Driving Operational Solutions from Estate Modelling

This project was the development and implementation of a forest planning system in Forests New South Wales (FNSW). This system uses optimisation techniques to ensure forests are managed profitably and harvesting is undertaken at a sustainable level in both the short term and the long term. It goes on to formulate harvesting instructions to FNSW staff and harvesting and haulage contractors to match variable weekly order schedules.

Our rationale is that the visibility of the supply scenario should be increased through provision of high quality information. This would not only improve the performance of our own business but also the many businesses within the region that rely on forestry along the supply chain, such as the fibre processing mills and harvest and haulage contractors.

The framework divides planning into 3 levels, each dealing with different timeframes and the different problems that need solving at different stages of the processing schedule. Importantly the results of each planning level are used as input to the next level.

<table>
<thead>
<tr>
<th>Level</th>
<th>Focus</th>
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<tbody>
<tr>
<td>Strategic</td>
<td>Developing 70 year woodflow modelling to ensure current contractual agreements can be met and to identify opportunities / problems with the future volumes and / or product mix.</td>
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<tr>
<td>Tactical</td>
<td>Developing annual &quot;Plans of Operation&quot; to identify the exact areas that will be harvested and when. This can involve: balancing area that can be harvested in winter with those which can be harvested in summer; ensuring there is local machinery capacity to harvest the selected areas; and ensuring the yield-modelled volumes will meet contractual requirements.</td>
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<tr>
<td>Operational</td>
<td>Formulating harvesting instructions to match weekly mill orders.</td>
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The crucial element of this system is that, at each level an “optimisation” algorithm is used. This enables a complete evaluation of the whole estate. Many factors are evaluated that could never be manipulated manually.

Other factors are:
- The ease with which a scenario can be evaluated enables contingency plans to be formulated.
- There is a huge potential for adaptation within the system to accommodate new pressures/influences on the business. The impacts can be modelled as they emerge. Eg: these techniques were used to model the effects of a fire where we lost a significant part of the plantation.
- It enhances the ability to communicate plans to managers, staff and customers. The visual presentation in graphs, maps and tables has made the plan very accessible to all levels of management.
- The process used to formulate the plans is now more transparent, documented and consequently better understood.

This paper will cover Strategic Planning or Estate Modelling, Tactical Planning and Operational Planning and how these processes have been linked to ensure the results are consistent with one another.

Inherently audiences tend to focus on the tools that are used for undertaking these tasks, which are important. Nevertheless I must also stress the importance of assigning resources and responsibilities to the mundane but vital task of maintaining the datasets that feed the models.
Background

FNSW method of matching harvest planning with supply has evolved into a sophisticated system over the past decade. In the early 1990s the volume of timber that was being harvested reached the capacity of the resource to provide and replace it. This placed pressure on the harvest planning function by restricting the options available. At the time, the regional planning, harvesting and sales functions existed as highly autonomous units, and links between each function were based on the personalities and networks of individuals rather than a managed, coordinated process. Plans of operation were formulated in unintegrated forms, relying mainly on spreadsheets using practical principles. This was a time-consuming, effectively manual process and there was no opportunity to do any "what if" analyses.

Operationally, with the introduction of delivered sales (ie where FNSW manages the logistics of harvesting and haulage), there are multiple customers, each with highly specific weekly orders, each with different pricing and delivery schedules, each at a different geographic location within the region. The multiplicity of harvesting areas yield different log mixes when different cutting strategies are applied. Furthermore there were many different logging crews with different capabilities and different cost structures. This was known as the "Market Supply Problem" and had to be solved manually, with inherent inaccuracies and biases. Once again this was done using practical know-how, no operations research techniques were feasible without an integrated system.

Strategic Planning

Estate Modelling software has been used in FNSW now for some years and has enabled market expansion opportunities to be identified. The first Linear Programme based software was introduced in the early 1990s, this brought the advantage of optimisation.

Estate Models were developed for particular needs rather than as a routine business process. The underlying data had to be developed from base data, each subsequent run was built by different people for a different purpose using different assumptions. Without systems Estate Models were very time-consuming to generate.

The introduction of FOLPI as a Linear Programming based estate model provided many answers but also raised questions; particularly:
- how to divide up the log grades within the model
- at what level of detail the estate should be described
- how to manage continuity ie : to ensure a current estate model reconciles with previous years’ estate models.

The following improvements were implemented to address these problems:
- The Yield Table Toolkit was developed – this provided a uniform format for yield tables to be stored. It introduced business rules associated with:
  - Log grades to be used for estate modelling (these were generalised grades eg; small, medium, large sawlog that could be applied across regions and would not be made redundant as markets changed).
  - Methods of building yield tables
  - Classification of stands into categories that describe the current status of the stand (planning unit). Incorporation of code that enables planning units to change as operations take place, for example thinnings or prunings.
  - Classification of stands into categories that describe the status of the stand at clearfell (crop type)
- Code that enables estate models to be written out
- Extensive data error checking must take place. For example:
Areas that have remained unthinned beyond their thinning date
- Areas without their crop types or planning unit status coded

The initial formulation of the model enabled clearfell age to be optimised. However production thinning age could not be optimised without exponentially expanding the number of yield tables available to the model, exceeding technical capacity. A compromise was later reached whereby a year either side of the planned thinning age allowed a 3 year window to optimise thinning age. At the strategic level constraints are highly generalised.

Tactical Planning
The introduction of Woodstock (in 2000) brought with it Spatial Woodstock as a module. This enabled a link to be made between strategic and tactical plans. Most importantly, Woodstock’s optimal solution was able to be mapped by harvesting period. Spatial Woodstock was thus a valuable tool for developing 5 year plans and particularly the annual plan of operation. By doing successive iterations of the model, the user can lock additional areas into particular periods. Iteratively, the harvest planner effectively ends up with a tactical plan guiding actual harvest planning, harvesting operation and deliveries.

Elements of the tactical planning problem required new data sets to be created:
- **seasonality layer** – all areas were classified to be suitable for wet, dry or intermediate weather harvesting
- **machine type layer** - all areas were classified by the machine type that was most suitable to harvest them

The quality of the existing **roading data set needed to be** improved, particularly the classifications of roads as being natural surface or gravel (or often mixed along its length). A feedback loop was created to ensure road upgrades prompted a review of the seasonality of the surrounding area for re-incorporation in the overall modelling.

The focus of the tactical plan is putting additional variables into the problem to bring it closer to reflecting operational capability:
- Seasonality – creating a balance so that approximately 40% of the area is suitable for wet weather harvesting, 40% dry weather and 20% intermediate.
- Customer requirements – The total volume yielded from harvesting must be sufficient to meet the totality of Forests NSW obligations to each of its customers.
- Balance of operation types – the area harvested by operation type must not exceed the capacity of harvesting crews.

One of the most important outputs of the tactical planning process is the map and report of planned harvesting activity. This greatly assists:
- Roading – planning where roading upgrades will be required and roadlines created
- Inventory – planning areas that will require pre-harvest inventory
- Budgeting – business processes increasingly require commercial justification as pressure increases on the organisation to meet financial targets.
- Management of recreation – commercial forests are also available for recreational use by the public. In recent years, many State forests have become available for licensed hunting. Maps of areas must be provided that exclude operating areas from hunting access.
- Financial Reporting and Analysis

Operational
At the operational level, staff are required to maximise commercial returns. However, in the past commercial returns were assumed so long as mills were supplied and thus the extent of mill supply became the major, if not sole, focus above that of optimal business profitability. This view
was exacerbated by the concern that many harvesting crews and mills were highly reliant on FNSW’s efficiency for their own profitability. A production and delivery schedule produced for the following 8 weeks was required to support the Delivered Sales business. FNSW had to embark on a major software development as there were no off-the-shelf software packages available.

Development of Market Supply
ATLAS Technology and FNSW signed an agreement to undertake a joint development of a Market Supply system. Initially there was considerable consultation between FNSW staff and operations research specialists, gathering sample data sets and discussing the formulation of the problem. They had to first establish that it could actually be represented as a mathematical formulation!

The most difficult part of this stage of the development was condensing the multiplicity of different sales agreements and customer specific log grades down to a base set of grades and a way of representing sales agreements so that they can be mathematically compared with one another.

While the Graphical User Interface (GUI) and the solver were being built by ATLAS, FNSW went about preparing data sets to be used for testing.

The first run of the solver took place in 2003. Unfortunately it took in excess of 30 hours computer time to solve! Solution times were progressively reduced by changing the model formulation, but it was only the introduction of the solver – XPRESS-MP- that reduced the normal solution time to around 20 minutes – a practical outcome.

Running Market Supply
Market Supply is run on a weekly basis and provides an 8-week delivery plan. Figure 1 shows the sources of data.

- Harvest Units are imported from Spatial Woodstock on an annual basis. Although additional areas must be added from time-to-time.
- Yields are imported from ATLAS Cruiser on an annual basis.
- Stocks are imported on a weekly basis from LOGTRACK
- Crews have to updated as new crews start or when rate adjustments occur
- Haulage information is the compartment to mill distances which is static
- Orders have a number of different types of data. For each customer:
  o Log pricing schedule
  o Grades accepted
  o Weekly order schedule

Management of the data feeding Market Supply has proved to be problematic. Legacy systems that provide Market Supply with data are constantly changing. This has required systems to be developed between the legacy system and Market Supply, these have required constant maintenance.

It takes about one full day to get the weekly data together. This involves updating:
- mill orders for the next 8 weeks
- in forest stocks
- harvesting progress
- current crew locations
Figure 1 shows how the Market Supply elements interact. Solving involves writing out an initial mathematical formulation of the problem which is then solved using XPRESS-MP, a generic LP solver. The solution is output as text files. These are then transformed into a suite of standard reports which the MS user reviews for a combination of error checking and generating weekly operational plans.
Figure 2 The Market Supply Process

Data -> Constraints

- Imported
- Entered into database
- Mathematical formulation using LINGO
- Solved in XPRESS-MP
- Solution built and sent to text files
- Custom reports generated using code
- Review
  - Alter Constraints
- Stop
As we expected, making the system operational has required a huge amount of effort, which is ongoing. IT developments are highly visible, expensive projects with no shortage of people willing to question their value, particularly in a commercial sense. It has required a lot of personal energy on the part of individuals to justify and “sell” the system.

One of the major successes of the project to date was winning first place in the Premiers Public Sector Performance Awards, where Forests NSW was recognised for taking a risk and now reaping tangible financial rewards for its investment.

The primary issues that had to be dealt along the way were:

- **Reliability of the systems that feed Market Supply** – this is an acid test of the quality of the business’ systems. With so many systems feeding Market Supply, if one of them is not functioning properly it immediately stops Market Supply functioning correctly.

- **Data** – data had to be imported from legacy systems in a format that was compatible with Market Supply. Frequent changes to the legacy systems meant the interface systems also needed to be altered in line. An example of this was the systems’s dependence on FNSW’s in-forest stock system LOGTRACK. Translation tables had been set up to enable LOGTRACK grades to be converted to Market Supply grades. Frequently new grades would be added to LOGTRACK, which would mean a lag before the volume would make its way into Market Supply. A Market Supply to LOGTRACK Transfer process had to be developed that also reported on new grades that had been entered.

- **Yield data** – the system was designed to import harvest unit based pre-harvest inventory. Prior to Market Supply FNSW did not do pre-harvest inventory at all. This would require a sizeable investment in inventory and there was considerable debate whether it was warranted as being significantly better than simply having an experienced forester make an educated selection from a suite of approximately 20 yield tables that were available.

- **Staff** – running Market Supply requires aptitude and expertise in dealing with data and computer systems, as well as having a good knowledge of the regional operations. In a region where there is a shortage of staff it is often difficult to assemble the resources to fully maintain and run the system.

- **Support** – from time-to-time technical problems occurred with the system and these were often time consuming to resolve. This meant solutions could not always be provided for production meetings, which naturally created disappointments and tensions between stakeholders.

**System Benefits**

The major quantitative benefits of the planning model are

- Better able to forecast timber availability – this enables the organisation to react to market opportunities. An example of this is a recent sale of 50 000 tonnes to Visy Industries.

- Better utilisation of the resource – information is now available to enable orders to be negotiated based on what the resource will yield. Formerly, our inability to do this had often lead to downgrading & wastage.

The major qualitative benefits of the planning model are

- The mutual benefits brought by the ability to model the whole estate has led to better cross-functional communication.
- It enables the integration of current harvesting with silvicultural modelling and long term estate goals. Each of these factors are linked, however because of the magnitude and complexity of the system they were previously dealt with in isolation. This lead to conflict between the functions and the creation of “silos of information.”
- Availability of information ensures that all the functions do their budgeting and business planning from the estate plan. This not only ensures consistency between the functions but it enables the plan to be better communicated to all levels of management.

FNSW always seeks to ensure its systems represent best practice. In this context, best practice is demonstrated by:
- Adaptability – This system has been developed to be able to maintain currency with changes in the business. It can be linked with spatial information as well as information supplied by external bodies eg: regulators. Changes to the system are necessary new factors come to play such as environmental regulations that will affect the spatial distribution of harvesting. Similarly increases in harvested volume will require more infrastructure planning. These will need to be modelled in this system.
- Replicability – To ensure that new staff are able to use this system in a consistent manner, a comprehensive support network is in place. This comprises of a systems expert that is able to provide technical or debugging advice. For even more difficult problems the software developers are able to provide support. This system is comprehensively documented.
- Continuous Improvement – with a number of staff using this system problems or improvement ideas are constantly being identified. These are noted by the systems expert and tabled at meetings where possible developments are discussed. Where necessary relevant developments are subsequently undertaken. Files are maintained with the minutes to ensure that the progress can be tracked.

Future

Market Supply
The biggest factor in the use of Market Supply is improving its reliability. This means improving the reliability of the systems that feed it.

Alteration in procedures - Examples of this are the GIS, harvest area is updated monthly, to get an accurate weekly plan area would need to get updated weekly

Enabling it to streamline FNSW’s business systems – examples of this are;
- generation of cutting plans to be given to crews
- generation of delivery plans to be given to haulage contractors
- setting up supply templates in the sales system.

Currently Market Supply “supports” scheduling on a weekly basis, its development has to continue to the point that it delivers the weekly schedule

Conclusion
FNSW is the major player in the forest industry, particularly in the SW Slopes region. Studies have shown that it contributes $1.16B to the regional economy, within 5 years expansions in the processing sector this will grow this a further 70%. Building systems such as this must result in sustained performance at a high level. An indirect indicator of success is the influx of investment in fibre processing in the Region. Currently the Forests NSW resource is fully committed which means that any logistical errors will have multiplying effects which will negatively affect FNSW’s ability to supply. To date the planning system has been able to identify and reflect changes in the nature of the resource in plenty of time to make contingency plans, which in turn are able to be communicated to other stakeholders along the delivery and production chain.
To attract investment in processing FNSW has identified that it must be able to provide information to ensure investors that it will be able to supply raw material on a sustainable basis. This is exactly the information provided by the planning system. From there managing the logistics of continuing supply in a profitable manner is a very difficult task. This is where the tactical and operational models come in to underpin managing continuing supply.

The hierarchical approach adopted in developing the Maket supply system assumes that the value of the estate can be managed by analysing the trade off between harvesting a stand of timber today versus keeping that stand to meeting future wood & cashflow obligations. Managing the trade off between short and long term woodflow is a complex, never ending process. The multitude of options available to management to meet its goals is best carried out by a computer which can evaluate millions of options.

FNSW’s strategy of intrinsically linking a three tired scheduling approach has meant that a 70 year optimised estate model would be run with constraints ensuring that the long term woodflow was matched to market expectations. The tactical plan is constructed from the main elements of the strategic and operational datasets are embedded into the problem to allow these issues to be optimised by the system.