Simulation of Sawmill Yields at Hyne Tuan Pine Mill

A dissertation submitted by

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ENG4112 Research Project

Supervisor

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Abstract

Tuan plant processes between six and seven hundred thousand cubic meters of plantation pine annually, on average this equates to around five thousand trees daily. Logs are cut to length through a Log Merchandising machine. The numerical data generated by the dimensional measuring system is proposed as feedstock for an ambitious computer program that is designed to imitate the computerised, electrical and mechanical processes of sawmill plant. Supposition being that a well fashioned predictive software can provide an element of competitive advantage through the potential to aid production planning. The program takes any user specified generic Tuan sawmill alpha-numeric cut pattern code and interrogates into dimensional pattern cross-sections. The software has been fashioned to select the sideboard width option that maximizes sawn volume yield recovery.

The board trimming process synthesises laser vision sensing and computer processing to determine the mechanical saw docking requirements; it is the vital final quality control mechanism at the sawmill. Sensed wane dimensions of the timber are paired up against programmed wane rules in the solutions computer to decide which trim saws will actuate and dock to chip. The yield predictor program does a virtual trimmer processing of every sawn board to assess the length output of sawn boards, dock to chip and sawdust exhaust by saws.

The program is predicting the sawmill yields for sawn timbers, chip and sawdust, all the yield indicators are reported as displayed outputs.
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Certification

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I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Mr. Eyre Jeffery Campbell

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Signature               Date
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Chapter 1

Introduction and Background

Hyne and Sons quality milled timber brand and products have been around for more than 120 years. During Hynes history there have been numerous boom and bust cycles in the economies but the Hyne family business has manoeuvred for survival in economic troughs, and then reinvigorated for expansion in the upswings. Originating in Queenslands Fraser Coast region Hyne began as a miller of native forest hardwoods. Figure 1.1 shows Hynes original hardwood mill situated on the banks of the Mary River along which, logs were originally ferried from from selective harvesting operations on Fraser Island.

Figure 1.1: Hyne and Sons original hardwood milling operation in Maryborough Qld.

Over the past 30 years Hyne has completely transitioned to milling only plantation
grown species of Pine. During the middle decade of this transition Hyne aspired to be
the number one softwood processor in Australia. Hyne now has three significant mills
dedicated to processing plantation pine. One is at Tuan (east of Maryborough) that
processes Exotic Pine varieties: Slash, Carribea , hybrids of the two and occasionally
native Hoop pine. The second operation is situated at Imbil (west of Gympie) is fully
focused on native Hoop pine and the third operation in Tumberrumba (west of Wagga)
is fully focused on exotic Radiata pine.

1.1 Softwood Milling

Softwood milling in many ways is vastly different to hardwood milling and to that extent
it is not so far fetched to classify them as different industries altogether. The softwood
industry operates from a base of large tracts of private and public plantations that have
been established and maintained primarily for the purpose of growing saw log and by
products. Figure 1.2 on the following page is a sample view of the Tuan plantation
forest that in total covers an area of 70 000 hectares, stretching from Maryborough in
the north right down to the northern fringes of Noosa in the south. Softwood mills can
be up to 20 times larger than hardwood mills generally because of the assured long term
availability of a resource that is fairly uniform.

Significant investment, foresight and hard work goes into the sustainable resource banks
that underpin softwood milling in this country. The rotation periods for the above men-
tioned species vary between 28 years to maturation for the exotics and 40 years for the
native hoop. In the meantime between harvesting these forests provide abundant eco-
logical habitats to a range of wildlife.

1.1.1 Securing a Position in Softwoods

To be a major player in the softwood industry requires significant capital investment in
plant and technology. Hyne annually processes volumes in the vicinity of 1.3 million cu-
ic metres. Very generally speaking recovered sawn percentage is around 50%, Table 1.1
Figure 1.2: *Tuan exotic pine plantation forest*

is the most recent and most comprehensive statistics for the Australian production of sawn timbers and wood products. The table gives a sense of Hynes relative share of the Australian sawn softwood, and contribution to wood products feedstock due to production of sawing by-products of chip and sawdust.

Hyne has geared mills with highly automated processes, incorporating various machine vision instruments, customized software and precisely controlled electronic, pneumatic and hydraulic systems in order to cope with the required productivity. Figure 1.3 is an aerial view of the Tuan pine processing plant, the finished timber section towards the front of this view, the log breakdown areas are all toward the middle-rear and plantation forest surrounds the plant.

All this machinery and technology comes at significant financial burden which predominantly must be leveraged by the business through financial institutions. When markets slide abruptly into negative growth territory as they did around 2008 the providers of financial leverage became increasing weary and the businesses ability to repay debts diminished due to an equally abrupt change in demand.
Table 1.1: Australia’s production of Sawn Timber plus selected Wood Products

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<td>SAWN Australian-Grown Timber</td>
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<td>Softwood/Pines '000m3</td>
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<td>4 012</td>
<td>4 263</td>
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<td>Hardwood/Eucalypts '000m3</td>
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<td>944</td>
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<td>Paper and paperboard products</td>
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Source: Australian Bureau of Agricultural and Resource Economics (online)

Figure 1.3: Overview of Tuan softwood processing plant.
1.1.2 Impact of Market Forces

When the Australian domestic building market is buoyant and the Australian dollar is below parity then generally the softwood mills primary concern for profit maximization is to maximize sawn recovery. This is because the highest cost to the business is the log resource and the highest return is from sawn yield. In this market scenario cut patterns are often selected so as to maximize the sawn yield which, is the highest value yield product. Stockpiling whether it be logs for the sawmill or finished packs of product in the warehouses is rarely a concern because the turn over of inventory is so positive and average sale price high.

When demand is weaker and the Australian dollar is above parity (as is the recent trend) the average sale price for timber is forced down; currently down some 25%. Housing Industry Association and Australian Bureau of Statistics modelling such as supplied in Figure 1.4, Figure 1.5 and Figure 1.6, the summary is that 2013 is to be a year of contraction for Australian new house starts and perhaps modest growth forecast for 2014 and 2015. These levels of activity are historically low.

Figure 1.4: Trend in Australian housing starts and forecasts

ABS 8731.0 (2013)
Primary focus switches to trying to cut only products that can be converted to sales with minimum storage period and costs. Stockpiling at any part of the process is undesirable because it represents a cost and risk to the business because of the market conditions. Hynes new mission for the business is to become the supplier of choice. Sensitivity and dynamic response to economic opportunities driven by solid relationships with customers underpin the new focus.

Figure 1.5: Monthly change in total dwelling units approved (trend).

Figure 1.6: Total dwelling units approved (trend), Queensland.

ABS 8731.0(2013)

1.2 Sawmill Simulation

Ertas & Jones’s (1996) elucidate the design process begins with an identified need that can be satisfied by a product of engineering effort. Identification of this need for a custom built sawmill simulator to suit the Tuan mould/model has grown through the authors journey with the stem and log breakdown team at the plant. Better management of wood flows within the wood supply chain has been a clear priority for the majority of forest products companies over the last couple of years (Apthorp 2013). Technology research and development designed for implementation into the operations to gain some improvement is a cultural driver at the plants. There are notable accomplishments to date that fuel a continuation.

Realising a fully functional sawmill simulation of yield software would rank as a technology development achievement for the company. The potential for such a system to
bring new knowledge to the organization is multifaceted from an analytical research perspective and product planning/mix perspective. It is desirable to have the provision to look at a piece of software and have it predict in real time what is likely to be the sawn output for the mill based (example of sawn material is on display at Figure 1.7) on sorted batches of logs sitting in storage at the log yard, see Figure 1.8. The plant Merchandiser is a reliable source of geometric data characteristics of stems.

Sawlog simulation could be programmed to display volumes of fibre likely to be recovered from log yard batches/classes. The implications of a sawmill forecasting facility relate primarily to production planning efficiencies. There is no foreseeable moral or ethical dilemma generated with either the development or end uses of this product. The intended system would be linked into the current log stock program and act merely as an informative aid for production planning. There is no intention for the predictive modelling to be linked into the machine control processes. Energy efficiency is certainly gaining momentum in the management priority stakes and as such there is scope to broaden simulation modelling to predict energy consumption in the sawmilling process for any batch of logs.

Figure 1.7: Sawn timber from the Tuan sawmill.

Under consideration is the breakdown section of the Pine Processing Plant i.e. the Merchandiser and the Linck Profiling line. Although common in Europe this plant combination is not known to be replicated anywhere else in Australia. Hence Tuan log breakdown systems must be considered as unique in nature and so the software will be sculpted to suit the intricacies of that plant. If there were a simulation process pre-
Figure 1.8: *Batch sorted log bays sitting in storage awaiting processing through the sawmilling plant.*

A small percentage increase in recovery translates into a significant financial advantage for the timber manufacturer. Sawn product even as valued out of the mill (i.e. not yet
seasoned or planed) returns a higher price on average ($200/cubic unit) than does chip ($40/cu) or sawdust ($20/cu). For this reasons sawn recovery is a significant factor in sawmill financial viability and there is always a strong push to maximise sawn recovery. Figure 1.10 is a brief demonstration of how each product of sawmill yield evolves.

Figure 1.10: *Black sections yield chip material and the yellow saw-lines yield dust*

This project will investigate the possibilities of developing a suitable strategy and try to design and build a computer program that might be integrated into current systems. Ultimately the program output is envisaged to be a tool that can aid the Optimization Engineer and Production Managers to improve production decision making. For example accurate forward forecasting of residue volumes would be a useful tool for planning the number of trucks needed to control residue levels in the bunkers for any given production schedule. The ultimate concept for simulation package is to build it up to be efficient enough to process individual logs as they are cut out of a parent stem, see Figure 1.11.

A simulation package could be developed for the log breakdown section of the mill and if eventually fine tuned it could be a useful tool for both production and sales planning alike. This project aims to investigate the possibilities of developing a suitable computer program that is a good fit for the intricacies of the Tuan log breakdown process i.e. Linck profiling lines and trimmers. Ultimately the program might be used by the optimization engineer and production managers to improve production decision making. For example more accurate forecasting of batch cutting volume requirements to meet customer
orders may influence more dynamic tuning of log sorting priorities. At another end of the spectrum, accurate prediction of residue volumes would be a useful tool for planning the number of trucks needed to control the level residue in the sawmill fed bunkers.

1.3 Sawmill Sawing Simulation Literature Review

The high Aussie dollar has created the difficult dichotomy of increased relative price paid by the international customer for exported timber and relatively low price paid by domestic customers for imported timbers. The languishing Australian domestic market for construction and building plus rising operating costs (e.g. power and labour), sees building material manufacturers embroiled in a constant battle to survive. Hyne Tuan sawmill, being a large volume manufacturer of solid wood framing, primarily for new houses, is certainly not immune to these prevailing conditions nor, the ever present threat of market failure. As the demand has contracted Hyne has worked to shift from supply driven to demand driven model for production planning. Moving closer to the customers needs has increasingly meant producing products that can be quickly converted to sales. Stockpiling of inventory as logs or as sawn is no longer desirable from an economic risk and cash flow perspective Maness & Adams’s (1991) suggest that to meet the trends in market demand sawmills need to adopt bucking and sawing practices that are flexible.
Todoroki’s (1990) work introduced AUTOSAW system for sawing simulation. With this software simulation was performed on both individual logs and batches of logs. Batch size was not a restriction. Flexibility also allowed simulations to run interactively or as an automated process. In 1990 automated sessions required 8 to 16 seconds to process each log. An interactive session provided graphic images of the log at each stage of simulation and it was possible to interrupt at any stage.

Maness & Adams (1991) presented and demonstrated three models for production planning for a sample sawmill. One of these models was a cutting pattern optimizer for simulating the sawing of a log. The goal of integrating the three models was to choose a sawing policy for a given log class that maximized the value of the lumber produced. Potential advantages of moving from conventional static optimization product values to dynamic product values where investigated by Todoroki & Ronnqvist (2002). Using AUTOSAW product values where updated regularly according to previous timber production. Todoroki & Ronnqvist found that this strategy could reduce the production of un-ordered timber which alleviates storage and stockpiling issues.

Again using AUTOSAW as a research tool Todoroki & Monserud’s (2004) studied the effect sweep has on lumber recovery. Todoroki & Monserud propose that a real log is unique in its form, with several independent sources of variation (e.g. sweep, diameter and knots). Each log can be sawn into products only once. To overcome multitude of potential variation in results the sample of 51 real logs were converted into digital formats and then increasingly bent at 1 inch increments in the virtual environment. Through simulation it was found that conversion losses due to increasing sweep were represented by an exponential decay function.

Later Todoroki, Monserud & Parry (2007) used AUTOSAW simulator to investigate the effect of log ovality on lumber yield. Through simulation of virtual logs at incremental rotations of 5 degrees (i.e. 0 to 355) they tested a hypotheses borrowed from Asikainen & Panhelainen’s (1970) who proposed that if oval logs are sawn correctly and cubic content is determined on the basis of the minimum diameter, the sawing yield of an oval
log is better than that of a round log of the same size. When sawing is carried out in the wrong position the opposite applies.

Todoroki et al. found that the most probable orientation for obtaining increased lumber yield from oval logs was if the first saw cut is parallel to the major axis. Maximum lumber yield was significantly greater from oval logs than from round logs. In some cases yield from oval logs is less than that from round logs if rotation is not optimum.

Usenius & Heikkila (2007) introduced WoodCIM software which is currently used in advanced planning at many Finnish sawmills. WoodCim is a computer aided sawmill planning and controlling software developed at the Technical Research centre of Finland. WoodCIM can be linked into mill computer system and provide support for product and material flow control. WoodCIM post installation outcomes are linked with increased sales value of production compared to less sophisticated planning methods. The goal of WoodCIM is to achieve best profitability for sawing periods. For example a one month strategy can be derived through an optimization model based on linear programming. This sawing model works to optimally combine log supply, sawing possibilities and sales.

Song & Usenius (2007) evaluated InnoSim, a sawing simulator that has been developed in an incremental manner in a series of research projects over the years. The paper emphasizes the push for logs used in simulation to better represent real logs. Aside from the external log characteristics of diameters, length, taper and sweep they suggest modelling the internal defects generated by knots and resin. They suggest that a distribution of lumber quality could be predicted in simulation if statistics are gathered through trial sawing investigations.

Lyhykainen et al. (2009) did sawing simulation using WoodCIM to predict sawn yields of lumber grades and byproducts for Scots pine (plantation raw material in Finland).

According to this collection of published works it is apparent that WoodCIM and AUTOSAW are two simulation packages that have been utilized extensively for valid industry research as well as for sawmill planning. WoodCIM has origins in Scandinavia and AUTOSAW in Canada. Enquiries to associated parties in each of these countries suggests
high levels of protection and privacy on these software. The Canadian group in particular indicated some strict rules regarding the AUTOSAW simulator because only Canadian Timber groups have the permission to access. This could indicate that the Canadians feel that the simulator is a valued resource for achieving some competitive advantages.

The Scandinavian group where more willing to communicate particularly in relation to apparent abilities of their simulator. However when it came to the nuts and bolts of the simulator software and/or potential provision of a demo version there was no response. Of the two major simulators uncovered in this review there is little doubt that the Scandinavian built system is likely to be the more commercial opportunity for a sawmill operation. AUTOSAW on the other hand, seems to be much more associated with research and study objectives in order to establish conventions of practice for efficient sawmilling.

1.4 Risk Assessment

Softwood sawmills comprise an abundance of heavy machinery and mobile plant such as trucks and forklifts. Entry to Tuan site is security restricted for several reasons least not the obligation to ensure that anyone entering site is sufficiently insured and have proven that they are aware of personal safety obligations. The two primary requirements for passing through security to the the plant is completion of a comprehensive induction and secondly ensuring one is in possession of adequate personal protective equipment, including: ear protection, isolation tags, high visibility clothing and steel capped boots. The induction will include compulsory completion of modules and assessment for Site Isolation and Emergency Response.

Walkways around site are clearly marked with yellow paint and must be followed by all pedestrians to avoid entering into forklift operation zones. Since this project is primarily a software development venture there is no real necessity to interrogate the physical machinery which negates a good deal of the hazards.
There is no foreseeable environmental effects arising out the main objectives of this project. The plant is concerned with processing plantation grown pine which is a renewable natural resource. All yields from the sawmill are renewable fibres all with useful secondary applications. Although the project seeks to enhance efficiency of yield conversion the potential advantages generally relate financially because the carbon conversion is fairly neutral. Perhaps there maybe some side effect where coal fire sourced electricity is more efficiently used as an input to the production timber fibres.

1.5 Resource Analysis

A driving factor for selecting this project is a desire to steer away from potential to be caught with ballooning costs or critical component failures. This does not suggest that the technical demands of simulating a high speed, highly automated plant are to be underestimated. Aside from sourcing critical technical information from machine manuals or from other technical staff the project has not acted as a burden to plant operation. Aside from plant technical information (gathered in the literature review, company sources and USQ project supervisor) the significant resources used in development are a laptop computer, backup memory facility, email access, MATLAB software, Latex software and feedstock Excel data files sourced from IT services.

Extension work would necessitate batch trial comparisons of sawmill runs and software predictions. Such trials would present increased burden to plant operation because the process would likely generate delays in production.

1.6 Project Time-lines

There a few essential foundation requirements and numerous potential avenues for enhanced software development. Technical analysis of log form parameters and how these relate to conventions for batch cutting in the sawmill is complicated. As such the development strategy is to simplify where possible in order to build a framework that is ready to be extended upon. The nature of this undertaking somewhat limits the time available for the dedicated programming orientation needed to get an algorithm and outputs for
Introduction and Background

all log form parameters. Some 50% of budgeted time is gobbled up by the technical presentation aspects of the project (including mastering Latex). The general order and approximated contributed workloads are listed below.

1. Literature review and contacting international bodies (40hrs);

2. Detailed background, machine and process specifics (30hrs);

3. Source stems and logs data file, import into MATLAB and write code to perform the necessary manipulations (20hrs);

4. Write MATLAB code for the conversion of a sawmill cut pattern into geometric dimensions of the associated cross-sectional representation (50hrs);

5. Write code for a virtual F1 sideboard, that determines the relative goodness of fit of the sideboard at log every bucket interval. This is done for all potential sideboard widths and the width that returns the highest volume sawn yield is selected. (80hrs)

6. Construct working code loops that for example find a matching batch log for processing and filters out non-matches (40hrs)

7. Code that volumates each 150mm section of the cant after virtual processing (30hrs)

8. Code that volumes each 150mm section of the F1 sideboard after virtual processing (40hrs)

9. Face and edge wane computation for F1 sideboards and outer cant products (30hrs)

10. Develop outputs for a single processed log and also for accumulated batch of logs (70hrs)
Chapter 2

Log Break Down Process

2.1 Log Bucking System

Stem level bucking can either be done in the bush using a harvesting machine or at the mill. Tuan is configured with a dedicated Log Merchandiser line that is fitted out with multidimensional measuring system, optimization software and precision cross cut sawing system. For Tuan Mill stems are trucked in from harvesting operations in the surrounding forests. Figure 2.1 shows the stems loaded onto the infeed deck of the log merchandiser line.

Figure 2.1: Stems (or trees) at approx. 19m length are input resource for the log merchandiser.

The target length for this resource is 18.3m so that if all things are ideal the mill based
bucking system can retrieve three six metre logs; 6.2m being the maximum length that
the sawmill process due to plant configuration. Some quantity of supplied stems in-
evitably come in under the desirable length due to smaller parent tree or error in the
processor length detection (as is the case for stems that come in longer). Figure 2.2
is a plan view of the Tuan merchandiser operation, it shows the flow of stems from
debarking infeed, through the scanning and cross-cut sawing system and then onto the
sorting line as logs. Mobile log handling machines pick sorted logs up out of the bins
and subsequently place logs in batch storage bays ready for sawmill processing.

![Figure 2.2: Overview of the log merchandiser system and process.](image)

The objective of bucking optimization at the stem level is to maximise the stem value
by selecting the combination of logs to cross-cut from a stem that maximises potential
revenue. To do this task anticipated market prices and operational constraints must be
balanced. This decision making process involves programming optimizer software (see
Figure 2.3 and Figure 2.4) to compute the highest value combination of log products.
Log product parameters such as small and large end diameter, sweep range (degree of
bendyness) and length are programmed into the optimizer along with a priority and
value combination.

When a stem passes through the scanning zone time of flight optical energy range sensing
along four quadrants is able to determine to within 1mm accuracy what is the diameter
of the stem. Operating at 60 HZ the system is able to collect some 90+ range sensed
Figure 2.3: Setup screen for loading product diameter and sweep allowances.

Figure 2.4: Setup screen for control of product length, destination and priority to value combination.

points every 33mm. The stem cross-section model is developed by considering the speed of light, halving the time the light beam takes to travel toward the wood then return to the receiver and so represent x and y co-ordinates of the outer shape of the stem. This geometric data is collated and the solutions computer works with the loaded software settings to calculate a combination of logs to be cut from the stem.

Solutioning time for each stem is around 15 seconds. When a solution is done it is transferred through data packet to the machine control Programmable Logic Controller (PLC). This data is used to control the solenoid proportional valves to traverse the saws to cut locations and make the necessary cuts. Figure 2.5 shows a cut solution for a stem with primary dimension details and the proceeding Figure 2.6 is one of the solutioned logs showing assigned cross-sectional diameters every 150mm.

Figure 2.7 shows the sawing solution process from a stem being conveyed through the scan zone on the right of figure. As the stem moves up the ladder to the top pocket the solution computer is running through all potential cut solution to find the best return. In the top pocket a hydraulic pusher 0-lines the stem with reference to saws position tracking and the solution is transferred to the PLC. Figure 2.7 shows merchandiser saws cutting a parent stem into log products. This has all been directed by a data packet transfer from solutions computer to the machine control PLC.

While scanned data is being analysed by the solutions computer there is a secondary
Figure 2.5: *Log cut solution for a stem and stem dimensions.*

Figure 2.6: *Log 1 from the parent stem above showing bucket diameters every 150mm.*

Figure 2.7: *Parent stem processing into logs, from geometric scanning through to cutting.*
process going on that is dedicated to storing geometric information about each stem, often referred to as a royalty process. Comma Separated Values (CSV) files are written for each forest compartment during real time processing. Each day the CSV files are securely copied through File Transfer Protocol out of the merch solutions computer for various business applications.

While the solutions computer moves on to solving for subsequent stems the PLC carries the responsibility of precisely (± 1 cm) driving each log to it’s correct batch location, otherwise called ‘bin destination’. Figure 2.8 shows the very beginning of a logs journey along the sorting process. There are 49 bin destinations on the sorter line. As the conveyor chain drives through the logs down the line an encoder sends pulses back to the PLC. These are transformed into a length of travel. In the PLC each log has a counter tagged to it and a loaded command count associated with where the solutions computer decided this log is to reside due to form characteristics. This information was also passed to the PLC in the data packet transfer for the cut solution.

![Image](image.png)

**Figure 2.8:** Log sorting process is initiated when pneumatic cylinder driven tipples drop logs in sequence to the sorter conveyor.

When the two counts match the PLC activates a solenoid valve for the relevant hydraulic bin kicker. The cylinder actuation rotates the steel kicker assembly about a central shaft to push the log into a bin. The top section of chain is around 150m in length (return section also 150m), log separation is about 60cm, so at any one time there is a great deal
of simultaneous machine routines involved with sorting the logs. Figure 2.9 is a perspective of the log sorting and storage facilities on the outfeed end of the merchandiser. Any orphaned logs go right to the end of the line and a presence sensor activates kicker 48. These logs will either be manually by log yard mobile plant or re-processed through the merchandiser.

![Log storage bays](image)

Figure 2.9: Showing the log sorting facilities, chain, kickers and bins.

Log output data from the merch is fed into a computer program called ‘virtual log-stock’. Figure 2.10 shows the virtual log yard program that is a real time account of logs in the log yard. Additions to stock are made by the merch cutting stems into logs and subtractions are made when logs are processed through the mill. The display of numbered squares in Figure 2.10, represents a plan view of the merch sorting system, showing all the physical classes of logs that are controlled and sorted by the merchandiser. There are 48 hydraulically powered kickers that actuate any time a log matching the bins class characteristics is driven to that location by the main chain.

With a mouse click on a particular bin (in the Figure 2.11, bin 24 has been selected) we see a detailed breakdown of the logs currently stored in that class. Log age, species, length and grade breakdown are all fairly vital indicators for production management decision making. Ultimately it is advantageous to integrate a recovery breakdown that has been assessed on a log by log and bucket by bucket basis using mathematical algorithms.
2.2 Milling Pre-sorted Logs

The Tuan sawmill is a sequential line of machines that chip, rotate, profile and saw the log into boards. Figure 2.12 gives a plan view of the Tuan sawmill showing the flow of logs from log infeed to board sorting. The sawline is a German designed installation from a company named Linck. The entire process is designed for high-speed production capability. Drive line speeds can be manually varied and the current high speed for driving logs down the sawline is 180m/min.

Each machine is equipped with tooling to perform the task, for example knives and segments for chipping and profiling actions (see Figure 2.13) and saws for cutting. New tooling is installed after every shift. Sometimes tooling might fail mid-shift, for example a set of saws might get damaged or a chipper segment might come lose.

Aside from changing the tooling there is virtually no manual handling required for processing logs down the sawline. The Linck line is a fully automated machine that reduces
Figure 2.11: *Virtual logstock data stored for each bin destination*

Figure 2.12: *Overview of the Tuan sawmill process and the flow direction of sawn products.*
Figure 2.13: *F1 & F2 Profiler unit and one of the internal heads.*
Log Break Down Process

a log batch down to sawn boards with seemingly little effort. Figure 2.14 to Figure 2.19 is a sequence of diagrams showing the log cross-sectional view, to demonstrate the Tuan profiling line working on a Bin 24 log.

Figure 2.14: Cut pattern with outside edges and kerfs dimensioned.
Figure 2.15: Chip removed for opening faces at first chipper canter.

Figure 2.16: After first rotation chip removed by second chipper canter.
Figure 2.17: After second rotation Profiler chips around the side boards.

Figure 2.18: Side boards sawn off producing sawdust.
Figure 2.19: After third rotation the cant is vertically sawn.

October 23, 2013
Chapter 3

Mining the Data Resource

With the proposal established to develop and apply a virtual sawmill cut regime, (based on potential cut patterns for each log class), on logs immediately after they have been produced at the merchandiser. Logs cut at the merchandiser will generally sit in storage as stock waiting for batch processing commands from the green mill. It is proposed that in the meantime before batch processing at the sawmill, the Optimization and Production Management personnel will have at their disposal, the luxury of an accurate output forecast of sawdust, chip and sawn volumes. In theory production planners will be informed (to some level of accuracy) about green mill output for any batch of logs prior to a batch being called for cutting. In effect virtual log yard stock will be enhanced to include virtual sawn stock.

Simulation of written code could only begin by sourcing a resource file. The ‘Logs and Stems file’ from the company Information Services Team has served as a resource platform function for foundations development. The stems sheet importantly contains the stem counter which, is reset every eight hours (every shift). It also has a row of diameters written at 150mm increments. These have been written to file by a three dimensional tri-cam laser scanner system as depicted in Figure 3.1 on the next page.
3.1 Geometric Stem Data Retrieval and Router Processing

Scan chain speed is 120m/min and the scan heads operate at 60 Hz which, equates to one snapshot scan produced every 33.3mm of the length of a stem. A high speed photocell ensures length error margins are significantly less than 30mm. In each ‘6’ in scan bucket, there will accordingly be between 4 and 5 ‘snapshots’ of scan data. Each snapshot retrieves something like 90-120 points per scanner head.

The geometric scanning software uses all the points scanned to draw a continuous line of best fit (setup to use line of least squares error method). This line of best fit forms a distorted circle (i.e. the line will travel through 360 degrees and close the circle). A total of 64 diameters are measured across this circle by calculating the centre point (centroid of the shape) then, drawing a vertical line and measuring its length, stepping around clockwise by 2.8 degrees (180 deg / 64 diameters), drawing the diameter through the
centre and measure the line length.

Data points scanned within the 6 inch bucket router are pushed together and a line of best fit is drawn through the points. From this irregular near-circular closed 2-d shape the 64 diameters at even spacing around the 360 degrees are calculated and averaged to form the bucket diameter. Figure 3.2 is a log xyz file viewed with looklog program from the side of a log. Figure 3.3 shows the end viewpoint of a log. The figures show the grouped 64 points sourced from all the individual scanned points in bucket range spaced at 6 inch intervals, particularly evident in the side view of Figure 3.2.

Figure 3.2: Side vision of a scanned log that has had scan points processed through a 6 in data bucket router.

Figure 3.3: End view of a scanned log where data has been processed through 6 inch data bucket router.
3.2 Data Bank for Stems and Logs

The high frequency of diameter readings written to the stems file gives rise to an opportunity for micro-scale simulation analysis on the logs. Although the logs sheet does not have the bucket information it does have a link to the stems via the parent stem number that is written in each log row, clearly indicated by the highlighted column in Figure 3.4. This parent stem number is used as a link to the stems sheet and the useful micro scale geometric information. Each stem however likely gives birth to on average three logs so there is a challenge in linking the log to its associated diameter buckets in the stems sheet. Given the log length from the logs sheet the number of buckets can be calculated (by dividing by 150mm). Last column on the second row of Figure 3.5 indicates that there is also a column (labelled ‘LogPosition’) in the logs sheet that identifies the log position in the stem starting from zero through to the highest log count in a stem.

![Figure 3.4: Extract from the logs file.](image)

One weakness of this log file data is that log diameters are given only for the Small End Diameter (SED) and Large End Diameter (LED). For increased predictive material recovery accuracy it would be very preferable to have and use bucket data. The more descriptive and desirable bucket data is only recorded in the stems CSV file. Data given in Figure 3.6 is an example extracted from a stems CSV file, note that only a portion of bucket diameters have been provided from a calibration event. Centre diameter is the Huber diameter (Hdia). The additional strength of referencing to the stem CSV bucket data is that the dimensional measuring system is regularly calibrated and trade measurement certified within tolerances of 1mm for diameters and 10mm on length.

There is a technical challenge to find some way to reference the log back to the stem...
from the CSV file to get the full bucket data, (refer to Figure 3.6) . Each log is (most often) only a portion of a parent stem. The solution will be to develop an algorithm that will both reference the parent stem and the matching range of bucket data. The added advantage of referencing to the stem CSV bucket data is that the Dimensional Measuring System is regularly calibrated and Trade Measurement Certified (applied tolerance standards of ± 1mm for diameter and ± 10mm on length.

Log zero is the last section of a stem to be measured due to the saws o-lining at the last bucket measured by the scanners (refer to Figure 3.7). To get the correct diameter buckets for log zero the program needs to go to the end of the parent stem. This end of the stem is most often the largest end of the stem due to taper and it is conventional to have the smaller end in the lead. Thus for log zero the program starts loading bucket diameters from the end of stems’ buckets minus the number of buckets associated with that logs’ length. For log one the program starts loading bucket diameters from the end of the stems buckets minus the number of buckets for log zero and minus the number of buckets for log one. The process of loading bucket data for a log in position one ceases when reaching the beginning of log zeros’ diameter buckets. The process increments for any other target logs parented by the same stem, Figure 3.8 is a flowchart example of this bucket diameter loading process.
Figure 3.6: Extract from a stems data file.
Wood in raw form as a log is mostly non-uniform character. Each log will be unique on the basis of combined physical characteristics including: sweep, taper, and diameters. Early development work on a program to gather useful log data from a provisioned file highlighted the need for data filtering. To begin with logs belonging to just one predetermined merchandised bin are to be searched for and returned. The idea is that this bin number plus a relevant sawmill cut pattern code can be input and changed by a user. These inputs will be taken up as global variables by the program’s processes.

A global counter variable counts the number logs retrieved by the program. This counter also offsets the row number for storing sequential log bucket data. Alternatively it would be possible to have only one row for storing the log bucket data, perform the required analysis, store those results then write over the single bucket data row with the next retrieved log. One of the drawbacks of storing all found logs bucket data is that logs are not all the same length hence zeros are written on the end of any logs shorter than the longest length. For example the longest log cut by the bucking system will nominally be a 6m log, having 40 buckets while a mid length log nominally 4.8m length will have 32 buckets. The 4.8m log having 8 zeros at the end of its bucket data storage row. Trailing zeros are obviously ignored during the application of cut pattern analysis to log diameter data.
Figure 3.8: Sourcing and loading the log profile from the stems file.
3.2.1 User Control for Log Batch Size

The program has been designed with an outer loop (a ‘For’ loop). This loop controls how many rows are to be incrementally searched for matches from within the logs file. From a user perspective in order to increase the number of rows searched for a designated batch of logs (say bin 24 logs) it is simply a matter of increasing the range allocated to this outer loop, as depicted by variable ‘k’ in Figure 3.9.

3.2.2 Loading Appropriate Log Data

Identifying the logs to capture is a matter of using an arrangement of ‘If’ statements. The process, as depicted in Figure 3.10 is designed to scan the contents of current logs bin number and compare to the pre-defined bin number. An ‘And’ statement is combined with the ‘If filter’ and serves to ascertain the log position. It is assumed that the maximum log count in any one stem would be no more than six. Therefore six ‘If’ statements exist to look for the combinational match of bin number and log position in the stem. Figure 3.11 condenses this particular process and explains how this part of the program fits into the overall structure. Figure 3.12 gives the Matlab log data summary output for a retrieved batch of logs, the counter returns how many logs matching the desired.

3.2.3 Cant Cross-sectional Target Products

To reveal these cross sectional dimensions code elements must be identified in particular order and decoded to reveal metric identities. To start from the centre with the thickness of the cant. The first character in a pattern code specifies the cant thickness, so this particular code says that the cant is three inches thick.

$$3^{-3-2 + c100 -300}$$

Cant thickness is going to be the same as the width of the boards cut from the cant after vertical saws break the cant down. According to Table 3.1 the 3 inch thick cant has a target thickness of 75.5mm actual and 75mm nominal.
Figure 3.9: Simulator loop that controls the quantity of logs scanned for batch suitability.
Figure 3.10: Locating the log in the parent stem.
Figure 3.11: General Program flowchart.
### Table 3.1: Nominal and Actual target widths of sawn timber

<table>
<thead>
<tr>
<th>Nominal(in)</th>
<th>Nominal(mm)</th>
<th>Actual(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>75</td>
<td>75.5</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>96 ¹</td>
</tr>
<tr>
<td>6</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>6</td>
<td>150</td>
<td>160 ²</td>
</tr>
<tr>
<td>8</td>
<td>200</td>
<td>200</td>
</tr>
</tbody>
</table>

¹ For most product, but 100 for 100×75 and 100×15.
² 160×38 in side boards are nominally 150 wide due to later resaw to 2 x (76 × 38).

### Table 3.2: Cut code for target thickness of sawn timber

<table>
<thead>
<tr>
<th>Code</th>
<th>Nominal(in)</th>
<th>Nominal(mm)</th>
<th>Actual(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5/8</td>
<td>15</td>
<td>15.7</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>25</td>
<td>26.5 ¹</td>
</tr>
<tr>
<td>3</td>
<td>1.5</td>
<td>38</td>
<td>39.6</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>50</td>
<td>50.0</td>
</tr>
</tbody>
</table>

¹ for most product, but 25.5 for 100 × 25.

### Table 3.3: Saw blade kerf

<table>
<thead>
<tr>
<th>Saw Unit</th>
<th>Kerf/cut (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sideboards:</td>
<td></td>
</tr>
<tr>
<td>Inner</td>
<td>5.4</td>
</tr>
<tr>
<td>Outer</td>
<td>4.8</td>
</tr>
<tr>
<td>Cant Breakdown</td>
<td>4.2</td>
</tr>
</tbody>
</table>
Figure 3.12: *Program gathered log batch data for pre-selected bin.*

The addition of the second alpha numeric character is to describe thickness (decoded by Table 3.2) of some cant boards. In the standard pattern code the thickness of these boards are known only by non coded convention.

\[3-32 + c100 -300\]

Programmable computation is made simpler with the addition of this character. This character is included to explain the thickness of timber pieces either at the centre of the cant or neighbouring the cant; depending on which of the two is not described by the second section of pattern code. In the example code the second section of code describes the ‘centre (c)’ as being 100mm wide. The preceding two characters say there are two pieces of timber to be cut at the thickness described by the introduced character i.e. two pieces at 39.6mm thick. These pieces will be cut from either side of the cant on the cant width plane.

\[3-32 + c100 -300\]

The three code characters in the middle (c100) say that there is a 100mm wide product being cut in the centre of the cant.

\[3-32 + c100 -300\]
Chapter 4

Mill Modelling

4.1 Decoding Sawmill Patterns

Tuan sawmill cut patterns (see Figure 4.1) are an important determinant of the sawmill yield process. It is critical to this project that the conversion process from any cut code to an understanding of the geometric dimensions is precise and fully automated. Matlab code has been written to perform the computation of perpendicular dimensions of a user selected pattern. Since the logs are modelled as circular, orientation convention has been described based upon the thickness and width plane orientation of the cant.

Figure 4.1: Mapping a Tuan sawmill cut pattern code.
The last three characters in the cut code is the code dedicated for side board locations and their respective thickness (decoded in Table 3.2). Sideboards are generally cut as a pair with each partner piece always cut opposite sides of the cant.

4.2 Sideboards

4.2.1 F1 Sideboards

The first character in the sideboard range (3) details presence or absence, if the character is zero then there will be no such sideboard and thickness of F1 sideboard pair is zero. If numeric character greater than zero is present F1’s are to be cut from above and below the cant (on the cant thickness plane). The kerf between cant and these particular sideboards is 5.4mm and for the pair there is 10.8mm (i.e. two saw cuts), refer to Table 3.3.

\[ 3-3-2 + c100 - 3_00 \]

4.2.2 F2 and F3 Sideboards

The second character (‘2’ in Figure 4.2) indicates presence and thickness of a sideboard pair, located outside the first pair but in the same plane. The kerf to cut each one of these sideboards is 4.8mm, so 9.6mm for the pair. The third character (‘2’ in Figure 4.3) indicates presence and thickness of a sideboard pair to be cut from the outsides of the cant in the cant width plane. These sideboards are removed at the cant breakdown saws hence the kerf is only 4.2mm and 8.4mm for the pair.

4.3 Transform Sawmill Pattern Code to Dimensions

In the enduring example of a sawmill cut pattern code there are only F1 sideboards which position above and below the thickness plane of the cant. To get the full dimension in this orientation of the pattern the requirement is to add total sideboard saw kerf and
thickness of both the cant and the sideboards. Kerf for the inner sideboards breakdown saw is 5.4mm, so the total kerf thickness for the removal of two sideboards is 10.8mm. Finally adding the thickness of the two sideboards, the kerf and the cant thickness gives one planar dimension of $75.5 + 2\times(39.6)+10.8 = 165.5$mm actual (difference compared with cut pattern diagram dimension is that product dimensions have been rounded to integers).

Figure 4.2: Cut pattern with F1 and F2 side-boards.

Figure 4.3: Cut pattern with F1 and F3 side-boards.

Figure 4.4: Dimensioned sawmill pattern.

Figure 4.5: Cant from pattern 3-3-2+c100-300.
Perpendicular to cant thickness plane is the cant width plane. This pattern dimension is the total width of the cant; all cant products plus the cant breakdown saw kerf of 4.2mm for every cut. For this particular cut pattern there are two cant breakdown cuts each with kerf of 4.2mm yielding three cant products; two at 39.6mm thick (code characters 3 and 5) and one at 100mm thick (code characters 7-10). The dimension in cant width plane is therefore: 100 + 2*(39.6) + 8.4 = 187.6mm actual.

\[3 \cdot \frac{3-2}{c100-300}\]

The thickness of a designated sideboard is always held constant (as prescribed by the pattern code) but the width can vary depending on: fit to an individual log, width categories (Table 3.1) and programmable priority and value settings. See Figure 4.6 for demonstration of a sample of some potential width of F1 side boards examined through simulation. At this stage of the development strategy it is decided to have the software designed specifically for targeting the highest potential sawn yield rather than to delve into the variables of optimising sideboard width according to fluctuations in customer demands.

For virtual simulation and decision making in regards to max sawn yield regime on the sideboards the potential vertices of the sideboards need be compared to corresponding adjacent points on the perimeter of the log, see Figure 4.8 on the following page.

### 4.4 Overlaying Cartesian Co-ordinates

An adoptive strategy involves overlaying a Cartesian \([x,y]\) coordinate profile with the origin at the centre of the log, \([x]\) is along the cant width plane and \([y]\) is along the cant thickness plane, see Figure 4.8. Cant thickness and sideboard breakdown kerf have been established which means the exact location of the inner sideboard face edge on \([y]\) axis is determinable. The thickness of the sideboard is locked, the outer face edge can be determined in a similar manner. By increasing the width of the sideboard the only coordinates that will be variable are in relation to \([x]\). If the radius of the log can be
established and the \( y \) intersect with sideboard face edge is constant then the intersect in terms of \( x \) is determinable.

By introducing \( x \) coordinates that match the array of sideboard width options (refer to Table 3.1) a comparative computational analysis between the vertices of the sideboard and intersects to the outer edge of the log is performed. The result of such analysis determines two things. Firstly if the vertices of the sideboard are located within the bounds of the log and secondly if a board corner is located outside the log then the relative percentage of wane along the width face is computed, Figure 4.7 illustrates wane introduced when projected sideboard edges stretch out beyond the perimeter of the log,
also see see Figure 4.9. The percentage wane parameter is highly sought after for this project because there are, specific wane tolerance ranges governing whether a piece of timber will be accepted by downstream grading stations or alternatively docked/rejected and converted into chip.

4.5 Processing Face and Edge Wane

There are two places or types of wane that must be predicted one on the width face (face of sawn), and the other on the thickness face (edge of sawn), refer Figure 4.9. At the profiling line product specific limits for both face and edge wane can be set independently. Primary and secondary wane limits can also be set where, primary wane is allowed full length and secondary is allowed for a percentage of length. Typical primary and secondary limits are 30% face \( \times \) 30% edge \( \times \) 100% length and 33% face \( \times \) 35% edge \( \times \) 30% length.

First a strategy for modelling face and edge wane is identified and demonstrated by example. In terms of \( x \) any point on a circle quadrant - 0 to \( \pi/2 \) can be described by:

\[
x^2 = r^2 - y^2
\]

If the sideboard vertices are assigned Cartesian co-ordinates \( [x_1,y_1] \) and \( [x_1,y_2] \) for the lower and upper corners respectively. For example if the radius of the log is 105 mm for pattern ‘3-3-2+c100-300’, the origin is at the centre of pattern and log, then \( y_1 \) co-ordinate will be \( 0.5 \times 75.5 \) + 5.4 = 43.15 and \( [y_2] \) is 82.75 (i.e. \( y_1 \) + sideboard thickness). The \( x \) axis intersects between the sideboard and the outside of the log can
then be solved by substituting the \( y \) values and the log radius into:

\[
x_n^2 = r^2 - y_n^2
\]

The solutions for which are:

\[
x_1 = 95.7 \quad \text{and} \quad x_2 = 59.8
\]

Mirroring the result about the \([y]\) axis indicates the maximum available material a sideboard located within the \(y\) axis range. The maximum material width of the inner face of the sideboard according to this method is 191.45mm. The outer face has less material as it is further from the centre; leaving cross section of only 119.6mm. If the sideboard vertices extend beyond these values then edges will not be cut square and will inherit wane on both face and edge.

The largest standard sideboard width (Table 3.1) that will fit inside the inner face is 160mm (actual). Projecting this width up to the top face means going beyond the outside of the log since the max material width here is 119.6mm. The difference between these two values is the absolute measure of wane on the top face (i.e. \(160 - 119.6 = 40.4\)). The relative percentage of face wane computed is \(40.4/160 \times 100 = 25.25\%\) which, is within the acceptable range.

In the instance of edge wane the intersection of the outside perimeter of the log and edge of the board needs be determined. In terms of \([y]\) any point on a circle quadrant - 0 to \(\pi/2\) can be described by:

\[
y_n^2 = r^2 - x_n^2
\]

hence:

\[
y_3^2 = r^2 - x_1^2
\]

The result for \(y_3\) is 68mm. Difference between \(y_3\) and \(y_2\) is 14.75mm (82.75 - 68). The relative percentage of edge wane computed is \(14.75/39.6 \times 100 = 37.25\%\). This would fail the typical wane rule test because edge wane percentage is too high.
Chapter 5

Trim Sawing Process

Board trimming is the final breakdown process for unseasoned sawn timber at the Tuan sawmill. Where once the inspection and docking process may have been manually performed by human operator/s, the shear rate of volume being supplied by the profiling line demands an automated solution with equal capacity handling capability.

5.1 Trimmer Machine Centre

The trimmer machine center is a system that integrates several major components. A computer system calculates the maximum value of recoverable timber and chips for each piece of material processed. The system uses accurate scanning, PCs and dedicated software packages. The system scans material and calculates board solutions. A Programmable Logic Controller (PLC) controls the timing and movement of machine centre equipment. The scanning system determines thickness, width and length for each material piece. A solution is computed by using the current set parameters and the scan data. The parameters can be edited and allows for customization.

The solutions PC:

- Calculates board solutions and controls saw movement/activation through the PLC.
- Sends commands to other PCs.
- Requests data from other PCs.
Figure 5.1: Block diagram of the trimming system.

Figure 5.2: Trimmer solution computers.
Trim Sawing Process

- Sends and receives PLC data.
- Stores solution parameters.

The Solutions PC is the controlling PC for the system. It uses scanner data to calculate board solutions and position data for each piece.

### 5.1.1 Material Flow

At the end of profiling line the sawn boards are shunted and subsequently chain conveyed in a perpendicular orientation of motion (in relation to board length). Each board from a parent log needs to be separated from its mates so that it can be analysed by a geometric scanning system. Using buttons on the consoles, the operator tells the computers to automatically scan and cut material (see Figure 5.3).

![Operator controls material flow into trimming system.](image)

Figure 5.3: *Operator controls material flow into trimming system.*

Cant and side board products alike move through the trimmer system in the following sequence (sourced from the Trimmer Operating Manual USNR (2002)):

1. Unscrambler separates the pieces and moves each onto the scanner infeed chain.
2. The scanner infeed transfer moves them onto a conveyor called the lug chain.
3. The ending rollers move the board against a fixed lumber line and boards move onto a scanner transfer chain.
4. An encoder on the lug chains tells the scanner computer the position of the piece as it moves under the scanner. The scanner tells the scanner computer the
thickness of the board. The scan data is sent to the solutions computer, refer to Figure 5.4.

5. The length scanner tells the scanner computer the length and width of the board. Data sourced from this length-cell is sent to the solutions computer. The scanner computer generates a geometric picture of each piece of material for the solutions computer.

![Figure 5.4: Trimmer geometric scanning module.](image)

6. The solution computer calculates the most valuable combination of boards and chips that can be cut from each board.

7. After passing through the scanner, the lug chain moves the board through the trim saws, producing a final board.

8. The boards are moved to the sorter. Using buttons on the consoles, the operator tells the computers to automatically scan and cut material.

### 5.1.2 Trimmer Laser Sensing

There are two trimmers in the Tuan sawmill. The laser spacing on trimmer 1 is one inch and on trimmer two is four inches. Trimmer one has 22 heads with 23 lasers on each, trimmer two has 20 heads with six lasers on each (half heads are on top and half on the bottom). The lasers in these trimmers are point lasers which means there are
blind spots along the length of the boards from the laser data. Both trimmers use lasers in coordination with a light curtain (spacing on Trimmer one and Trimmer two light curtain is 2.5mm). Lasers measure the thickness and the wane profile, the light curtains measure the length and combination of lasers/light curtain measures the width of the board.

Briefly (also refer to Figure 5.5 and Figure 5.6) the laser scanner module for trimmer machine centre generates geometric representation data in following manner:

- Lasers emit beams of infrared light into the scan area.
- The laser beams reflect off the material surface and the cameras sense the reflected light. The reflected laser beam angle and intensity corresponds to the thickness of measured material.
- Centroid data is the reflection position on the camera and peak data is the maximum intensity of the reflected beams. The scan head signal processor encodes the camera centroid and peak data.
- A fiber optic cable transmits the data to a receiving card in the scanner processor.

Figure 5.5: Point lasers scanning a board as it moves through.

The slashed pieces of board (i.e. pieces removed by the trim saws) drop down between the trimmer conveyor chains onto a belt that feeds into a chipper. Subsequently all slashed board is converted into saleable wood chip.
Figure 5.6: Trimmer scan head block diagram.

Figure 5.7: Scanned and solutioned boards entering the trim saws.

Figure 5.8: Trimmed boards exiting the trim saw booth.
5.1.3 Trim for Wane Criteria

Wane allowances are programmed through the trimmer interface computer system. These parameters can be edited at any time by production controllers to control the wane quality characteristics of timber boards to be processed in an upcoming run. When setting up for wane by board rules data entry and changes are made in the Face, Edge and Area Wane tables of the trimmer control interface. Wane is the percentage of wood that can be missing. For example, face wane of 25% means that 75% of the face of the board must be good wood and 25% can be missing, see Figure 4.9.

Primary and secondary wane limits control the total combined length over which threshold face and edge wanes are allowed to be present on any one board product. These limits are applied in the sawmill trimming process and as such if limits are exceeded trim saws will activate to cut a section of the board off so that the remaining length meets the specified limits. Figure 5.7 and Figure 5.8 illustrate sawn boards first moving into the trim saws and second exiting the saws as finished sawmill board product. If a length section not greater than the minimum required board length (usually around 2.4m) cannot, be solved along the full length of a scanned board then trim saws at 150mm spacing along the length of the board will be activated to go down and cut up the entire length of board.

Primary wane is allowed full length and secondary is allowed for a percentage of the length. Typical primary and secondary limits are (30% face x 30% edge x 100% length) and (33% face x 35% edge x 30% length). The program has already predicted the face and edge wane at 150mm increments along the length of the sawn F1 sideboards. The next step is to simulate how the trimmer systems are likely to treat each virtually generated sideboard width based upon the wane rules. Consideration must also be given toward the physical spacing of the trim saws which ultimately also has a bearing on the recovered length.
5.1.4 Trim for Length Criteria

If a board is over the minimum required length but under the actual trim saw spacing, it would be allowed through without trimming. If a board is over the actual trim saw spacing, it would be docked to the actual trim saw spacing. Figure 5.9 and Figure 5.10 gives an internal top perspective and almost side view of trim saw elements. Short barrel hydraulic cylinders provide the mechanical thrust to drop saws into a board for cutting then retract the saw up and clear of the next board.

Figure 5.9: Top view of a trim saw elements. Figure 5.10: Isometric view of three trim saws.

Trim saw spacings do vary, but usually sits around what is supplied in Table 5.1. Minimums also vary from one trimmer to the other, but sit around the +20mm mark, except for 2.4 / 3.0 which are 2.415 and 3.018.

Table 5.1: Trim saw table

<table>
<thead>
<tr>
<th>Board nominal trim length (m)</th>
<th>2400</th>
<th>3000</th>
<th>3600</th>
<th>4200</th>
<th>4800</th>
<th>5400</th>
<th>6000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trim saw fixed position (m)</td>
<td>2420</td>
<td>3026</td>
<td>3632</td>
<td>4238</td>
<td>4844</td>
<td>5450</td>
<td>6056</td>
</tr>
<tr>
<td>Min. allowed board length (m)</td>
<td>2415</td>
<td>3018</td>
<td>3620</td>
<td>4220</td>
<td>4820</td>
<td>5420</td>
<td>6020</td>
</tr>
</tbody>
</table>

The optimisers have the capacity to solution 2 boards from any single input piece however the trimming systems don’t have the hardware (mechanicals or control system) to recover 2 pieces from 1 piece. The optimiser only considers a single product...
output and so logically chooses the most valuable single product solution, usually this will be the longest length, but not always. If there’s two possible positions for the same product out (i.e. a 2.4 from either the near end or far end of a 6.0m input) it takes the solution closest to the 0 line. Provided it meets the wane criteria, there’s no value difference between a board with no wane and a board with maximum wane.

Each virtual sideboard is first processed through the wane rules. Later a determination is done on how well the remaining length fits with standard sawmill lengths so as to ultimately determine which trim saw actuate down for the cross cut. Eventual yield for that board at the trimmer is categorised into three:

1. Sawn board that will go to the sorter
2. Chip, which is produced from the docked sections and
3. Sawdust, which is produced by the sawcuts.

Given wane predictions at 150mm increments for F1 side boards for the various potential widths, query is raised about handling the sections in between the points of measurement. One way (also currently the way the program works) is to assume uniformity of wane over the entire 150mm bucket. This is certainly the easiest way to deal with the wane and reassuringly the trimmers do it this way. Slightly more complicated manners would include assuming linear increase between end of bucket to centre of preceding bucket data or effectively cut bucket sizes in half by assuming that the plane where two data buckets join is the average of the 2 buckets.
Chapter 6

Virtual Product Volumation

6.1 F1 Sideboards

In terms of programming it is critical to understand that in a board length there can be multiple regions that are distinguished by their resulting dimensional geometry which ultimately can be graded into two separate classes being either:

1. Within wane tolerance specification, or

2. Outside wane tolerance specifications.

The developing simulation program has an existing inclination to sequence through the log buckets using conditional ‘IF’ statements and counters. There are five standard sawmill board widths that must be considered as potential sideboard candidates (refer Table 3.1). Co-ordinated interaction between scanner system, computer and solutions software, machine controller and the profiling machine creates the useful capability for variable width sideboard recovery.

Imitating this process reveals that trimmer wane tolerances are vital to predicting the best width sideboard to profile and saw from any particular log. Wane tolerances, both Primary and Secondary have been discussed in the trimming process. If a board is sent to the trimmer post profiling, sawing and if wane is found to exceed tolerance specifications on any section of the board then the trim saws will be told to cut the non conformance out. Recovered sawn yield is ultimately affected by what is docked at the trimmer.
In the developing simulation program each and every potential sideboard width is consecutively considered on a bucket by bucket basis (refer to Figure 6.1) and a predicted length and volume yield is returned based upon predicted yield at the trimmers (see Figure 6.2). This process concentrates solely on sawn yield loss at the trimmer due to the defect of higher than allowed wane on boards. There are several other defects that will present at the trimmer machine centre that might impact on sawn yield. Most, if not all of these additional defects are internal to the log and as such cannot be predicted with the current level of scanning technology. There is technology on the market that can see internal defects in the log, Tuan mill currently uses only external log scanning systems. Some of the internal defects which may affect trimmer/sawmill yield are internal resin pockets, splits and knot concentrations.

<table>
<thead>
<tr>
<th>Bucket</th>
<th>% Edge Wane</th>
<th>% Face Wane</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>75mm</td>
<td>96mm</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 6.1: *Computed Percentage Edge and Face wane results for F1 sideboards on a bin 24 log.*

Figure 6.2: *Predicted length and volume recovery for all potential sideboard widths.*
For the developing simulation program, considering primarily wane defect as explained, if initially there is an in tolerance section followed by a section that is determined to be not in tolerance then the program works to transfer the in tolerance bucket counter to a storage account and then resets the original incrementing counter for new use. If a new in tolerance section occurs along the length of a single board then the in tolerance counter is always ready to accumulate new length sections. It is not useful to store an in specification section length if it falls below the minimum sawmills length for board production. Nominally this length is 2400mm.

![Figure 6.3: Extract from program code that checks that good section of 96mm wide F1 sideboard is longer than minimum standard length.](image)

To simplify computations the number of buckets in each log are truncated to integer level and hence the nominal rule of rejecting sections that are less than 2.4m is convenient and robust. As shown in the program code sample in Figure 6.3 a counter is not allowed to pass to storage unless it contains the equivalent bucket count to construct a minimum length sawmill board. The practical sense of this law is that if in the transition from an in-tolerance section of board to an out of tolerance section, the counter is even ‘one’ count less than the 2.4m required, then the in tolerance section is impacted by being aggregated to trimmer docking. Subsequent yield is converted to chips and sawdust (sawn residue). When the processing of an individual logs buckets is completed then storage counters and live counters need to be compared against each other to find the longest length for recovery.
6.1.1 Total Sideboard Volume

If aggregation, tracking and reporting of length sections destinations is multifarious enough then the associated volume calculation process is more so. Without any wane board cross-section is a simple rectangle. Incorporate wane at a corner or on either face or edge of the board and level of algorithmic involvedness needed to solve the board cross-section area grows. Computing volume for out of specification sections is as important to a yield simulation program as is the calculation of sections of sawn board with no wane defect.

The code actively works on two independent pathways. Firstly every bucket of a board is volumated regardless of the wane defect. This first round of volume calculations does not pass nor fail a section of board but merely works to calculate a boards absolute and total volume. Figure 6.4 is a sample taken from the simulation program code showing how this process is executed. Discrimination at this point is applied in order to have geometrically workable procedures in each instance, see Figure 6.10. The basis of this discrimination is on which corners of the sawn board are affected by wane, diagrams of four of the five cases are given in Figure 6.5 to Figure 6.8.

The fifth case is of course where there is no wane and the cross-section is easily determined as a rectangle. In the other four instances the cross-section is divided into geometric sections so that the area of each section can be independently determined. The corners of each component shape are located by co-ordinate system using standard x and y axis, where the virtual centre of the log is origin. Total cross-sectional area is then computed by summing the component sections.

Since there is the underlying supposition that log bucket cross-sections are circular then intersection co-ordinates of board lines with the outer perimeter of the log can be found, (see Figure 6.11). This is very useful in computation of the sectional components of cross-sectional area. Take for example the calculation of the area of the segment separated by the chord created when the board has wane. The mathematical solution: connect the circle’s centre to the two sides of the chord to obtain a sector of the circle separated by two radii (see Figure 6.12). The angle of this sector is calculable from the length of the chord and the radius and hence its area is known. The segment
Figure 6.4: Extract of program code showing volumation of sideboard sections.

Figure 6.5: Face wane < 100% and Edge wane < 100%.
Figure 6.6: Face wane = 100% and Edge wane < 100%.

Figure 6.7: Face wane = 100% and Edge wane = 100%.

Figure 6.8: Face wane < 100% and Edge wane = 100%.
### PREDICTED RECOVERY FOR F1 SIDE BOARD WIDTH:

<table>
<thead>
<tr>
<th>Nominal sideboard width:</th>
<th>75 mm</th>
<th>96 mm</th>
<th>150 mm</th>
<th>160 mm</th>
<th>200 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of F1 board recovered:</td>
<td>4620</td>
<td>4620</td>
<td>3620</td>
<td>3026</td>
<td>0.00</td>
</tr>
<tr>
<td>Percent length of log:</td>
<td>99.2</td>
<td>99.2</td>
<td>74.5</td>
<td>62.3</td>
<td>0.00</td>
</tr>
<tr>
<td>Untrimmed F1 sideboard volume:</td>
<td>0.0143</td>
<td>0.0182</td>
<td>0.0280</td>
<td>0.0294</td>
<td>0.0317</td>
</tr>
<tr>
<td>Trimmed F1 sideboard volume:</td>
<td>0.0143</td>
<td>0.0182</td>
<td>0.0146</td>
<td>0.0207</td>
<td>0.0000</td>
</tr>
<tr>
<td>Percent F1 sideboard volume recovered:</td>
<td>100.0</td>
<td>100.0</td>
<td>52.0</td>
<td>70.4</td>
<td>0.00</td>
</tr>
<tr>
<td>F1 board trim volume:</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0134</td>
<td>0.0087</td>
<td>0.0317</td>
</tr>
<tr>
<td>F1 accumulated trim volume:</td>
<td>0.0000</td>
<td>0.0011</td>
<td>0.0314</td>
<td>0.0265</td>
<td>0.0722</td>
</tr>
</tbody>
</table>

*******************************************************************************

Batch of class 24 log details:

<table>
<thead>
<tr>
<th>Count</th>
<th>Length</th>
<th>Class</th>
<th>Sweep</th>
<th>Buckets</th>
<th>Log Posa.</th>
<th>Stem no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6960.0</td>
<td>24</td>
<td>34.3</td>
<td>40</td>
<td>1</td>
<td>642</td>
</tr>
<tr>
<td>2</td>
<td>4860.0</td>
<td>24</td>
<td>29.0</td>
<td>32</td>
<td>1</td>
<td>643</td>
</tr>
<tr>
<td>bin 24 counter</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 6.9: Summary yields for potential F1 sideboard widths.
Figure 6.10: Flowchart for volumating sawn board sections.
area is the difference between the area of the sector and the isosceles triangle made by the chord and the two radii.

For example the F1 sideboard option where Edge wane = 100% and Face wane < 100%:

**F1 Cross-section Area** = (Area 1 + Area 2 + Area by Chord) \times 2

\[
\text{Area 1} = (y_2 - y_1) \times x_2
\]

\[
\text{Area 2} = 0.5 \times ((x_3 - x_2) \times (y_2 - y_1))
\]

Figure 6.11: *Area grouping for F1 sideboard when Face wane < 100% and Edge wane = 100%*

\[
\begin{align*}
\text{Length} &= \sqrt{(y_2 - y_1)^2 + (x_3 - x_2)^2} \\
\theta &= \cos((2 \times \text{Radius}^2 - \text{Length}^2)/2 \times \text{Radius}^2) \\
\text{Area} &= (\text{Radius}^2/2 \times (\theta - \sin \theta))
\end{align*}
\]
6.1.2 Sideboard Volume Within Wane Tolerances

This refined volumation process integrates two filters built in to categorize those sections that pass the primary wane test, those sections that pass the secondary wane test and sections that fail both of the prior. This is working out which section to store as likely sawn yield and which sections to store as likely chip yield, basis of which is how the trimmer is programmed to make decisions. This volumation process is intrinsically tied into the coded length recovery procedure. Figure 6.9 & Figure 6.2 shows a sawmill predicted yield summary for the full range of F1 sideboard widths.

6.2 Cant Products

The cant products make up a significant proportion of a sawmill patterns overall volume. Figure 4.5 is a cross-sectional view of the cant products from the cut pattern shown in Figure 4.4. The sawmill yield simulation program has been designed to process outer cant products (like the two 40 x 76 in Figure 4.4) in a similar manner as the F1 side boards were shown to be evaluated. Hence the program processes every log bucket diameter to determine the percentage edge and face wane, Figure 6.14 and Figure 6.15 demonstrates the general process by which the simulation software works to divide the outer cant board cross-sections of each 150mm bucket in order to accurately compute area and eventually the bucket volume. The cross-sectional
Figure 6.13: Flowchart for volumating within wane specification sections of sideboard
breakup process is determined by edge and face wane categorization, similar to that explained for the F1 sideboards which, occurs (within the software filtering processing) for every 150mm bucket section.

Figure 6.14: Segmenting the right outer side-board for computing area.

Figure 6.15: Cartesian co-ordinates are applied for geometric computation of outer cant board area.

Total length recoverable (considering also trimmer parameters refer Table 5.1) and volume are processed and then lengths and volumes passing the primary and secondary wane rules are computed. The 100 x 76 centre cant product is handled a little differently in that it is assumed that there will not be any wane on a product situated in this region of a pattern or log. Hence the only particular issue affecting yield that can and is re-created in the virtual yield simulator is to focus on trimmer length categories.
Chapter 7

Performance of Simulation Software

7.1 Software Outputs

This software has been designed to be a technology aid for production planners at Tuan sawmill. The first set of outputs (Figure 7.1) generated for the Tuan user are the relevant statistics to describe the last log to be processed through the cut and yield simulation. Potentially individual log statistics and yield outcomes can be viewed as well as batch outcomes. The individual log statistics including which stem number it derived, length and volume, go some way in providing an amount of credibility to the way the software sources the correct set of data prior to moving into the predictive computation phases. This information can be fairly easily cross-referenced manually to find that the software is indeed sourcing the correct feedstock.

FIGURE 7.1: Log statistics

LOG STATISTICS:

Parent Stem no.: 732
Length of Parent Log: 6060.0
Volume of Parent Log: 0.2674
7.1.1 Sideboard Yield

Sideboard yield has significant potential to affect the sawmill yield outcomes for any log and batch of logs. There is flexibility built into control software and profiler machinery movement to allow the width of sideboards to change from one log to the next. This same degree of dynamic behaviour has been created in the yield software. When the software is computing yields, the sideboard option priority (in the default state) is set to maximise the potential sawn volume yielded from a sideboard set. Figure 7.2 demonstrates the comprehensive range of indicators the software can currently provide in relation to a set of F1 sideboards for any log and pattern combination.

This set of indicators explain the source of chip and sawdust production in terms of whether it has come from the Sawmill-line or the Trimmer. This allows for comprehensive analysis of trimmer activity. The F1 sideboard width that has been determined as the highest volume sawn yield option and their predicted length is displayed in these results.

<table>
<thead>
<tr>
<th>F1 SIDEBOARDS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>High volume F1 Side Board option (mm):</td>
</tr>
<tr>
<td>Length of high volume F1 Side Boards (mm):</td>
</tr>
<tr>
<td>F1 sawdust from saving (m^3):</td>
</tr>
<tr>
<td>F1 volume to Sorter (m^3):</td>
</tr>
<tr>
<td>F1 trimmed to chip volume (m^3):</td>
</tr>
<tr>
<td>Number of trim saw cuts for F1 boards:</td>
</tr>
<tr>
<td>F1 cross cut (trimmer) sawdust volume (m^3):</td>
</tr>
</tbody>
</table>

Figure 7.2: F1 sideboard yield indicators

7.1.2 Cant Products Yield

The width and thickness of the cant boards is locked and controlled only by the cut pattern code, still there is no guarantee that any log will be a good fit for a designated pattern. The simulator assumes that inside cant boards will always be a good fit for a pattern, running on the reasonable assumption that the user is at least competent.
Performance of Simulation Software

enough to select a pattern log combination that will not result in wane along the edges of inner cant boards.

The outer cant boards however come under the same sort of scrutiny that is applied to the sideboards. This involves bucket by bucket analysis for edge and face wane, precise volumation and any necessary trimmer activity based upon the wane rules. Figure 7.3 demonstrates the range of indicators the software can currently provide in relation to a set of cant boards. Wood that is predicted to get through to the ‘Sorter’ is finished sawmill/sawn stock, it is the highest value yield category. Figure 7.3 demonstrates that the program describes both the length and volume of inner and outer cant boards sent to the Sorter.

<table>
<thead>
<tr>
<th>CANT BOARDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cant sawdust from saving</td>
</tr>
<tr>
<td>Length trimmed off centre cant boards (m) :</td>
</tr>
<tr>
<td>Volume trimmed off centre cant boards (m³) :</td>
</tr>
<tr>
<td>Length trimmed off outer cant boards (m) :</td>
</tr>
<tr>
<td>Volume trimmed off outer cant boards (m³) :</td>
</tr>
<tr>
<td>Number of trim saw cuts for cant boards:</td>
</tr>
<tr>
<td>Cant cross cuts (trimmer) sawdust volume (m³) :</td>
</tr>
<tr>
<td>To the sorter</td>
</tr>
<tr>
<td>Length of outer cant boards recovered (mm) :</td>
</tr>
<tr>
<td>Volume outer cant boards to Sorter (m³) :</td>
</tr>
<tr>
<td>Length of centre boards recovered (mm) :</td>
</tr>
<tr>
<td>Volume centre cant boards to Sorter (m³) :</td>
</tr>
</tbody>
</table>

Figure 7.3: Cant board yield indicators

7.2 Accumulating Yields

It is vital that a yield program have the capability to accumulate all the yield indicators over a batch of logs which, when cut through the sawmill can number into the thousands. Each log will vary in some way in it’s geometric characteristics, for example taper, sweep and bucket diameter profiles. Figure 7.4 shows the production of accumulated yield indicator outputs by the developed program. The accumulated yield outputs detail firstly the number of logs that have been processed to arrive at those
Performance of Simulation Software

totals. Figure 7.5 is the plot of sawmill yields. Total volume yield for sawn, dust and chip are accumulated for each consecutive log processed. The overall sawn recovery is the percentage of wood fibre from all logs processed that is predicted to be yielded as sawn material i.e. flow through the trimmer to the sorter.

| ACCUMULATED SAWMILL YIELDS:                          |
| Number of select batch logs processed: 14             |
| Accumulated Sawn_Yield: 1.696                         |
| Accumulated Dust_Yield: 0.211                         |
| Accumulated Chip_Yield: 1.376                         |
| Overall Sawn Recovery: 81.58%                         |

Figure 7.4: *Accumulated sawmill yield indicators*

The final outputs are what the program is all about and that which is a provision for predicting sawn inventory. This software function gives a predicted sawn output in actual numbers of product cross-sections and lengths recoverable through saw milling a batch of logs, see Figure 7.6. There is a counter in the program, currently named ‘bin 24 counter’ which indicates how many logs have been processed through the yield simulator in order to achieve the displayed sawn inventory. For the results displayed in this section the batch sample size is 14 logs. It is significant that products are differentiated on the basis of their location on the log (i.e. ‘Sideboard’, ‘Centre Cant’ or ‘Outer Cant’). Products sourced from the centre of a pine log are generally of lesser quality, weaker strength rating and prone to warping whereas products from the outside of the log are destined to be finished as high grade structural product.

7.3 Comparison of Software Yields and Actual Mill Yields

Comparing actual sawmill sawn recovery for a full day (see Figure 7.7) with that predicted by accumulated yield in the software batch log processing (Figure 7.4) indicates a fairly reasonable match for percent sawn recovered, generally all in the vicinity of 50%.
Figure 7.5: Sawmill yield by log from simulator chart
Output of Sawn Products

<table>
<thead>
<tr>
<th>F1 Sideboard Products</th>
<th>Centre Cant Products</th>
<th>Outer Cant Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>T</td>
<td>W</td>
</tr>
<tr>
<td>6.0</td>
<td>40</td>
<td>96</td>
</tr>
<tr>
<td>5.4</td>
<td>40</td>
<td>150</td>
</tr>
<tr>
<td>4.8</td>
<td>40</td>
<td>150</td>
</tr>
<tr>
<td>4.2</td>
<td>40</td>
<td>160</td>
</tr>
<tr>
<td>3.6</td>
<td>40</td>
<td>150</td>
</tr>
</tbody>
</table>

Figure 7.6: Predicted sawn stock

![Fibre Recovery Table]

**Fibre Recovery**
Data for: 05 Jul 2013 to 05 Jul 2013

<table>
<thead>
<tr>
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**Fibre Recovery**
Data for: 05 Jul 2013 to 05 Jul 2013

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**Fibre Recovery**
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<td>Input Volume</td>
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Figure 7.7: Sawmill actual sawn recovery sample
Residue materials are separated out into sawdust and chip which are conveyed on separate belts to designated bunkers. Each residue conveyor has a weigh scale fitted to measure the rate of production. Figure 7.8 is typical production charted rates of production supplied from the residue weigh scales. The blue line is a typical rate of production (t/hr) for chips and the red line for sawdust production (t/hr). Notice that in Figure 7.8 that the magnitude of chip production generally seems to be twice the rate of sawdust production. Zooming into a typical section of the chart Figure 7.9 further supports the observation that in relative terms at the sawmill chip production is approximately two times the production rate of sawdust.

What this means is that the predictive model is underestimating sawdust production relative to chip production. Further analysis of the sawmill tooling indicates that the saw segments in the profiling units may indeed be a source for this error because currently the model produces only chip residue through the profiling units. Given that there are saw segments top and bottom of profiling units to produce clean straight edges, it is reasonable to assume saw kerf and associated sawdust production in the profilers.

Figure 7.8: *Sawmill residues production monitor chart*

To make the appropriate substitution of sawdust generated by the profiler saw segments requires further precision evaluation of cross-sectional areas. In this case it is necessary to account for the cutting action of the profiler saw segments which in between the top and bottom set of chipper knives of a profiler head (refer to Figure 7.10). This equates to material sections 5mm either side of the F1 sideboards and also outer can boards. In Figure 7.11 the purple shaded segments represent...
sections that in the future need to be modelled as sawdust yield. In the current software version these identified sections (in purple) are modelled as chip which result in an inaccurate division of residue yield; higher than expected chip yield.

Figure 7.10: *Profiler head*

Figure 7.11: *Addition of profiling saw segment kerfs from profiling units*
Chapter 8

Summary of Findings and Future Direction

A competitive foot hole in the softwoods saw milling industry relies upon sourcing, adapting or developing technology features that either enhance the plant or management capabilities. This is a capital intensive industry with all manner of computer controlled process for handling the timber. It is easy for the casual observer to underestimate the importance of being one or two steps ahead in terms of matching up machine processes with the characteristics of the log stocks. One only need consider that a one percent gain in optimized efficiency can add a magnitude of seven figures to mill annual profit. The human brain or even experience alone cannot legitimately be considered capable of handling these extreme rates of processing and decision making without the aid of customised software. The literature review provided evidence that some international regions (namely Finland and Canada) are well advanced in the science of sawing simulation and further that these versions provide an element of competitive advantage.

The log breakdown at Tuan mill has been covered in some detail ensuring a clear understanding of all relevant machine processes and their application in the log breakdown sequence. Matlab code has been written to simulate the log breakdown process with particular attention given to the standard timber lengths and cross-sections. There are numerous cut patterns for saw milling of logs dependant on log batch characteristics and customer specified demand for product. The Matlab
algorithm interprets pattern codes and runs a comparison of ideal effective geometry vs every 150mm bucket diameter of virtual input log. The added complication handled by the program code was to search and find matches for a desired batch number and then for each matched log retrieve the diameter bucket data from the corresponding parent stem file.

Sideboard product computation was by far the most demanding aspect to code. Matlab code predicts the interface of board extremities with the outer perimeter of each log bucket and all potential board widths are checked for viability. For the purpose of this investigation highest sawn volume return from sideboards was given priority.

The final simulation process centred on quality control through the trimmer stations. Of particular interest here is the relative percentage of wane along any length of a board compared against primary and secondary wane criteria. The trimmers are the ultimate dictators of finished board length, the software imitates this responsibility. For example an the software runs an internal check of trimmer saw spacing and allowable tolerance ranges compared with predicted sawn timber length. Each trim cut contributes dust from saw kerf and dockings are converted to chip.

Recommended projects to further the commercial value of this sawing simulation software:

1. Log sweep algorithm;
2. Multi-batch comparative testing and analysis against real log runs;
3. Enhance graphical user interface;
4. Investigate and model energy consumption for log batches.
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Appendices
Appendix A - Project Specification

University of Southern Queensland
Faculty of Engineering and Surveying
ENG4111/4112

**TOPIC:** Simulating Yield for Tuan Sawmill

**SUPERVISOR:** Kazem Ghabrie

**ENROLMENT:** Mechatronic Engineering

**PROJECT AIM:** This project will investigate the bucking and profiling processes at Tuan Pine Manufacturing plant and highlight potential for improved all round production planning by simulating crosscut logs into sawn yield at Tuan sawmill.

It is envisaged that initially a model computer program for a batch of logs belonging to one user selected bin class will be developed in Matlab. This program shall work to integrate a cut pattern code and Linck profiling line parameters to generate some yield predictions. The initial model program will source log and stem data from a static file provisioned from the company.

The program will filter the source file to find a user selected batch of logs, convert a user selected profiling line cut pattern to dimensions and try to maximize sideboard recovery.

**SPONSORSHIP:** HYNE & SONS TIMBER   TUAN TRUEFRAME

**PROGRAMME:** Issue A, 24th March 2013

1. Investigate the data collected and stored in regards to the bucked logs. Source database files from the Hyne Information Services Team.

2. Investigate and detail the Linck (brand) profiling line process to form an understanding of what each machine centre does to the log and what effect that has on the yield.

3. Write a program that can match any log back to the parent stem in the CSV file in order to get the correct range of bucket diameter data. Use this micro-scale set of diameters in the computation of processes affecting sawmill yield.

October 23, 2013
4. Over the length of an input log use a Matlab program to check the goodness of fit for selected pattern relative to the cross-section of the log at 150mm (bucket) intervals.

5. Look closely at the sideboard profiling process and write a Matlab program that will search and find the widest possible sideboards (F1, F2, F3) that can fit the pattern designated location; while considering primary and secondary face and edge wane rules.

6. Investigate standard product lengths as controlled by the sawmill trimmers.

7. Use the Matlab program to maximise the length and volume of recovered sideboards from a virtual trimming process.

8. Use the program to compute the length, cross-section and volume of simulated sawn yield from a virtual log.

9. Use the program to compute the simulated chip and sawdust yield from a virtual log.

10. Write into a Matlab program length control for simulated sawn product yield and track the volume conversion from simulated sawn dockings to chip yield.

If time permits:

1. Integrate sweep parameter into the program.

2. Store a real batch of logs, process through the bucking system, collect the data files, process through custom yield program then run the same batch of logs through the sawmill and try to collect actual yield results. Compare the two and suggest sources of variance.

3. Investigate Structured Query Language (SQL) and try to get the developing simulation package integrated into current online and real time system.