							29.87
SAWN U/T 0896 X 31 X 15.5			3.66			12.81				12.81			29.28
SAWN U/T 1689 X 28 X 28		13.90				13.90							27.81
SAWN U/T 1722 X 32 X 16			11.29	14.99									26.27
SAWN GRN 2700X100X50 PERGOLA							12.08				13.87		25.95
SAWN U/T 1600 X 45 X 15				12.96		12.96							25.92
SAWN GRN 2700X100X100 1 NOTCH							12.22				13.57		25.79
SAWN U/T 0610 X 100 X 50 2 ANG	2.29		13.62		2.75	2.02							20.67
SAWN GRN 3000 X 075 X 050							20.25						20.25
SAWN U/T 1725 X 050 X 030								20.07					20.07
SAWN U/T 1134 X 31 X 15.5	4.63										13.89		18.53
SAWN U/T 2285 X 028 X 028				17.91									17.91
SAWN U/T 1828 X 045 X 028						17.27							17.27
SAWN U/T 0914 X 31 X 15.5			11.20		5.60								16.80
SAWN U/T 1117 X 50 X 30	4.19	12.57											16.76
SAWN GRN 2700 X 075 X 075							16.74						16.74
SAWN U/T 1753 X 028 X 028				16.49									16.49
SAWN U/T 1785 X 060 X 036							16.29						16.29
SAWN U/T 3050 X 45 X 28						15.37							15.37
SAWN U/T 2415 X 045 X 028						15.21							15.21
SAWN U/T 0890 X 50 X 34		15.13											15.13
SAWN U/T 2100 X 050 X 050								9.66	5.25				14.91
SAWN U/T 1100 X 61 X 08 1 ANG				10.91				3.76					14.67
SAWN U/T 0832 X 32 X 16				14.48									14.48
SAWN U/T 2100 X 175 X 175					13.51								13.51
SAWN U/T 1630 X 28 X 28					13.42								13.42
SAWN U/T 1419 X 28 X 28						13.35							13.35
SAWN U/T 1800 X 143 X 143			13.25										13.25
SAWN U/T 0840X68X16 GROOVE R/T	2.19			2.19		2.19	2.19	2.19	2.19				13.16
SAWN U/T 0520 X 28 X 28				12.84									12.84
SAWN U/T 1660 X 45 X 28					12.15								12.15
SAWN U/T 1290 X 20 X 15				12.09									12.09
SAWN U/T 0896 X 32 X 16			11.70										11.70
SAWN U/T 0870X68X16 GROOVE R/T	2.27			2.27		2.27	2.27	2.27					11.36
SAWN U/T 1828 X 44 X 15.5 CAP	11.22												11.22
SAWN U/T 1800 X 75 X 75				10.63									10.63
SAWN U/T 1200 X 32 X 16			10.44										10.44
SAWN U/T 0810X68X16 GROOVE R/T				2.12		2.12	2.12	2.12					8.46
SAWN U/T 0780X68X16 GROOVE R/T			2.04			2.04	2.04					2.04	8.15
SAWN U/T 1505 X 32 X 16			7.40										7.40
SAWN U/T 0750X68X16 GROOVE R/T	1.96			1.84				1.43	1.84				7.06
SAWN GRN 0900X68X16 GROOVE R/T											2.35	4.70	7.05
SAWN GRN 0610 X 100 X 50 2 ANG											6.89		6.89
SAWN U/T 2400 X 75 X 75					6.68								6.68
SAWN U/T 1630 X 75 X 50	6.42												6.42
SAWN U/T 1828 X 32 X 16			5.99										5.99
SAWN GRN 1828 X 72 X 22 GROOVE											5.07		5.07
SAWN U/T 1340 X 028 X 028				4.20									4.20
SAWN U/T 0914 X 32 X 16			3.98										3.98
SAWN U/T 0814 X 050 X 030	3.05												3.05
SAWN U/T 2700X100X100 1 NOTCH				10.73		-10.73							0.00
SAWN U/T 2700 X 100 X 50					9.08	-9.08							0.00
Grand Total	**1749.28**	**2256.31**	**4351.01**	**3894.03**	**3796.80**	**3252.73**	**3425.63**	**2217.98**	**1136.77**	**2304.53**	**2572.96**	**963.05**	**31921.08**

Appendix 3: optimal log length associated to the final product.

sawn pr oduct length Interval (mm)	Optimal log le ngth (m)
701-750	3.1
751-800	2.5
801-850	3.5
851-866	2.7
867-915	3.7
916-1000	3.1
1001-1050	4.3
1051-1100	4.5
1101-1133	3.5
1134-1150	4.7
1151-1200	2.5
1201-1220	3.7
1221-1300	2.7
1301-1333	4.1
1334-1400	4.3
1401-1466	4.5
1467-1500	3.1
1501-1533	4.7
1534-1600	4.9
1601-1700	3.5
1701-1830	3.7
1831-2000	4.1
2001-2100	4.3
2101-2200	4.5
2201-2300	4.7
2301-2400	2.5
2401-2600	2.7
2601-3000	3.1
3001-3400	3.5
3401-3660	3.7
3661-4000	4.1
4001-4200	4.3
4201-4400	4.5
4401-4600	4.7
4601-4800	4.9

Appendix 4: VBA code for the wood supply planning tool.

```
Sub ConvertWRME_Click()

If Not SheetExists("Weekly supply") Then
   ActiveWorkbook.Worksheets.Add.Name = "Weekly supply"
   Sheets("Weekly supply").Move after:=Sheets(2)
End If

Dim OS, WS As Worksheet
Set OS = Sheets("OS orders")
Set WS = Sheets("Weekly supply")


Dim FilteredRange, FilteredCell As Range

Dim rowCount, minWeek, maxWeek, check As Integer
rowCount = OS.Range("A1").CurrentRegion.Rows.Count
OS.Select
Range("T2:T"  & r  owCount).Replace W  hat:="", R  eplacement:="0",  LookAt:=xlPart,
SearchOrder:= _
      xlByRows, MatchCase:=False, SearchFormat:=False, ReplaceFormat:=False
With OS
   .Range("R1").Formula = "Source part"
   .Range("R2").Formula =  "  =INDEX('PART C  ODES'!A:K,MATCH(E2,'PART
CODES'!A:A,0),10)"
   '.Range("R2").Formula =  "  =IF(ISERROR(INDEX('PART
CODES'!A:K,MATCH(E2,'PART C  ODES'!A:A,0),10)),""  -  "",INDEX('PART
CODES'!A:K,MATCH(E2,'PART CODES'!A:A,0),10))"
   .Range("R2").Copy
   .Range("R2:R" & rowCount).Select
   ActiveSheet.Paste
   Selection.Copy
   Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
      :=False, Transpose:=False

   .Range("S1").Formula = "m3 part"
   .Range("S2").Formula =  "  =IF(ISERROR(INDEX('PART
CODES'!A:K,MATCH(E2,'PART C  ODES'!A:A,0),11)*N2),""  -  "",INDEX('PART
CODES'!A:K,MATCH(E2,'PART CODES'!A:A,0),11)*N2)"
   .Range("S2").Copy
   .Range("S2:S" & rowCount).Select
   ActiveSheet.Paste
   Selection.Copy
   Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
      :=False, Transpose:=False
  .Range("T1:T" & rowCount).Select
   minWeek = Application.WorksheetFunction.Subtotal(5, .Range("T1:T" & rowCount))
   maxWeek = Application.WorksheetFunction.Max(.Range("T1:T" & rowCount))

   r = 2
```

```
    For i = minWeek To maxWeek

        .Cells.AutoFilter field:=20, Criteria1:=i

        Dim source()
        ReDim Preserve source(0)
        source(0) = .Range("R1").Value
        Set FilteredRange = .Range("R1:R" & rowCount).SpecialCells(xlCellTypeVisible)
        .Range("R1:R" & rowCount).SpecialCells(xlCellTypeVisible).Select

        For Each FilteredCell In FilteredRange
            If Application.WorksheetFunction.IsError(FilteredCell.Value) Then
                'if an order does not match with any source part this warns the user
                MsgBox ("Check orders: row number " & FilteredCell.Row & " does not match
with any source part (it will be ignored)")
            Else
                check = 0
                For j = 0 To UBound(source)
                    If FilteredCell.Value = source(j) Then
                        check = check + 1
                        Exit For
                    End If
                Next

                'if the source part code has not been encoutered yet
                If check = 0 Then
                    ReDim Preserve source(UBound(source) + 1)
                    source(UBound(source)) = FilteredCell.Value
                    .Cells.AutoFilter field:=18, Criteria1:=FilteredCell.Value

                    If i <> 0 Then
                    WS.Range("A" & r).Formula = "Week " & i
                    Else: WS.Range("A" & r).Formula = "Summary"
                    End If
                    WS.Range("B" & r).Formula = FilteredCell.Value
                    WS.Range("C" & r).Formula = "=SUBTOTAL(9,'OS orders'!S:S)"
                    WS.Range("C" & r).Copy
                    WS.Range("C" & r ).PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
                    :=False, Transpose:=False
                        r = r + 1
                    .Cells.AutoFilter field:=18
                End If
            End If
        Next FilteredCell
        .Cells.AutoFilter

    Next
End With

'sort the result per week and per ascending lengths and diameter ranges
WS.Select
```

```
WS.Range("A1").Select
Dim rowCount2 As Integer
rowCount2 = WS.Range("A1").End(xlDown).Row
ActiveWorkbook.Worksheets("Weekly supply").Sort.SortFields.Add Key:=Range( _
      "A2:A" & rowCount2), SortOn:=xlSortOnValues, Order:=xlAscending, DataOption:= _
      xlSortNormal
   ActiveWorkbook.Worksheets("Weekly supply").Sort.SortFields.Add Key:=Range( _
      "B2:B" & rowCount2), SortOn:=xlSortOnValues, Order:=xlAscending, DataOption:= _
      xlSortNormal
   With ActiveWorkbook.Worksheets("Weekly supply").Sort
      .SetRange Range("A1:C" & rowCount2)
      .Header = xlYes
      .MatchCase = False
      .Orientation = xlTopToBottom
      .SortMethod = xlPinYin
      .Apply
   End With

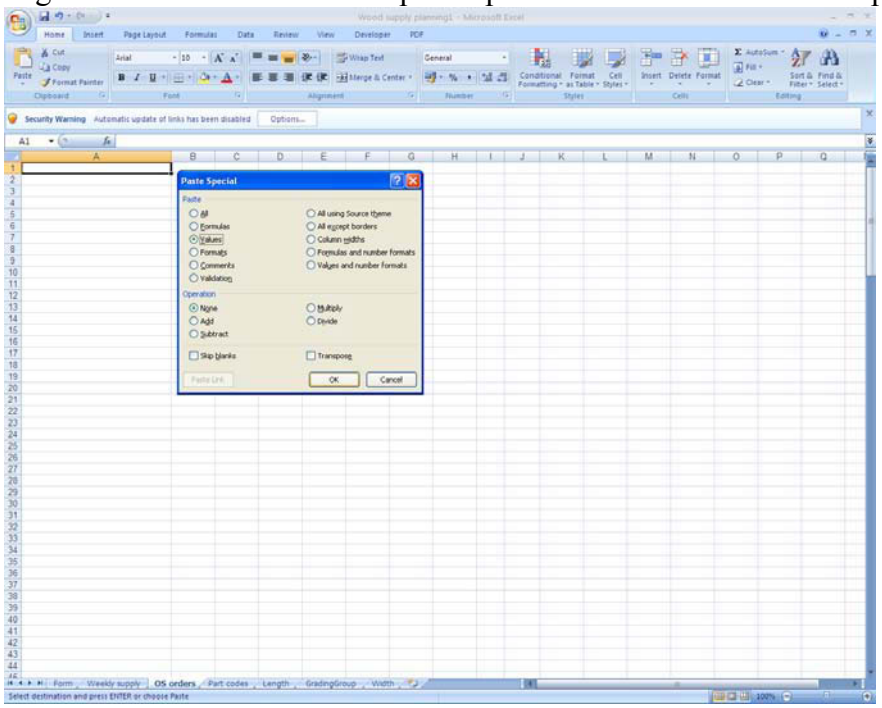
   Range("A1:C" & rowCount2).Select
   Selection.Borders(xlDiagonalDown).LineStyle = xlNone
   Selection.Borders(xlDiagonalUp).LineStyle = xlNone
   With Selection.Borders(xlEdgeLeft)
      .LineStyle = xlContinuous
      .ColorIndex = xlAutomatic
      .TintAndShade = 0
      .Weight = xlThin
   End With
   With Selection.Borders(xlEdgeTop)
      .LineStyle = xlContinuous
      .ColorIndex = xlAutomatic
      .TintAndShade = 0
      .Weight = xlThin
   End With
   With Selection.Borders(xlEdgeBottom)
      .LineStyle = xlContinuous
      .ColorIndex = xlAutomatic
      .TintAndShade = 0
      .Weight = xlThin
   End With
   With Selection.Borders(xlEdgeRight)
      .LineStyle = xlContinuous
      .ColorIndex = xlAutomatic
      .TintAndShade = 0
      .Weight = xlThin
   End With
   With Selection.Borders(xlInsideVertical)
      .LineStyle = xlContinuous
      .ColorIndex = xlAutomatic
      .TintAndShade = 0
      .Weight = xlThin
   End With
   With Selection.Borders(xlInsideHorizontal)
```

```
        .LineStyle = xlContinuous
        .ColorIndex = xlAutomatic
        .TintAndShade = 0
        .Weight = xlThin
    End With

End Sub
Function SheetExists(SheetName As String) As Boolean
' returns TRUE if the sheet exists in the active workbook
    SheetExists = False
    On Error GoTo NoSuchSheet
    If Len(Sheets(SheetName).Name) > 0 Then
        SheetExists = True
        Exit Function
    End If
NoSuchSheet:
End Function
```

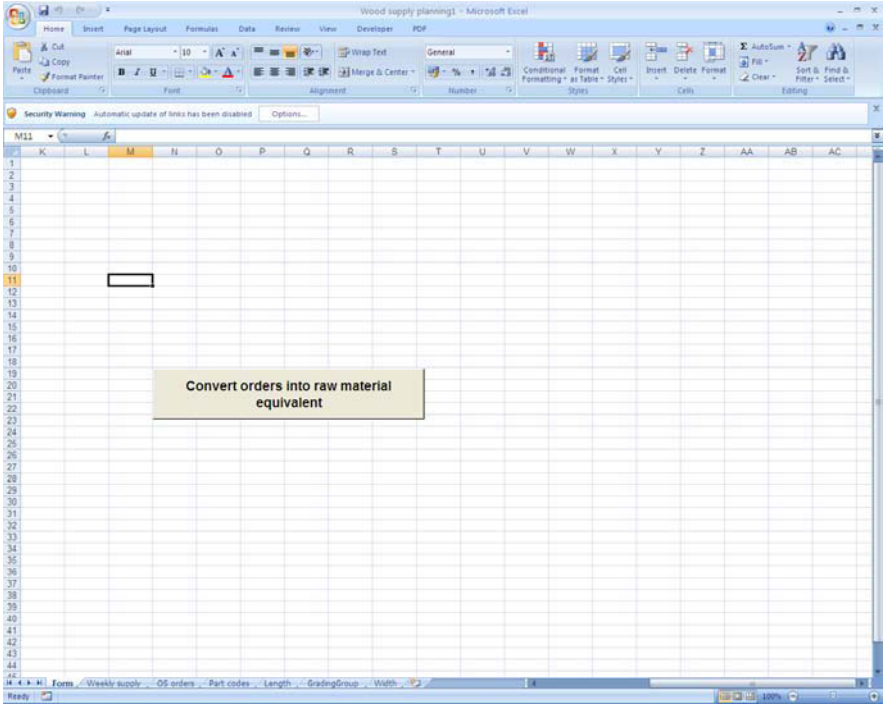
Appendix 5: wood supply planning tool user guide.

Open the Excel template file named ***Wood supply planning***.
Get and copy the data of the out standing orders from the order book, including the headers.
Activate ***Wood supply planning*** window and select ***OS orders*** sheet.
Right-click on the cell **A1** and paste special with the value of the copied orders data.

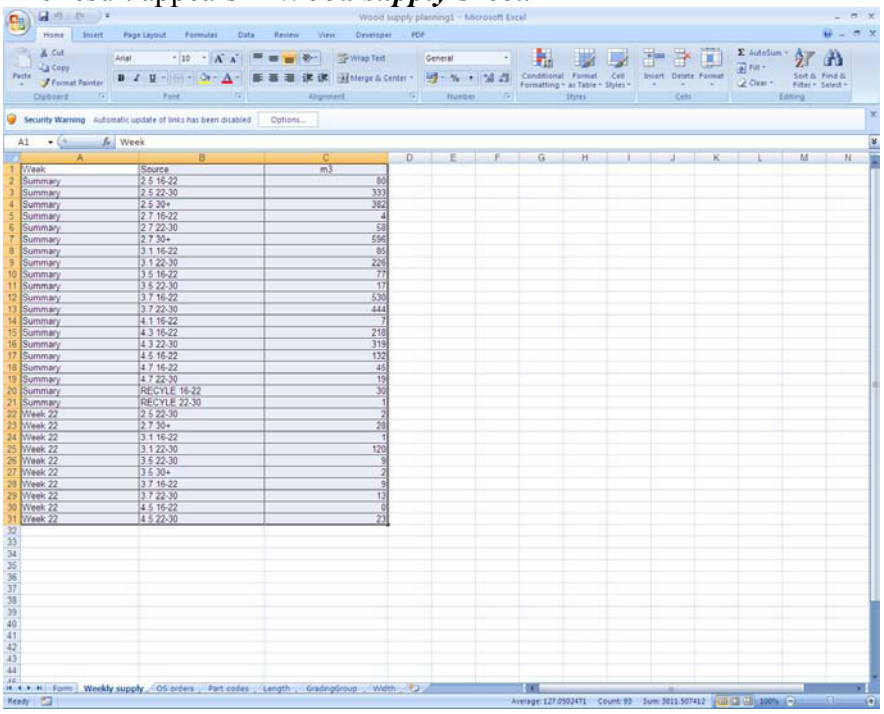


This step is not compulsory. You can allocate in front of each order the week number it will be dealt writing it in the column **T** and the row corresponding to the order. In this case the orders which were allocated the same week will be considered jointly in the result.
If you choose to plan per week but you do not plan for the whole out standing orders then the remainder will be processed together under the name of "Summary".

Select ***Form*** sheet and click on the button “Convert orders into raw material equivalent”



The result appears in ***Wood supply*** sheet.



Save the file with the name the path desired.

Appendix 6: function of the yard stock control tool.

To reduce the time needed as well as fastidious manipulation on dozens of excel spreadsheet containing data required to assess the stock, I opted for writing many of those manipulations under Visual Basic for Editor.

Weighbridge data processing

The weighbridge data processing steps can be described as follows:

1) Daily delivery tickets have to be saved as *.csv format file in a folder specially created to contain only those files.
2) .The user select folder path where *.csv files are stored and those are gathered in a unique spreadsheet to make data utilisation possible. This excel file location is saved by default.
3) Copy of this spreadsheet data in *W_list* sheet in the yard stock template excel file.
4) The user has to input the dates of beginning and end of the period concerned by the inventory since the last update. It is necessary to filter data because daily delivery tickets are stored in a weekly spreadsheet, therefore data may include previous or following days from the studied period.
5) Data in this *W_list* sheet are processed and result in a second spreadsheet, *WeighB,* which stores weighbridge logs throughput breaking down by species, length specifications, diameter range, and associate the quantity of logs supplied to the mill for each of these categories.
6) WeighB sheet data serves of source to fill automatically *W_input* sheet which presents all products specifications the mill is used to be supplied with and the quantity of each supplied during the period studied.

The user is highly used to realise this sequence because steps from two to five included are done through an excel macro execution merely after the user click on "Update weighbridge data" button which is located in Form sheet of the yard stock template excel workbook. This button activates a macro (Appendix 6: VBA code behind the Weighbridge button.).The user only needs to follow user manual instructions and pop-up windows appearing before his eyes on the screen.

Grading line data processing

In the same manner, grading line data processing steps may be summed up as follows:

1) Daily grading line throughput files, already in a *.csv format, must be copied into a folder created only to receive those files.
2) The user select folder path where *.csv files are stored and those are gathered in a unique spreadsheet to make data utilisation possible. This excel file location is saved by default.
3) Data in this sheet are processed and result in a breakdown by category sorting (graded or rejected), species (spruce or mixed conifers), length specifications, diameter range, and the volume associated to each of these categories. Those data are stored in a second sheet in this workbook called grading analysis.
4) Copy of grading analysis spreadsheet data in *Grading* sheet in yard stock template excel workbook.
5) Grading sheet data serves of source to fill automatically *G_input* sheet which presents all products specifications the mill is used to be supplied with and the quantity of each supplied during the period studied.

Steps from two to four are assisted for the user thanks VBA codes; the user only need to click on "Update grading line throughput" button which activate a macro (Appendix 7: VBA code for the grading line button.).

Appendix 7: VBA code behind the Weighbridge button.

```
Declare Function OpenProcess Lib "kernel32" _
                             (ByVal dwDesiredAccess As Long, _
                              ByVal bInheritHandle As Long, _
                              ByVal dwProcessId As Long) As Long

Declare Function GetExitCodeProcess Lib "kernel32" _
                                    (ByVal hProcess As Long, _
                                     lpExitCode As Long) As Long

Public Const PROCESS_QUERY_INFORMATION = &H400
Public Const STILL_ACTIVE = &H103
```

```
Function SheetExists(SheetName As String) As Boolean
' returns TRUE if the sheet exists in the active workbook
    SheetExists = False
    On Error GoTo NoSuchSheet
    If Len(Sheets(SheetName).Name) > 0 Then
        SheetExists = True
        Exit Function
    End If
NoSuchSheet:
End Function
```

```
Public Sub ShellAndWait(ByVal PathName As String, Optional WindowState)
    Dim hProg As Long
    Dim hProcess As Long, ExitCode As Long
    'fill in the missing parameter and execute the program
    If IsMissing(WindowState) Then WindowState = 1
    hProg = Shell(PathName, WindowState)
    'hProg is a "process ID under Win32. To get the process handle:
    hProcess = OpenProcess(PROCESS_QUERY_INFORMATION, False, hProg)
    Do
        'populate Exitcode variable
        GetExitCodeProcess hProcess, ExitCode
        DoEvents
    Loop While ExitCode = STILL_ACTIVE
End Sub
```

```
Sub WeighBThroughput()
    Dim BatFileName As String
    Dim TXTFileName As String
    Dim XLSFileName As String
    Dim FileExtStr As String
    Dim FileFormatNum As Long
    Dim DefPath As String
    Dim Wb As Workbook
    Dim oApp As Object
    Dim oFolder
    Dim foldername

    'Create two temporary file names
    BatFileName = Environ("Temp") & _
            "\CollectCSVData" & Format(Now, "dd-mm-yy-h-mm-ss") & ".bat"
    TXTFileName = "PER_DAY_SPREADSHEET" '"\AllCSV" & Format(Now, "dd-mm-yy-h-mm-ss") & ".txt"
    'Environ("Temp") & _

    'Folder where you want to save the Excel file
    DefPath = Application.DefaultFilePath
    If Right(DefPath, 1) <> "\" Then
        DefPath = DefPath & "\"
    End If

    'Set the extension and file format
    If Val(Application.Version) < 12 Then
        'You use Excel 97-2003
        FileExtStr = ".xls": FileFormatNum = -4143
    Else
        'You use Excel 2007
        FileExtStr = ".xlsx": FileFormatNum = 51
        'If you want to save as xls(97-2003 format) in 2007 use
        'FileExtStr = ".xls": FileFormatNum = 56
    End If

    'Name of the Excel file with a date/time stamp
    XLSFileName = DefPath & "MasterCSV " & _
    Format(Now, "dd-mmm-yyyy h-mm-ss") & FileExtStr
```

```
    'Browse to the folder with CSV files
    Set oApp = CreateObject("Shell.Application")
    Set oFolder = oApp.BrowseForFolder(0, "Select folder with CSV files", 512)
    If Not oFolder Is Nothing Then
        foldername = oFolder.Self.Path
        If Right(foldername, 1) <> "\" Then
            foldername = foldername & "\"
        End If

        'Create the bat file
        Open BatFileName For Output As #1
        Print #1, "Copy " & Chr(34) & foldername & "*.csv" _
        & Chr(34) & " " & TXTFileName
        Close #1

        'Run the Bat file to collect all data from the CSV files into a TXT file
        ShellAndWait BatFileName, 0
        If Dir(TXTFileName) = "" Then
            MsgBox "There are no csv files in this folder"
            Kill BatFileName
            Exit Sub
        End If

        'Open the TXT file in Excel
        Application.ScreenUpdating = False
        Workbooks.OpenText Filename:=TXTFileName, Origin:=xlWindows, StartRow _
        :=1, DataType:=xlDelimited, TextQualifier:=xlDoubleQuote, _
        ConsecutiveDelimiter:=False, Tab:=False, Semicolon:=False, Comma:=True, _
        Space:=False, Other:=False

        'Save text file as a Excel file
        Set Wb = ActiveWorkbook
        Application.DisplayAlerts = False
        Wb.SaveAs Filename:=XLSFileName, FileFormat:=FileFormatNum
        Application.DisplayAlerts = True

        Wb.Close SaveChanges:=False
        MsgBox "You find the Excel file here: " & vbNewLine & XLSFileName

        'Delete the bat and text file you temporary used
        Kill BatFileName
        Kill TXTFileName

        Application.ScreenUpdating = True
    Else: Exit Sub
    End If
  Application.Workbooks.Open XLSFileName
    Dim WeighBridge As Workbook
    Set WeighBridge = ActiveWorkbook

If Sheets("PER_DAY_SPREADSHEET").AutoFilterMode = True Then
    Sheets("PER_DAY_SPREADSHEET").AutoFilterMode = False
End If

'input From To so that to filter the value needed to the iventory
Dim StartStock As Date
Dim EndStock As Date
StartStock = CDate(Application.InputBox(prompt:="starting date: Format(dd/mm/yy)"))
EndStock = CDate(Application.InputBox(prompt:="ending date: Format(dd/mm/yy)"))

StartStock = CLng(CDate(StartStock))
EndStock = CLng(CDate(EndStock))
ddS = Left(StartStock, 2)
mmS = Right(Left(StartStock, 5), 2)
yyS = Right(StartStock, 2)
ddE = Left(EndStock, 2)
mmE = Right(Left(EndStock, 5), 2)
yyE = Right(EndStock, 2)


Sheets("PER_DAY_SPREADSHEET").Select
Cells.AutoFilter Field:=1, Criteria1:=">=" & mmS & "/" & ddS & "/" & yyS, Operator:=xlAnd, _
    Criteria2:="<=" & mmE & "/" & ddE & "/" & yyE
    Selection.AutoFilter Field:=10, Criteria1:="=RS*" _
        , Operator:=xlAnd


    Range("A1").Select
    Range("A1:R1").Select
    Range(Selection, Selection.End(xlDown)).Select
    Selection.Copy
```

```
    Windows("Yard stock_Template1").Activate
    Dim YSC As Workbook
    Set YSC = ActiveWorkbook

    Sheets("W_list").Select
    Range("A2").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
                                :=False, Transpose:=False
    ActiveWindow.SmallScroll Down:=54

    YSC.Sheets("W_list").Rows(2).EntireRow.Delete
    ' correct typing mistake due to the conversion in CSV file
    Cells.Replace What:="œ", Replacement:="", LookAt:=xlPart, SearchOrder:= _
        xlByRows, MatchCase:=False, SearchFormat:=False, ReplaceFormat:=False

'Work out the data gathered in Per_day spreasheet
Sheets("W_list").Select

With Sheets("W_list")
    Cells.Select
    Selection.AutoFilter

    If .AutoFilterMode = False Then
    Cells.Select
    Selection.AutoFilter
    End If


    nbr = Range("A1").CurrentRegion.Rows.Count
    Dim length() As String
    Dim diameter() As String

    'length(0) = 0
    nbl = 1
    siz = 1
    For i = 1 To nbr 'loop all the rows

        'stock the different value of length
       check = 0
        ReDim Preserve length(nbl) 'redim the array(size+1)
        For j = 1 To nbl - 1

            If .Range("L" & i) = length(j) Then
            check = 1
            Exit For
            End If
        Next

        If check = 0 Then

        length(nbl) = .Range("L" & i).Value
        a = length(nbl)
        nbl = nbl + 1
        End If

        'Stock the different value of diameter
        check2 = 0
        ReDim Preserve diameter(siz) 'redim the array(size+1)
        For j = 1 To siz - 1
            If .Range("M" & i) = diameter(j) Then
            check2 = 1
            Exit For
            End If
        Next

        If check2 = 0 Then
            diameter(siz) = .Range("M" & i).Value
            b = diameter(siz)
            siz = siz + 1
        End If
    Next
End With

Dim diam(5) As String
diam(0) = 60
diam(1) = 40
diam(2) = 30
diam(3) = 22
diam(4) = 16
diam(5) = 10
r = 1
```

```
Range("N1").Select
Dim rng As Range
Range(Selection, Selection.End(xlDown)).Select
ActiveWorkbook.Names.Add Name:="rng", RefersTo:=Selection

Columns("L:L").Select
    Selection.NumberFormat = "General"
Columns("M:M").Select
    Selection.NumberFormat = "General"

Dim nbval As String

'On the spruce
Sheets("W_list").Select
        Cells.Select
        Selection.AutoFilter Field:=11, Criteria1:="SPR"

    For i = 2 To UBound(length)
        Sheets("W_list").Select
        Cells.Select
        Selection.AutoFilter Field:=12, Criteria1:=length(i)
        If length(i) <> "" Then
        For j = 1 To UBound(diameter)
            Sheets("W_list").Select
            Cells.Select
            Selection.AutoFilter Field:=13, Criteria1:=diameter(j)
            Range("N1").Select

            Range("T1").Formula = "=Subtotal(3, rng)"
            If Range("T1") > 1 Then
                Sheets("WeighB").Select
                Range("A" & r).Formula = "SPR"
                Range("B" & r).Formula = length(i)
                Range("C" & r).Formula = diameter(j)
                Range("D" & r).FormulaR1C1 = "=IF(AND(RC[-1]>=14,RC[-1]<22),""16-22"",&"
IF(AND(RC[-1]>=22,RC[-1]<30),""22-30"",IF(AND(RC[-1]>=30,RC[-1]<49),""30+"",IF(ISTEXT(RC[-1]),& _
""22-30"",""OS""))))"

                Range("E" & r).Formula = "=Subtotal(9, rng)"
                Range("E" & r).Select
                Selection.Copy
                Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
                        :=False, Transpose:=False
                r = r + 1
            End If
        Next
        End If
    Next

'On the mixed conifers
Sheets("W_list").Select
        Cells.Select
        Selection.AutoFilter Field:=11, Criteria1:="<>SPR"
    For i = 2 To UBound(length)
        Sheets("W_list").Select
        Cells.Select
        Selection.AutoFilter Field:=12, Criteria1:=length(i)
        If length(i) <> "" Then
        For j = 1 To UBound(diameter)
            Sheets("W_list").Select
            Cells.Select
            Selection.AutoFilter Field:=13, Criteria1:=diameter(j)
            Range("N1").Select

            Range("T1").Formula = "=Subtotal(3, rng)"
            If Range("T1") > 1 Then
                Sheets("WeighB").Select
                Range("A" & r).Formula = "MC"
                Range("B" & r).Formula = length(i)
                Range("C" & r).Formula = diameter(j)
                Range("D" & r).FormulaR1C1 = "=IF(AND(RC[-1]>=14,RC[-1]<22),""16-22"",& "
IF(AND(RC[-1]>=22,RC[-1]<30),""22-30"",IF(AND(RC[-1]>=30,RC[-1]<49),""30+"",& _
IF(ISTEXT(RC[-1]),""22-30"",""OS"")))"

                Range("E" & r).Formula = "=Subtotal(9, rng)"
                Range("E" & r).Select
                Selection.Copy
                Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
                        :=False, Transpose:=False
                r = r + 1
            End If
        Next
        End If
    Next
```

```
Cells.AutoFilter

Sheets("WeighB").Select
'Standardisation of random length wagon: stored as RL
Range("B:B").Replace What:="R*", Replacement:="RL", LookAt:=xlPart, SearchOrder:= _
        xlByRows, MatchCase:=False, SearchFormat:=False, ReplaceFormat:=False
Range("B:B").Replace What:="M*", Replacement:="RL", LookAt:=xlPart, SearchOrder:= _
        xlByRows, MatchCase:=False, SearchFormat:=False, ReplaceFormat:=False

Dim rowfill As Integer
rowfill = Range("E1").End(xlDown).Row

Range("F1").Select
ActiveCell.FormulaR1C1 = "=IF(ISTEXT(RC[-4]),RC[-4],& "
INDEX('code length'!WeighbridgeCode,MATCH(RC[-4],'code length'!WeighbridgeCodeMin,1),1))"
Range("F1").Select
    Selection.AutoFill Destination:=Range("F1:F" & rowfill)

Sheets("FORM").Select
End Sub
```

Appendix 8: VBA code for the grading line button.

```
Sub GradingThroughput()

    Dim BatFileName As String
    Dim TXTFileName As String
    Dim XLSFileName As String
    Dim FileExtStr As String
    Dim FileFormatNum As Long
    Dim DefPath As String
    Dim Wb As Workbook
    Dim oApp As Object
    Dim oFolder
    Dim foldername

    'Create two temporary file names
    BatFileName = Environ("Temp") & _
          "\CollectCSVData" & Format(Now, "dd-mm-yy-h-mm-ss") & ".bat"
    TXTFileName = " SUM_MONTH" '"\AllCSV" & Format(Now, "dd-mm-yy-h-mm-ss") &
".txt"
    'Environ("Temp") & _

    'Folder where you want to save the Excel file
    DefPath = Application.DefaultFilePath
    If Right(DefPath, 1) <> "\" Then
       DefPath = DefPath & "\"
    End If

    'Set the extension and file format
    If Val(Application.Version) < 12 Then
       'You use Excel 97-2003
       FileExtStr = ".xls": FileFormatNum = -4143
    Else
       'You use Excel 2007
       FileExtStr = ".xlsx": FileFormatNum = 51
       'If you want to save as xls(97-2003 format) in 2007 use
       'FileExtStr = ".xls": FileFormatNum = 56
    End If

    'Name of the Excel file with a date/time stamp
    XLSFileName = DefPath & "MasterCSV " & _
    Format(Now, "dd-mmm-yyyy h-mm-ss") & FileExtStr

    'Browse to the folder with CSV files
    Set oApp = CreateObject("Shell.Application")
    Set oFolder = oApp.BrowseForFolder(0, "Select folder with CSV files", 512)
    If Not oFolder Is Nothing Then
       foldername = oFolder.Self.Path
       If Right(foldername, 1) <> "\" Then
          foldername = foldername & "\"
       End If
```

```
        'Create the bat file
        Open BatFileName For Output As #1
        Print #1, "Copy " & Chr(34) & foldername & "*.csv" _
        & Chr(34) & " " & TXTFileName
        Close #1

        'Run the Bat file to collect all data from the CSV files into a TXT file
        ShellAndWait BatFileName, 0
        If Dir(TXTFileName) = "" Then
           MsgBox "There are no csv files in this folder"
           Kill BatFileName
           Exit Sub
        End If

        'Open the TXT file in Excel
        Application.ScreenUpdating = False
        Workbooks.OpenText Filename:=TXTFileName, Origin:=xlWindows, StartRow _
        :=1, DataType:=xlDelimited, TextQualifier:=xlDoubleQuote, _
        ConsecutiveDelimiter:=False, Tab:=False, Semicolon:=False, Comma:=True, _
        Space:=False, Other:=False

        'Save text file as a Excel file
        Set Wb = ActiveWorkbook
        Application.DisplayAlerts = False
        Wb.SaveAs Filename:=XLSFileName, FileFormat:=FileFormatNum
        Application.DisplayAlerts = True

        Wb.Close SaveChanges:=False
        MsgBox "You find the Excel file here: " & vbNewLine & XLSFileName

        'Delete the bat and text file you temporary used
        Kill BatFileName
        Kill TXTFileName

        Application.ScreenUpdating = True
    End If
  Application.Workbooks.Open XLSFileName



If Not SheetExists("grading analysis") Then
    ActiveWorkbook.Worksheets.Add.Name = "grading analysis"
    Sheets("grading analysis").Move After:=Sheets(2)
End If

Dim GA As Worksheet
Set GA = Sheets("grading analysis")

Dim SM As Worksheet
Set SM = Sheets("SUM_MONTH")
```

```
Sheets("SUM_MONTH").Select
Dim diam As Variant
diam = Array(0, 139, 220, 300, 400, 800)

Dim length, lengthCode As Variant
'length = Array(2.1, 2.3, 2.5, 2.7, 2.9, 3.1, 3.3, 3.5, 3.7, 3.9, 4.1, 4.3, 4.5, 4.7, 4.9, "OL")
length = Array(2.45, 2.65, 3.05, 3.45, 3.65, 4.05, 4.15, 4.45, 4.65, 4.85, 4.99)
lengthCode = Array(2.5, 2.7, 3.1, 3.5, 3.7, 4.1, 4.3, 4.5, 4.7, 4.9, "OL")
Dim DiamSpec As Variant
DiamSpec = Array("Poles", "16-22", "22-30", "30+", "OS")

Dim Spp As Variant
Spp = Array("Spruce", "<>Spruce")

Dim grade As Variant
Grd = Array("Normal", "<>Normal")

With Sheets("SUM_MONTH")
   If .AutoFilterMode = True Then
      Cells.AutoFilter

   End If

   If .Range("A1") <> "Nb date" Then
      Rows("1:1").Select
      Selection.Insert Shift:=xlDown, CopyOrigin:=xlFormatFromLeftOrAbove
      Range("A1").Select
      ActiveCell.FormulaR1C1 = "Date"
      Range("B1").Select
      ActiveCell.FormulaR1C1 = "Time"
      Range("F1").Select
      ActiveCell.FormulaR1C1 = "Species"
      Range("J1").Select
      ActiveCell.FormulaR1C1 = "Length"
      Range("K1").Select
      ActiveCell.FormulaR1C1 = "Top Diam"
      Range("L1").Select
      ActiveCell.FormulaR1C1 = "Tube Diam"
      Range("M1").Select
      ActiveCell.FormulaR1C1 = "Mid Diam"
      Range("N1").Select
      ActiveCell.FormulaR1C1 = "Butt Diam"
      Range("O1").Select
      ActiveCell.FormulaR1C1 = "Crook"
      Range("P1").Select
      ActiveCell.FormulaR1C1 = "Taper"
      Range("Q1").Select
      ActiveCell.FormulaR1C1 = "Physical V"
      Range("R1").Select
      ActiveCell.FormulaR1C1 = "Tube V"
      Range("S1").Select
```

```
        ActiveCell.FormulaR1C1 = "Sorted"


        Columns("A:A").Select
            Selection.Insert Shift:=xlToRight, CopyOrigin:=xlFormatFromLeftOrAbove
            Range("A1").Select
            ActiveCell.FormulaR1C1 = "Nb date"
            Range("A2").Select
            ActiveCell.FormulaR1C1 = "1"
            Range("A3").Select
            ActiveCell.FormulaR1C1 = "=IF(RC[1]=R[-1]C[1],R[-1]C,R[-1]C+1)"
            Range("A3").Select
            Selection.Copy
            Range("B3").Select
            Selection.End(xlDown).Select
            ActiveCell.Offset(0, -1).Select
            Range(Selection, Selection.End(xlUp)).Select
            ActiveSheet.Paste
    End If

.Cells.AutoFilter
r = 1
For g = 0 To UBound(Grd)
    For k = 0 To UBound(Spp)
        For i = 0 To UBound(length)
            For j = 1 To UBound(diam)

                If Grd(g) = "Normal" Then
                GA.Range("A" & r).Formula = "Graded"
                Else: GA.Range("A" & r).Formula = "Rejected"
                End If

                If Spp(k) = "Spruce" Then
                GA.Range("B" & r).Formula = "SPR"
                Else: GA.Range("B" & r).Formula = "MC"
                End If

                GA.Range("C" & r).Formula = lengthCode(i)
                GA.Range("D" & r).Formula = DiamSpec(j - 1)
                If i < UBound(length) Then
                GA.Range("E"                    & r                    ).Formula =
"=sumifs(SUM_MONTH!$R:$R,SUM_MONTH!$T:$T,""" &              Grd(g) &
""",SUM_MONTH!$G:$G,""" & Spp(k) & """,SUM_MONTH!$K:$K, "">=" & length(i) &
""",SUM_MONTH!$K:$K, ""<" & length(i + 1) & """,SUM_MONTH!$L:$L, "">" & diam(j
- 1) & """,SUM_MONTH!$L:$L, ""<=" & diam(j) & """)"
                Else
                GA.Range("E" &                  r                    ).Formula =
"=sumifs(SUM_MONTH!$R:$R,SUM_MONTH!$T:$T,""" &              Grd(g) &
""",SUM_MONTH!$G:$G,""" & Spp(k) & """,SUM_MONTH!$K:$K, "">=" & length(i) &
""",SUM_MONTH!$L:$L, "">" & diam(j - 1) & """,SUM_MONTH!$L:$L, ""<=" & diam(j)
& """)"
                End If
```

```
            r = r + 1
          Next
        Next
    Next
Next

.AutoFilterMode = False


End With

GA.Select
    Cells.Select
    Selection.Copy
    Windows("Yard stock_Template.xls").Activate
    Sheets("Grading").Select
    Range("A1").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False

End Sub
```

Appendix 9: VBA code for the mill intake button

```
Option Explicit

Sub MillThroughput()
   Dim NewName As String
   Dim nm As Name
   Dim ws As Worksheet
   Dim YSC As Workbook
   Set YSC = Workbooks("Yard stock_Template")

    Workbooks.Open Filename:= _
      "\\Ajspdc\SHAREDOCS\ProductionThroughput\Mill7 C ube i nput.xls", U pdateLinks:=
_
      0

   If MsgBox("Copy specific sheets to a new workbook" & vbCr & _
   "New sheets will be pasted as values, named ranges removed" _
   , vbYesNo, "NewCopy") = vbNo Then Exit Sub

Dim StartStock As Date
Dim EndStock As Date
StartStock = CDate(Application.InputBox(prompt:="starting date: Format(dd/mm/yy)"))
EndStock = CDate(Application.InputBox(prompt:="ending date: Format(dd/mm/yy)"))

StartStock = CLng(CDate(StartStock))
EndStock = CLng(CDate(EndStock))
Dim ddS, mmS, yyS, ddE, mmE, yyE, dd, m m, yy, weekNbS, weekNbE, weekNb, w, r, i,
sunday As Integer
Dim SDay As Date
ddS = Left(StartStock, 2)
mmS = Right(Left(StartStock, 5), 2)
yyS = Right(StartStock, 2)
ddE = Left(EndStock, 2)
mmE = Right(Left(EndStock, 5), 2)
yyE = Right(EndStock, 2)
sunday = Application.WorksheetFunction.Weekday(StartStock, 2)
weekNbS = Application.WorksheetFunction.WeekNum(StartStock, 2)
weekNbE = Application.WorksheetFunction.WeekNum(EndStock, 2)
i = 1
Do Until sunday = 7
   SDay = StartStock + i
   sunday = Application.WorksheetFunction.Weekday(SDay, 2)
   i = i + 1
Loop
dd = Left(SDay, 2)
mm = Right(Left(SDay, 5), 2)
yy = "20" & Right(SDay, 2)


weekNb = weekNbE - weekNbS + 1
```

```
Dim sheetarray() As Variant

r = 0
For w = weekNbS To weekNbE
   ReDim Preserve sheetarray(r)
   r = r + 1
   sheetarray(r - 1) = "WK" & Chr(32) & w & Chr(32) & dd & mm & yy
   SDay = SDay + 7
   dd = Left(SDay, 2)
   mm = Right(Left(SDay, 5), 2)
   yy = "20" & Right(SDay, 2)

Next
        '      Copy specific sheets
        '      *SET THE SHEET NAMES TO COPY BELOW*
        '      Array("Sheet Name", "Another sheet name", "And Another"))
        '      Sheet names go inside quotes, seperated by commas

   With Application
      .ScreenUpdating = False

      On Error GoTo ErrCatcher

      Sheets(sheetarray).Copy
      On Error GoTo 0

       '      Paste sheets as values
       '      Remove External Links, Hperlinks and hard-code formulas
       '      Make sure A1 is selected on all sheets
      For Each ws In ActiveWorkbook.Worksheets
        'ws.Cells.AutoFilter          Field:=1, C          riteria1:="<>", O          perator:=xlAnd,
Criteria2:="<>""Date"""
        ws.Cells.AutoFilter F ield:=1,  Criteria1:=">=" & mmS  &  " /" &  ddS & " /"  &  yyS,
Operator:=xlAnd, Criteria2:="<=" & mmE & "/" & ddE & "/" & yyE

        ws.Range("A2:K" & Range("A" & Rows.Count).End(xlUp).Row).Copy
        Windows("Yard stock_Template.xls").Activate
        Sheets("Mill7").Range("A" & Rows.Count).End(xlUp).Offset(1, 0).Select
        Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
      :=False, Transpose:=False
        'ws.[A1].PasteSpecial Paste:=xlValues
        'ws.Cells.Hyperlinks.Delete
        Application.CutCopyMode = False
        Cells(1, 1).Select
        ws.Activate

      Next ws
      Cells(1, 1).Select

       '      Remove named ranges
      For Each nm In ActiveWorkbook.Names
        nm.Delete
```

```
        Next nm



         '      Save it with the NewName and in the same directory as original
        'ActiveWorkbook.SaveCopyAs ThisWorkbook.Path & "\" & NewName & ".xls"
        ActiveWorkbook.Close SaveChanges:=False

        .ScreenUpdating = True
    End With

    Windows("Yard stock_Template.xls").Activate
Dim rowfill As Integer
rowfill = Range("K2").End(xlDown).Row
Range("M1").Select
ActiveCell.FormulaR1C1 = "Diameter"
Range("L1").Select
ActiveCell.FormulaR1C1 = "L"
Range("L2").Select
ActiveCell.FormulaR1C1 =   " =INDEX('code l ength'!Mill7Code,MATCH(RC[-4]/100,'code
length'!Mill7CodeMin,1),1)"
Range("L2").Select
    Selection.AutoFill Destination:=Range("L2:L" & rowfill)
Range("M2").Select
ActiveCell.FormulaR1C1 = _
     "=IF(AND(RC[-7]>=140,RC[-7]<220),""16-22"",IF(AND(RC[-7]>=220,RC[-
7]<300),""22-30"",IF(AND(RC[-7]>=300,RC[-7]<490),""30+"",""OS"")))"
Range("M2").Select
    Selection.AutoFill Destination:=Range("M2:M" & rowfill)

    Exit Sub

ErrCatcher:
    MsgBox "Specified sheets do not exist within this workbook"




End Sub
```

Appendix 10: Code VBA for the cutting pattern form.

```
Private Sub cmdOK_Click()
Dim CP As Worksheet
Sheets("cutting pattern").Select
Set CP = Sheets("cutting pattern")
Range("A2:V" & Range("A2").End(xlDown).Row).ClearContents
Columns("D:D").NumberFormat = "0"
Columns("E:E").NumberFormat = "0"
Columns("F:F").NumberFormat = "0"
Columns("G:G").NumberFormat = "0"
Columns("H:H").NumberFormat = "0"
Columns("I:I").NumberFormat = "0"
Columns("J:J").NumberFormat = "0"
Columns("K:K").NumberFormat = "0"
Columns("L:L").NumberFormat = "0"
Columns("M:M").NumberFormat = "0"
Columns("N:N").NumberFormat = "0"
Columns("O:O").NumberFormat = "0"
Columns("P:P").NumberFormat = "0"
Columns("Q:Q").NumberFormat = "0.00%"
Columns("R:R").NumberFormat = "0.00%"
Columns("S:S").NumberFormat = "0.00%"
Columns("T:T").NumberFormat = "0.00%"
Columns("U:U").NumberFormat = "0.00%"
Columns("V:V").NumberFormat = "0.00%"


Dim Width, Thick, CBwidth, CBthick, d, blade

Dim NbBoard As Integer
Width = Me.TextWidth.Value 'Application.InputBox("Width", Type:=1) / 1000
Thick = Me.TextThick.Value 'Application.InputBox("Thick", Type:=1) / 1000
If Width = "" Then
Exit Sub
End If
If Thick = "" Then
Exit Sub
End If
Width = Width / 1000
Thick = Thick / 1000

Dim taper, final, bought
taper = Me.TextTaper.Value / 1000
bought = Me.TextBL.Value / 1
final = Me.TextFL.Value / 1

Dim SBthick(), SB2thick()
t = 0
For i = 1 To 5
If Me.Controls("check" & i).Value = True Then
ReDim Preserve SBthick(t)
SBthick(t) = Me.Controls("check" & i).Caption / 1000
t = t + 1
End If
Next


t = 0
For i = 6 To 10
If Me.Controls("check" & i).Value = True Then
ReDim Preserve SB2thick(t)
SB2thick(t) = Me.Controls("check" & i).Caption / 1000
t = t + 1
End If
Next

If CheckFixedSB.Value = True Then
    Dim SBwidth(4)
    If Me.Controls("TextSBW1").Value <> "" Then
    fixedSBW1 = Me.Controls("TextSBW1").Value
    Else: fixedSBW1 = 0
    End If
    If Me.Controls("TextSBW2").Value <> "" Then
    fixedSBW2 = Me.Controls("TextSBW2").Value
    Else: fixedSBW2 = 0
    End If
    If Me.Controls("TextSBW1").Value > Me.Controls("TextSBW2").Value Then
        SBwidth(1) = fixedSBW2 / 1000
        SBwidth(2) = fixedSBW1 / 1000
        If fixedSBW2 <> 0 Then
        SBwidth(3) = fixedSBW2 * 2 / 1000 + 0.005
        End If
        If fixedSBW1 <> 0 Then
        SBwidth(4) = fixedSBW1 * 2 / 1000 + 0.005
        End If
    Else
        SBwidth(1) = fixedSBW1 / 1000
        SBwidth(2) = fixedSBW2 / 1000
        If fixedSBW1 <> 0 Then
        SBwidth(3) = fixedSBW1 * 2 / 1000 + 0.005
        End If
        If fixedSBW2 <> 0 Then
        SBwidth(4) = fixedSBW2 * 2 / 1000 + 0.005
        End If
    End If
End If

Dim diameter()
If Me.TextBL.Value > 3 Then
diameter = Array(0.14, 0.16, 0.18, 0.2, 0.23, 0.26, 0.28, 0.3, 0.32, 0.34, 0.36, 0.38, 0.4, 0.42)
Else
diameter = Array(0.14, 0.16, 0.18, 0.2, 0.22, 0.24, 0.26, 0.28, 0.3, 0.32, 0.34, 0.36, 0.38, 0.4, 0.42, 0.44)
End If

fourarberblade = 0.0058
multiripblade = 0.0042
```

```
'Check if the side boards might be include inside the inner our the outter circle
If Me.CheckCirc.Value = True Then
innercircle = 0
Else: innercircle = 1
End If
'side boards dimensions

'SBthick = Array(0.016, 0.018, 0.021, 0.024, 0.031)
r = 2
For NbD = 0 To UBound(diameter) - 1
'find the maximum number of boards so that the whole thick of the CB be close to the width
For NbCB = 1 To 3
CBwidth = NbCB * Width + (NbCB - 1) * fourarberblade
If (Thick ^ 2 + CBwidth ^ 2) ^ (1 / 2) <= diameter(NbD) Then
    NbBoard = 1

    CBthick = NbBoard * Thick + (NbBoard - 1) * multiripblade
    closest = Abs(Thick - CBwidth)
    Boards = 1
    Do
    diagonal = (CBthick ^ 2 + Width ^ 2) ^ (1 / 2)
        If (CBthick ^ 2 + Width ^ 2) ^ (1 / 2) <= diameter(NbD) Then
            circleVabssis = ((diameter(NbD) / 2) ^ 2 - (CBwidth / 2) ^ 2) ^ (1 / 2)
            If circleVabssis >= CBthick / 2 Then
                NbBoard = NbBoard + 1
                CBthick = NbBoard * Thick + (NbBoard - 1) * multiripblade
            Else:
                Exit Do
            End If
        Else: Exit Do
        End If
    Loop

    Boards = NbBoard - 1
    CBthick = Boards * Thick + (Boards - 1) * multiripblade


    'check the whole CB is inside the tube
    Dim big, small, limit
    If CBthick > Width Then
        big = CBthick
        small = CBwidth
    Else: big = CBwidth
        small = CBthick
    End If

If Me.CheckFixedSB = False Then
        'search the side boards dimensions among the current ones
        Dim maxWforVSBthick  'maximum width in the circle for vertical side board of SBthick thickness
        Dim maxWforHSBthick  'maximum width in the circle for horizontal side board of SBthick thickness
    If CheckPass = True Then
    NbPass = 2
    maxV1SBw = 0
    maxV1SBt = 0
    maxV2SBw = 0
    maxV2SBt = 0
    maxV3SBw = 0
    maxV3SBt = 0
    maxH1SBw = 0
    maxH1SBt = 0
    maxH2SBw = 0
    maxH2SBt = 0
    maxH3SBw = 0
    maxH3SBt = 0
    For sbt1 = 0 To UBound(SBthick)
        For sbt2 = 0 To UBound(SB2thick)
        For sbt4 = 0 To UBound(SBthick)


            V1SB = 0
            V1SBthick = 0
            maxWforV1SBthick = 0
            V2SB = 0
            V2SBthick = 0
            maxWforV2SBthick = 0
            V3SB = 0
            V3SBthick = 0
            maxWforV3SBthick = 0

            'Vertical side boards
            If (CBwidth / 2 + fourarberblade + SBthick(sbt1)) < (diameter(NbD + innercircle) / 2) Then
            maxWforV1SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade + SBthick(sbt1)) ^ 2) ^ (1 / 2)
            V1SB = maxWforV1SBthick * SBthick(sbt1)
            V1SBthick = SBthick(sbt1)

            If NbCB = 1 Then
                If (CBwidth / 2 + fourarberblade * 2 + SBthick(sbt1) + SBthick(sbt4)) < (diameter(NbD + innercircle) / 2) Then
                maxWforV2SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade * 2& _
                + SBthick(sbt1) + SBthick(sbt4)) ^ 2) ^ (1 / 2)
                V2SB = maxWforV2SBthick * SBthick(sbt4)
                V2SBthick = SBthick(sbt4)
                End If
                If (CBwidth / 2 + fourarberblade * 3 + SBthick(sbt1) + SB2thick(sbt2) * 2) < (diameter(NbD + innercircle) / 2) Then
                maxWforV3SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade * 3& _
                + SBthick(sbt1) + SB2thick(sbt2) * 2) ^ 2) ^ (1 / 2)
                V3SB = maxWforV3SBthick * SB2thick(sbt2)
                V3SBthick = SB2thick(sbt2)
                End If
                Else
                If (CBwidth / 2 + fourarberblade * 2 + SBthick(sbt1) + SB2thick(sbt2)) < (diameter(NbD + innercircle) / 2) Then
                maxWforV2SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade * 2& _
                + SBthick(sbt1) + SB2thick(sbt2)) ^ 2) ^ (1 / 2)
                V2SB = maxWforV2SBthick * SB2thick(sbt2)
                V2SBthick = SB2thick(sbt2)
                End If
```

```
            End If

        End If

        'Horizontal side boards
        For sbt3 = 0 To UBound(SBthick)
        H1SB = 0
        H1SBthick = 0
        maxWforH1SBthick = 0
        H2SB = 0
        H2SBthick = 0
        maxWforH2SBthick = 0
        H3SB = 0
        H3SBthick = 0
        maxWforH3SBthick = 0


            If (CBthick / 2 + fourarberblade + SBthick(sbt3)) < (diameter(NbD + innercircle) / 2) Then
                maxWforH1SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBthick / 2 + fourarberblade + SBthick(sbt3)) ^ 2) ^ (1 / 2)
                If maxWforH1SBthick > SBthick(sbt3) Then
                H1SB = maxWforH1SBthick * SBthick(sbt3)
                H1SBthick = SBthick(sbt3)
                End If
                If (CBthick / 2 + fourarberblade * 2 + SBthick(sbt3) + SB2thick(sbt2)) < (diameter(NbD + innercircle) / 2) Then
                    maxWforH2SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBthick / 2 + fourarberblade * 2& _
                    + SBthick(sbt3) + SB2thick(sbt2)) ^ 2) ^ (1 / 2)
                    If maxWforH2SBthick > SB2thick(sbt2) Then
                    H2SB = maxWforH2SBthick * SB2thick(sbt2)
                    H2SBthick = SB2thick(sbt2)
                    End If
                    If (CBthick / 2 + fourarberblade * 3 + SBthick(sbt3) + SB2thick(sbt2) & _
                    SB2thick(sbt2)) < (diameter(NbD + innercircle) / 2) Then
                        maxWforH3SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBthick / 2 + fourarberblade * 3& _
                        + SBthick(sbt3) + SB2thick(sbt2) + SB2thick(sbt2)) ^ 2) ^ (1 / 2)
                        If maxWforH3SBthick > SB2thick(sbt2) Then
                        H3SB = maxWforH3SBthick * SB2thick(sbt2)
                        H3SBthick = SB2thick(sbt2)
                        End If
                    End If
                End If
            End If

            'search the highest area covered by the side boards
            VHSB = V1SB + V2SB + H1SB + H2SB + H3SB
            If VHSB > maxVHSB Then
                maxVHSB = VHSB
                maxV1SBw = maxWforV1SBthick
                maxV1SBt = V1SBthick
                maxV2SBw = maxWforV2SBthick
                maxV2SBt = V2SBthick
                maxV3SBw = maxWforV3SBthick
                maxV3SBt = V3SBthick
                maxH1SBw = maxWforH1SBthick
                maxH1SBt = H1SBthick
                maxH2SBw = maxWforH2SBthick
                maxH2SBt = H2SBthick
                maxH3SBw = maxWforH3SBthick
                maxH3SBt = H3SBthick
            End If
        Next
        Next
    Next
Next

Dim TubeAreaMin, CB, SB, recoveryMin, recoveryCBMin, recoverySBMin
Dim TubeareaMax, recoveryMax, recoveryCBMax, recoverySBMax
TubeAreaMin = Application.WorksheetFunction.Pi() / 4 * bought * (diameter(NbD) + bought / 2 * taper) ^ 2
TubeareaMax = Application.WorksheetFunction.Pi() / 4 * bought * (diameter(NbD + 1) + bought / 2 * taper) ^ 2
recoveryCBMin = Width * Thick * Boards * NbCB * final / TubeAreaMin
recoverySBMin = (maxV1SBw * maxV1SBt * 2 + maxV2SBw * maxV2SBt * 2 + maxH1SBw * maxH1SBt * 2& _
+ maxH2SBw * maxH2SBt * 2) * final / TubeAreaMin
recoveryMin = recoveryCBMin + recoverySBMin
recoveryCBMax = Width * Thick * Boards * NbCB * final / TubeareaMax
recoverySBMax = (maxV1SBw * maxV1SBt * 2 + maxV2SBw * maxV2SBt * 2 + maxH1SBw * maxH1SBt * 2& _
+ maxH2SBw * maxH2SBt * 2) * final / TubeareaMax
recoveryMax = recoveryCBMax + recoverySBMax

CP.Select

With CP
    .Range("A" & r).Formula = diameter(NbD) * 1000
    .Range("B" & r).Formula = NbCB
    .Range("C" & r).Formula = Boards
    .Range("D" & r).Formula = NbPass
    .Range("E" & r).Formula = maxV1SBw * 1000
    .Range("F" & r).Formula = maxV1SBt * 1000
    .Range("G" & r).Formula = maxV2SBw * 1000
    .Range("H" & r).Formula = maxV2SBt * 1000
    .Range("I" & r).Formula = maxV3SBw * 1000
    .Range("J" & r).Formula = maxV3SBt * 1000
    .Range("K" & r).Formula = maxH1SBw * 1000
    .Range("L" & r).Formula = maxH1SBt * 1000
    .Range("M" & r).Formula = maxH2SBw * 1000
    .Range("N" & r).Formula = maxH2SBt * 1000
    .Range("O" & r).Formula = maxH3SBw * 1000
    .Range("P" & r).Formula = maxH3SBt * 1000
    .Range("Q" & r).Formula = recoveryCBMin
    .Range("R" & r).Formula = recoverySBMin
    .Range("S" & r).Formula = recoveryMin
    .Range("T" & r).Formula = recoveryCBMax
    .Range("U" & r).Formula = recoverySBMax
    .Range("V" & r).Formula = recoveryMax

End With
```

```
r = r + 1
End If

If CheckPass2 = True Then
If NbCB = 1 Then
NbPass = 1
maxVHSB = 0
maxV1SBw = 0
maxV1SBt = 0
maxV2SBw = 0
maxV2SBt = 0
maxV3SBw = 0
maxV3SBt = 0
maxH1SBw = 0
maxH1SBt = 0
maxH2SBw = 0
maxH2SBt = 0
maxH3SBw = 0
maxH3SBt = 0
For sbt1 = 0 To UBound(SBthick)
    For sbt2 = 0 To UBound(SB2thick)
    For sbt4 = 0 To UBound(SBthick)


        V1SB = 0
        V1SBthick = 0
        maxWforV1SBthick = 0
        V2SB = 0
        V2SBthick = 0
        maxWforV2SBthick = 0
        V3SB = 0
        V3SBthick = 0
        maxWforV3SBthick = 0

        'Vertical side boards
        If (CBwidth / 2 + fourarberblade + SBthick(sbt1)) < (diameter(NbD + innercircle) / 2) Then
        maxWforV1SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade + SBthick(sbt1)) ^ 2) ^ (1 / 2)
        V1SB = maxWforV1SBthick * SBthick(sbt1)
        V1SBthick = SBthick(sbt1)

                If NbCB = 1 Then
                    If (CBwidth / 2 + fourarberblade * 2 + SBthick(sbt1) + SBthick(sbt4)) < (diameter(NbD + innercircle) / 2) Then
                        maxWforV2SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade * 2& _
                        + SBthick(sbt1) + SBthick(sbt4)) ^ 2) ^ (1 / 2)
                        V2SB = maxWforV2SBthick * SBthick(sbt4)
                        V2SBthick = SBthick(sbt4)
                    End If
                    If (CBwidth / 2 + fourarberblade * 3 + SBthick(sbt1) + SB2thick(sbt2) * 2) < (diameter(NbD + innercircle) / 2) Then
                        maxWforV3SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade * 3& _
                        + SBthick(sbt1) + SB2thick(sbt2) * 2) ^ 2) ^ (1 / 2)
                        V3SB = maxWforV3SBthick * SB2thick(sbt2)
                        V3SBthick = SB2thick(sbt2)
                    End If
                Else
                    If (CBwidth / 2 + fourarberblade * 2 + SBthick(sbt1) + SB2thick(sbt2)) < (diameter(NbD + innercircle) / 2) Then
                        maxWforV2SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade * 2& _
                        + SBthick(sbt1) + SB2thick(sbt2)) ^ 2) ^ (1 / 2)
                        V2SB = maxWforV2SBthick * SB2thick(sbt2)
                        V2SBthick = SB2thick(sbt2)
                    End If
                End If

        End If

        'Horizontal side boards
        For sbt3 = 0 To UBound(SBthick)
        H1SB = 0
        H1SBthick = 0
        maxWforH1SBthick = 0
        H2SB = 0
        H2SBthick = 0
        maxWforH2SBthick = 0
        H3SB = 0
        H3SBthick = 0
        maxWforH3SBthick = 0
            If (CBthick / 2 + fourarberblade + SBthick(sbt3)) < (diameter(NbD + innercircle) / 2) Then
                maxWforH1SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBthick / 2 + fourarberblade + SBthick(sbt3)) ^ 2) ^ (1 / 2)
                If maxWforH1SBthick > SBthick(sbt3) Then
                H1SB = maxWforH1SBthick * SBthick(sbt1)
                H1SBthick = SBthick(sbt1)
                End If

            End If

            'search the highest area covered by the side boards
            VHSB = V1SB + V2SB + H1SB
            If VHSB > maxVHSB Then
                maxVHSB = VHSB
                maxV1SBw = maxWforV1SBthick
                maxV1SBt = V1SBthick
                maxV2SBw = maxWforV2SBthick
                maxV2SBt = V2SBthick
                maxV3SBw = maxWforV3SBthick
                maxV3SBt = V3SBthick
                maxH1SBw = maxWforH1SBthick
                maxH1SBt = H1SBthick
            End If
        Next
        Next
    Next
Next

'Dim TubeAreaMin, CB, SB, recoveryMin, recoveryCBMin, recoverySBMin
'Dim TubeareaMax, recoveryMax, recoveryCBMax, recoverySBMax
TubeAreaMin = Application.WorksheetFunction.Pi() / 4 * bought * (diameter(NbD) + bought / 2 * taper) ^ 2
TubeareaMax = Application.WorksheetFunction.Pi() / 4 * bought * (diameter(NbD + 1) + bought / 2 * taper) ^ 2
```

```
    recoveryCBMin = Width * Thick * Boards * NbCB * final / TubeAreaMin
    recoverySBMin = (maxV1SBw * maxV1SBt * 2 + maxV2SBw * maxV2SBt * 2 + maxH1SBw * maxH1SBt * 2& _
    + maxH2SBw * maxH2SBt * 2) * final / TubeAreaMin
    recoveryMin = recoveryCBMin + recoverySBMin
    recoveryCBMax = Width * Thick * Boards * NbCB * final / TubeareaMax
    recoverySBMax = (maxV1SBw * maxV1SBt * 2 + maxV2SBw * maxV2SBt * 2 + maxH1SBw * maxH1SBt * 2& _
    + maxH2SBw * maxH2SBt * 2) * final / TubeareaMax
    recoveryMax = recoveryCBMax + recoverySBMax

    CP.Select

    With CP
        .Range("A" & r).Formula = diameter(NbD) * 1000
        .Range("B" & r).Formula = NbCB
        .Range("C" & r).Formula = Boards
        .Range("D" & r).Formula = NbPass
        .Range("E" & r).Formula = maxV1SBw * 1000
        .Range("F" & r).Formula = maxV1SBt * 1000
        .Range("G" & r).Formula = maxV2SBw * 1000
        .Range("H" & r).Formula = maxV2SBt * 1000
        .Range("I" & r).Formula = maxV3SBw * 1000
        .Range("J" & r).Formula = maxV3SBt * 1000
        .Range("K" & r).Formula = maxH1SBw * 1000
        .Range("L" & r).Formula = maxH1SBt * 1000
        .Range("M" & r).Formula = maxH2SBw * 1000
        .Range("N" & r).Formula = maxH2SBt * 1000
        .Range("O" & r).Formula = maxH3SBw * 1000
        .Range("P" & r).Formula = maxH3SBt * 1000
        .Range("Q" & r).Formula = recoveryCBMin
        .Range("R" & r).Formula = recoverySBMin
        .Range("S" & r).Formula = recoveryMin
        .Range("T" & r).Formula = recoveryCBMax
        .Range("U" & r).Formula = recoverySBMax
        .Range("V" & r).Formula = recoveryMax

    End With
    r = r + 1
    End If
    End If

'End If

Else
If CheckPass = True Then
    NbPass = 2
    maxVHSB = 0
    maxV1SBw = 0
    maxV1SBt = 0
    maxV2SBw = 0
    maxV2SBt = 0
    maxV3SBw = 0
    maxV3SBt = 0
    maxH1SBw = 0
    maxH1SBt = 0
    maxH2SBw = 0
    maxH2SBt = 0
    maxH3SBw = 0
    maxH3SBt = 0
    For sbt1 = 0 To UBound(SBthick)
        For sbt2 = 0 To UBound(SB2thick)
        For sbt4 = 0 To UBound(SBthick)


            V1SB = 0
            V1SBthick = 0
            V1SBwidth = 0
            maxWforV1SBthick = 0
            V2SB = 0
            V2SBwidth = 0
            V2SBthick = 0
            maxWforV2SBthick = 0
            V3SB = 0
            V3SBwidth = 0
            V3SBthick = 0
            maxWforV3SBthick = 0

            'Vertical side boards
            If (CBwidth / 2 + fourarberblade + SBthick(sbt1)) < (diameter(NbD + innercircle) / 2) Then
            maxWforV1SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade + SBthick(sbt1)) ^ 2) ^ (1 / 2)
            For SBW1 = 0 To UBound(SBwidth)
                If SBwidth(SBW1) <= maxWforV1SBthick Then
                V1SBwidth = SBwidth(SBW1)
                End If
            Next
            V1SB = V1SBwidth * SBthick(sbt1)
            V1SBthick = SBthick(sbt1)

                    If NbCB = 1 Then
                    If (CBwidth / 2 + fourarberblade * 2 + SBthick(sbt1) + SBthick(sbt4)) < (diameter(NbD + innercircle) / 2) Then
                        maxWforV2SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade * 2& _
                        + SBthick(sbt1) + SBthick(sbt4)) ^ 2) ^ (1 / 2)
                            For sbw2 = 0 To UBound(SBwidth)
                                If SBwidth(sbw2) <= maxWforV2SBthick Then
                                V2SBwidth = SBwidth(sbw2)
                                End If
                            Next
                        V2SB = V2SBwidth * SBthick(sbt4)
                        V2SBthick = SBthick(sbt4)
                    End If
                        If (CBwidth / 2 + fourarberblade * 3 + SBthick(sbt1) + SB2thick(sbt2) * 2) < (diameter(NbD + innercircle) / 2) Then
                        maxWforV3SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade * 3& _
                        + SBthick(sbt1) + SB2thick(sbt2) * 2) ^ 2) ^ (1 / 2)
                        For sbw2 = 0 To UBound(SBwidth)
                            If SBwidth(sbw2) <= maxWforV3SBthick Then
                            V3SBwidth = SBwidth(sbw2)
                            End If
```

```
                Next
                V3SB = V3SBwidth * SB2thick(sbt2)
                V3SBthick = SB2thick(sbt2)
                End If
            Else
                If (CBwidth / 2 + fourarberblade * 2 + SBthick(sbt1) + SB2thick(sbt2)) < (diameter(NbD + innercircle) / 2) Then
                    maxWforV2SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade * 2& _
                    + SBthick(sbt1) + SB2thick(sbt2)) ^ 2) ^ (1 / 2)
                    For sbw2 = 0 To UBound(SBwidth)
                        If SBwidth(sbw2) <= maxWforV2SBthick Then
                        V2SBwidth = SBwidth(sbw2)
                        End If
                    Next
                    V2SB = V2SBwidth * SB2thick(sbt2)
                    V2SBthick = SB2thick(sbt2)
                End If
            End If

        End If

        'Horizontal side boards
        For sbt3 = 0 To UBound(SBthick)
        H1SB = 0
        H1SBwidth = 0
        H1SBthick = 0
        maxWforH1SBthick = 0
        H2SB = 0
        H2SBwidth = 0
        H2SBthick = 0
        maxWforH2SBthick = 0
        H3SB = 0
        H3SBwidth = 0
        H3SBthick = 0
        maxWforH3SBthick = 0


            If (CBthick / 2 + fourarberblade + SBthick(sbt3)) < (diameter(NbD + innercircle) / 2) Then
                maxWforH1SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBthick / 2 + fourarberblade + SBthick(sbt3)) ^ 2) ^ (1 / 2)
                For sbw = 0 To UBound(SBwidth)
                    If SBwidth(sbw) <= maxWforH1SBthick Then
                    H1SBwidth = SBwidth(sbw)
                    End If
                Next
                H1SB = H1SBwidth * SBthick(sbt3)
                H1SBthick = SBthick(sbt3)

                If (CBthick / 2 + fourarberblade * 2 + SBthick(sbt3) + SB2thick(sbt2)) < (diameter(NbD + innercircle) / 2) Then
                    maxWforH2SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBthick / 2 + fourarberblade * 2& _
                    + SBthick(sbt3) + SB2thick(sbt2)) ^ 2) ^ (1 / 2)
                    For sbw = 0 To UBound(SBwidth)
                        If SBwidth(sbw) <= maxWforH2SBthick Then
                        H2SBwidth = SBwidth(sbw)
                        End If
                    Next
                    H2SB = H2SBwidth * SB2thick(sbt2)
                    H2SBthick = SB2thick(sbt2)

                    If (CBthick / 2 + fourarberblade * 3 + SBthick(sbt3) + SB2thick(sbt2) & _
                    SB2thick(sbt2)) < (diameter(NbD + innercircle) / 2) Then
                        maxWforH3SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBthick / 2 + fourarberblade * 3& _
                        + SBthick(sbt3) + SB2thick(sbt2) + SB2thick(sbt2)) ^ 2) ^ (1 / 2)
                        For sbw = 0 To UBound(SBwidth)
                            If SBwidth(sbw) <= maxWforH3SBthick Then
                            H3SBwidth = SBwidth(sbw)
                            End If
                        Next
                        H3SB = H3SBwidth * SB2thick(sbt2)
                        H3SBthick = SB2thick(sbt2)

                    End If
                End If
            End If

            'search the highest area covered by the side boards
            VHSB = V1SB + V2SB + H1SB + H2SB + H3SB
            If VHSB > maxVHSB Then
                maxVHSB = VHSB
                maxV1SBw = V1SBwidth
                maxV1SBt = V1SBthick
                maxV2SBw = V2SBwidth
                maxV2SBt = V2SBthick
                maxV3SBw = V3SBwidth
                maxV3SBt = V3SBthick
                maxH1SBw = H1SBwidth
                maxH1SBt = H1SBthick
                maxH2SBw = H2SBwidth
                maxH2SBt = H2SBthick
                maxH3SBw = H3SBwidth
                maxH3SBt = H3SBthick
            End If
        Next
        Next
    Next
Next


TubeAreaMin = Application.WorksheetFunction.Pi() / 4 * bought * (diameter(NbD) + bought / 2 * taper) ^ 2
TubeareaMax = Application.WorksheetFunction.Pi() / 4 * bought * (diameter(NbD + 1) + bought / 2 * taper) ^ 2
recoveryCBMin = Width * Thick * Boards * NbCB * final / TubeAreaMin
recoverySBMin = (maxV1SBw * maxV1SBt * 2 + maxV2SBw * maxV2SBt * 2 + maxH1SBw * maxH1SBt * 2 + maxH2SBw * maxH2SBt * 2) * final / TubeAreaMin
recoveryMin = recoveryCBMin + recoverySBMin
recoveryCBMax = Width * Thick * Boards * NbCB * final / TubeareaMax
recoverySBMax = (maxV1SBw * maxV1SBt * 2 + maxV2SBw * maxV2SBt * 2 + maxH1SBw * maxH1SBt * 2 + maxH2SBw * maxH2SBt * 2) * final / TubeareaMax
recoveryMax = recoveryCBMax + recoverySBMax
```

```
CP.Select

With CP
    .Range("A" & r).Formula = diameter(NbD) * 1000
    .Range("B" & r).Formula = NbCB
    .Range("C" & r).Formula = Boards
    .Range("D" & r).Formula = NbPass
    .Range("E" & r).Formula = maxV1SBw * 1000
    .Range("F" & r).Formula = maxV1SBt * 1000
    .Range("G" & r).Formula = maxV2SBw * 1000
    .Range("H" & r).Formula = maxV2SBt * 1000
    .Range("I" & r).Formula = maxV3SBw * 1000
    .Range("J" & r).Formula = maxV3SBt * 1000
    .Range("K" & r).Formula = maxH1SBw * 1000
    .Range("L" & r).Formula = maxH1SBt * 1000
    .Range("M" & r).Formula = maxH2SBw * 1000
    .Range("N" & r).Formula = maxH2SBt * 1000
    .Range("O" & r).Formula = maxH3SBw * 1000
    .Range("P" & r).Formula = maxH3SBt * 1000
    .Range("Q" & r).Formula = recoveryCBMin
    .Range("R" & r).Formula = recoverySBMin
    .Range("S" & r).Formula = recoveryMin
    .Range("T" & r).Formula = recoveryCBMax
    .Range("U" & r).Formula = recoverySBMax
    .Range("V" & r).Formula = recoveryMax

End With
r = r + 1
End If

If CheckPass2 = True Then
If NbCB = 1 Then
NbPass = 1
maxVHSB = 0
maxV1SBw = 0
maxV1SBt = 0
maxV2SBw = 0
maxV2SBt = 0
maxV3SBw = 0
maxV3SBt = 0
maxH1SBw = 0
maxH1SBt = 0
maxH2SBw = 0
maxH2SBt = 0
maxH3SBw = 0
maxH3SBt = 0
For sbt1 = 0 To UBound(SBthick)
    For sbt2 = 0 To UBound(SB2thick)
    For sbt4 = 0 To UBound(SBthick)


        V1SB = 0
        V1SBwidth = 0
        V1SBthick = 0
        maxWforV1SBthick = 0
        V2SB = 0
        V2SBwidth = 0
        V2SBthick = 0
        maxWforV2SBthick = 0
        V3SB = 0
        V3SBwidth = 0
        V3SBthick = 0
        maxWforV3SBthick = 0

        'Vertical side boards
        If (CBwidth / 2 + fourarberblade + SBthick(sbt1)) < (diameter(NbD + innercircle) / 2) Then
        maxWforV1SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade + SBthick(sbt1)) ^ 2) ^ (1 / 2)
        For SBW1 = 0 To UBound(SBwidth)
            If SBwidth(SBW1) <= maxWforV1SBthick Then
            V1SBwidth = SBwidth(SBW1)
            End If
        Next
        V1SB = V1SBwidth * SBthick(sbt1)
        V1SBthick = SBthick(sbt1)

                If NbCB = 1 Then
                    If (CBwidth / 2 + fourarberblade * 2 + SBthick(sbt1) + SBthick(sbt4)) < (diameter(NbD + innercircle) / 2) Then
                        maxWforV2SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade * 2& _
                        + SBthick(sbt1) + SBthick(sbt4)) ^ 2) ^ (1 / 2)
                        For sbw = 0 To UBound(SBwidth)
                            If SBwidth(sbw) <= maxWforV2SBthick Then
                            V2SBwidth = SBwidth(sbw)
                            End If
                        Next
                        V2SB = V2SBwidth * SBthick(sbt4)
                        V2SBthick = SBthick(sbt4)
                    End If
                    If (CBwidth / 2 + fourarberblade * 3 + SBthick(sbt1) + SB2thick(sbt2) * 2) < (diameter(NbD + innercircle) / 2) Then
                        maxWforV3SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade * 3& _
                        + SBthick(sbt1) + SB2thick(sbt2) * 2) ^ 2) ^ (1 / 2)
                        For sbw = 0 To UBound(SBwidth)
                            If SBwidth(sbw) <= maxWforV3SBthick Then
                            V3SBwidth = SBwidth(sbw)
                            End If
                        Next
                        V3SB = V3SBwidth * SB2thick(sbt2)
                        V3SBthick = SB2thick(sbt2)
                    End If
                Else
                    If (CBwidth / 2 + fourarberblade * 2 + SBthick(sbt1) + SB2thick(sbt2)) < (diameter(NbD + innercircle) / 2) Then
                        maxWforV2SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBwidth / 2 + fourarberblade * 2& _
                        + SBthick(sbt1) + SB2thick(sbt2)) ^ 2) ^ (1 / 2)
                        For sbw = 0 To UBound(SBwidth)
                            If SBwidth(sbw) <= maxWforV2SBthick Then
                            V2SBwidth = SBwidth(sbw)
```

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                            End If
                        Next
                        V2SB = V2SBwidth * SB2thick(sbt2)
                        V2SBthick = SB2thick(sbt2)
                    End If
                End If

            End If

            'Horizontal side boards
            For sbt3 = 0 To UBound(SBthick)
            H1SB = 0
            H1SBwidth = 0
            H1SBthick = 0
            maxWforH1SBthick = 0

                If (CBthick / 2 + fourarberblade + SBthick(sbt3)) < (diameter(NbD + innercircle) / 2) Then
                    maxWforH1SBthick = 2 * ((diameter(NbD + innercircle) / 2) ^ 2 - (CBthick / 2 + fourarberblade + SBthick(sbt3)) ^ 2) ^ (1 / 2)
                    For sbw = 0 To UBound(SBwidth)
                        If SBwidth(sbw) <= maxWforH1SBthick Then
                        H1SBwidth = SBwidth(sbw)
                        End If
                    Next
                    H1SB = H1SBwidth * SBthick(sbt1)
                    H1SBthick = SBthick(sbt1)


                End If

                'search the highest area covered by the side boards
                VHSB = V1SB + V2SB + H1SB
                If VHSB > maxVHSB Then
                    maxVHSB = VHSB
                    maxV1SBw = V1SBwidth
                    maxV1SBt = V1SBthick
                    maxV2SBw = V2SBwidth
                    maxV2SBt = V2SBthick
                    maxV3SBw = V3SBwidth
                    maxV3SBt = V3SBthick
                    maxH1SBw = H1SBwidth
                    maxH1SBt = H1SBthick
                End If
            Next
            Next
        Next
    Next

    'Dim TubeAreaMin, CB, SB, recoveryMin, recoveryCBMin, recoverySBMin
    'Dim TubeareaMax, recoveryMax, recoveryCBMax, recoverySBMax
    TubeAreaMin = Application.WorksheetFunction.Pi() / 4 * bought * (diameter(NbD) + bought / 2 * taper) ^ 2
    TubeareaMax = Application.WorksheetFunction.Pi() / 4 * bought * (diameter(NbD + 1) + bought / 2 * taper) ^ 2
    recoveryCBMin = Width * Thick * Boards * NbCB * final / TubeAreaMin
    recoverySBMin = (maxV1SBw * maxV1SBt * 2 + maxV2SBw * maxV2SBt * 2 + maxH1SBw * maxH1SBt * 2 + maxH2SBw * maxH2SBt * 2) * final / TubeAreaMin
    recoveryMin = recoveryCBMin + recoverySBMin
    recoveryCBMax = Width * Thick * Boards * NbCB * final / TubeareaMax
    recoverySBMax = (maxV1SBw * maxV1SBt * 2 + maxV2SBw * maxV2SBt * 2 + maxH1SBw * maxH1SBt * 2 + maxH2SBw * maxH2SBt * 2) * final / TubeareaMax
    recoveryMax = recoveryCBMax + recoverySBMax

    CP.Select

    With CP
        .Range("A" & r).Formula = diameter(NbD) * 1000
        .Range("B" & r).Formula = NbCB
        .Range("C" & r).Formula = Boards
        .Range("D" & r).Formula = NbPass
        .Range("E" & r).Formula = maxV1SBw * 1000
        .Range("F" & r).Formula = maxV1SBt * 1000
        .Range("G" & r).Formula = maxV2SBw * 1000
        .Range("H" & r).Formula = maxV2SBt * 1000
        .Range("I" & r).Formula = maxV3SBw * 1000
        .Range("J" & r).Formula = maxV3SBt * 1000
        .Range("K" & r).Formula = maxH1SBw * 1000
        .Range("L" & r).Formula = maxH1SBt * 1000
        .Range("M" & r).Formula = maxH2SBw * 1000
        .Range("N" & r).Formula = maxH2SBt * 1000
        .Range("O" & r).Formula = maxH3SBw * 1000
        .Range("P" & r).Formula = maxH3SBt * 1000
        .Range("Q" & r).Formula = recoveryCBMin
        .Range("R" & r).Formula = recoverySBMin
        .Range("S" & r).Formula = recoveryMin
        .Range("T" & r).Formula = recoveryCBMax
        .Range("U" & r).Formula = recoverySBMax
        .Range("V" & r).Formula = recoveryMax

    End With
    r = r + 1
    End If
    End If

End If
End If
Next
Next



CP.Select
CP.Range("A1").Select
Dim rowCount2 As Integer
rowCount2 = CP.Range("A1").End(xlDown).Row
If cboSort1.Value <> "" Then
    If cboSort1 = "smallest to largest" Then
    sortOrder1 = 1
    Else: sortOrder1 = 2
    End If
    If cboSort2 = "smallest to largest" Then
```

```
    sortOrder2 = 1
    Else: sortOrder2 = 2
    End If
    Range("A1:V" & rowCount2).Sort Key1:=cboSort1.Value, Order1:=sortOrder1, Key2:=cboSort2.Value, _
    Order2:=sortOrder2, Header:=xlGuess, OrderCustom:=1, MatchCase _
            :=False, Orientation:=xlTopToBottom ', DataOption1:=xlSortNormal, _
            DataOption2:=xlSortNormal
End If


End Sub
Private Sub cmdCancel_Click()
    Unload Me
End Sub
Private Sub UserForm_Initialize()



cboSort1.List() = Array("", "CB minD", "CB maxD", "SB minD", "SB maxD", "Total minD", "Total maxD")
cboSort2.List() = Array("", "Nb Boards", "Diameter")
cboSortCrit1.List() = Array("", "smallest to largest", "largest to smallest")
cboSortCrit2.List() = Array("", "smallest to largest", "largest to smallest")


For i = 1 To 10
Me.Controls("check" & i).Value = True
Next
Me.CheckCirc.Value = True
Me.CheckPass.Value = True
Me.CheckPass2 = True
TextTaper.Value = 7
TextBL.Value = 3.75
TextFL.Value = 3.66

cboSort1.Value = "CB maxD"
cboSortCrit1.Value = "largest to smallest"
End Sub
```

ABSTRACT

The UK's wood industries massively invested over the last twenty years and they are now extremely competitive. But competition rhymes with a good organisation. A & S Scott, a sawmill processing homegrown timber, encounters difficulties to control the round wood stock level. This is mainly due to a lack of production planning and a poor data flow between production staff and timber procurement staff. This thesis presents an analysis of the wood supply chain of the sawmill, aiming to highlight its strengths and weaknesses. Then guidance support tools are proposed in order to improve the stock level management, helping the decision-makers in their choices.