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Framework Design and Concepts for a Value Chain DSS

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EXECUTIVE SUMMARY

Systems to predict the quantity and quality of forest production are based on models of distinct biological and physical processes. A framework is needed to connect these models into a logical sequence and to marshal the inputs and outputs of each one. The framework is also required to provide facilities such as scenario persistence and management, data import/export, reporting, optimisation and visualisation.

From prior work in this objective, it is clear that there is a range of potential users of a forestry value chain decision support system – they may vary from a research scientist or company analyst who seeks detailed answers to complex questions, through to the operational forester or planner who performs routine forecasts or scheduling. The aim is to cater for a range of user groups within the one system, offering different user interfaces for different types of problem solving. Research use will drive the need for solving detailed complex problems, potentially with fewer data, while commercial use often has emphasis on large volumes of data that can be processed quickly.

The general Framework concept is of a modular system that allows for seamless transfer between modules. This will allow for different uses to be made of parts of the system, or of the full framework, depending on the problem. The framework will allow for modelling annual and monthly time steps, and cater for both deterministic and stochastic models. It will be extendable, to allow inclusion of emergent science and technologies, and testable at three levels. To ensure it will remain supportable for its full lifecycle, development will use “industry standard” operating systems and development tools.

To demonstrate the framework concepts, a Silvicultural Scheduling prototype has been developed. This simplifies user interface and some levels of automation. This prototype also demonstrates the strategy of getting easily defined and useable components out to members quickly, without waiting for the overall framework.

BACKGROUND

Objective 3 in the Radiata Management Theme research programme began with a survey of members on decision making (FFR Report R02, Heine and West), and expectations of tools by key decision makers. A pilot study of value chain modelling was conducted while concurrently assessing from a selected user group the likely requirements that they will have of the system.

This report proposes a design for the Framework that links modules that describe the Forestry Value Chain (also previously referred to as the Virtual Forest) and aims to satisfy the requirements as reported in the requirements analysis. The design is also informed by the pilot study, which illustrated gaps and weaknesses in current systems and modelling tools, and the initial survey of decision-making practice in the forest industry.

INTRODUCTION

Some decision-support frameworks, especially for forest ecosystem management, attempt to solve multi-goal problems (timber, water, ecological, etc). An example is NED-2 (Nute *et al* 2003) which uses AI techniques coded in Prolog under a blackboard architectural model. However, the decision-making survey undertaken at the beginning of 2008 emphasized the importance of the setting in which decisions are made. There are many facets to the forestry business, and a large number of factors (for example: company strategy, risk management, environmental issues, strategic location, contractual obligations, strategic alliances or health and safety issues) are considered during the process. A modelling system cannot attempt to do more than support the process by providing estimates of the physical consequences of a particular course of action that is within the scope of the model. Perhaps of most importance is the ability to compare different scenarios and confidently decide whether any differences are significant or not. Final estimates are always adjusted by experience and intuition.

Therefore users should understand how the modelling system works, so the results can be interpreted sensibly, and usefully incorporated into the decision-making process.

SCOPE

Before architecture can be designed, the scope of the system must be decided. It is assumed that the following capabilities should be allowed for, even if models are not currently available:

- Ability to simulate from site selection and land preparation through to end-product (fibre or solid wood) performance, including modelling of forest growth and changes to the site over time.
- Support for both decision-making (prediction) and research (understanding) by providing a modular system from which results can be extracted at each stage.

The diagram below (Figure 1) shows the scope.

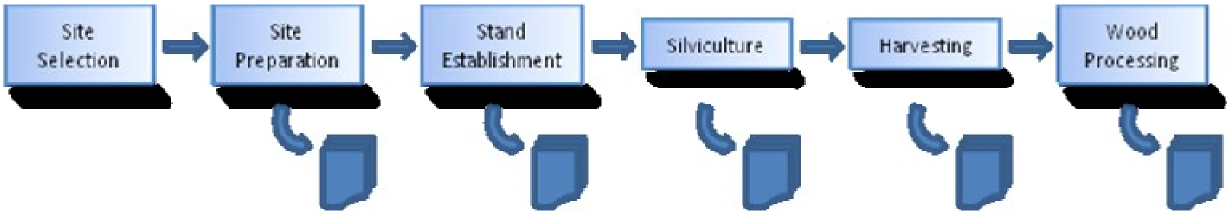


Figure 1. Scope of the Value Chain DSS

The purpose of the framework is to connect and control the models that are specific to each biological or mechanical process, and to provide facilities such as scenario persistence and management, data import/export, reporting and visualisation.
Note that the Value Chain DSS is not a supply chain simulation, and will not deal with supply and demand or logistics/transport. There is no global optimization capability incorporated into the framework[1], although the command-line interface could be used by an optimization/goal-seeking system.

Modular Components

Within the proposed framework, there are a number of areas where modules already exist to cover algorithms and functions. While these will not by default be what is used in the framework, experience in these areas has proved that models and frameworks can be provided to operate effectively to give outputs that are backed by the science underpinning the models. The VFS plans to move into areas where much of the underlying science is yet to be completed, and much of this is planned within other objectives of the IFS bid, or within other funding streams. It should be noted that a framework is not species-specific, but process-specific. The modules underlying the framework are not species-specific but the algorithms, functions and growth models embedded in them are likely to be. These models and functions will determine the ability of the VFS to model alternate species, additional internal wood properties or any other properties that are not currently covered by existing models.

For most of the modules, the outputs will be designed as input into the following module. In most decisions made within the industry, (e.g., land use, species to plant, or whether to perform a specific operation on a specific stand), the outcome needs to be compared using an economic analysis. This can be a two-step process, starting with a yield table predicting grade and volume outturn at various ages, matched then to revenue using grade prices, or net revenue adjusted for harvesting and delivery costs. This can be further extended to a discounted cashflow to reflect the impact of cost throughout the rotation. Options may be evaluated on the basis of a yield table comparison.

[1] Optimal log making within a stem piece may be used for compatibility with production systems.

Inputs / Outputs

Each module within the framework will have specific inputs and outputs, and these may alter as new technologies or information become available through the work in other objectives. These have been detailed below. Ideally where the output from one module serves as the infeed for another, the data transfer will be seamless.

Risk

The risk associated with completing the framework is directly related to the current level of information available compared with the level of proposed information supplied through new research or technology. In a number of areas, modelling frameworks have been built and used, and the risk associated with development is minimised through experience. Importing data from new technologies (such as directly from digital imagery) will carry all the risks inherent in any new software development. These have been highlighted below.

Genotype Selection

Based on the industry survey, there is a perceived gap in modelling knowledge in linking genetic gains, through modelling, directly to quantified increases in yield and grade recovery. The comments from the survey were generally aimed at standard plantation species; however the gap is much wider if this is extended to include alternative species that may come into focus with the introduction of the ETS.
Risk assessment - This is high risk due to the complexity of the interaction between genetics, site and management, the inherent variability across these factors, and therefore the difficulty of modelling a wide range of combinations. These issues are a focus of Objective 1 and 2. This part of the framework will be dependant on results from these objectives.
Close work between framework developers and the scientists working on Objective 1 and 2 is required to ensure that the incorporation of new models into the framework is a seamless as possible.

Site Management

There is an industry need for tools that give good evaluations of the economics of certain operations against their impact on final productivity. The earlier in the rotation the operation is performed, the more pronounced the financial impact, and while operational costs are easily quantified, the end result final productivity and quality, is not. Potential use may be made of existing Site Management Coop information and models.

Risk assessment - Due to the possibility of a interaction between genetics, site and management, as discussed under “Genotype Selection”, this is moderately high risk. Again, this part of the framework will be dependent on results from objectives 1 and 2. The impact is likely to be site-specific; therefore site management effects may be difficult to reflect in a generic tool. It may be necessary to represent the negative impacts of not performing the operation (some sites may have high mortality which will be difficult to represent in modelling).

Site

The impact of a specific site on the productivity, volume and grade outturn, and on specific internal wood properties, can be major. With huge variation in potential site factors, this may be difficult to reflect accurately in a generic model. It may be possible to incorporate existing models and information available from the Site Management Co-op and other research as appropriate into the framework. A number of site attributes can be incorporated into the framework, but they will impact only on the resulting growth and yield predictions if they are utilised by the growth model selected. Users need to be aware of the limitations of different models and the implications of model and algorithm selection.
Risk assessment - This is high risk due to the complexity of the interaction between genetics, site and management, as discussed under “Genotype Selection”.. Again, this part of the framework will be dependent on results from objectives 1 and 2.

Stand Management

The viability of intensive or simple stand management can currently be reasonably well modelled by available software for common plantation species. There are a number of growth models that can be used to represent the impact of common silviculture operations on a crop. The selection of the appropriate model is imperative, and there may not be models that are representative for a number of species. Improvements and enhancements of existing models, and the addition of new models, will be an output from other objectives. These will be incorporated into the framework as available. Such models are likely to offer better and more detailed modelling, potentially requiring different attributes as infeed, and producing information on different characteristics.

This module will also function as a scheduling tool to allow the timing of operations to be scheduled to gain maximum benefit (for example scheduling a prune to achieve maximum clearwood, while staying within other parameters to minimise the impact on growth).

Risks - are minimised in this area as framework performance has been proved. However if the form of underlying models changes dramatically, this will increase the risks associated with implementing them.

Resource Assessment

There are traditional methods of assessment embedded within the industry, and developed tools exist to support data capture, analysis and storage of data, including spatially. Further research may add to these methods, resulting in changes being required to existing software. Alternative sampling methods (single tree sampling / variable probability sampling) will be incorporated as these methods are proved. Technology advances may create opportunities to source alternative data automatically, including tree counts from imagery and two-dimensional or three-dimensional standing tree scanning technologies.

Risks - Risks are minimised in this area as framework performance has been proved. Incorporation of new technologies (tree counts directly from spectral images, for example) will increase risk.

Bucking

Tools for log bucking based on a stem description have been available for many years. However, if the complexity of the stem description increases (e.g., by inclusion of more detailed descriptions of internal wood properties), traditional bucking software may need to be updated to deal effectively with this new level of detail.

Risks - are minimised in this area, as framework performance has been proved. However, the introduction of more detailed attribute definition will require existing tools to be upgraded

Processing time may become an issue if the detail required in the log and stem description increases. Experience suggests that this will need to be managed to allow acceptable processing times for simpler problems, particularly where annual growth is modelled for every stem to determine internal properties.

Primary Processing

Primary processing models are currently available, but the level of detail required to model lumber quality effectively is not available from current log descriptions. Wood property models need to be improved to be able to deliver the required attributes at a greater level of detail. At this time considerable effort is being put into rationalising the new approach for Growth and Wood Property modelling, and the resulting strategy will have considerable impact on this area of the framework.

Risks – Risks are associated with the level of detail required from the log description. The use of a framework to transfer data has been successfully tested in the Value Chain Pilot Study (FFR report R04 - task 3.1.2). Current modelling methods leave gaps in required knowledge as highlighted in this report.

Economics

Economic analysis is likely to be required at all stages or pathways within the framework. This may be based on primary product outturn, or carried further to reflect the impacts on processing. Currently it is likely that most forestry entities carry their analysis only to the primary product stage. This will need to be flexible enough to reflect changes in economic drivers, such as the impact of the ETS on decisions made throughout a regime.

Risks - are minimised in this area as framework performance has been proved, and once the volume and grade outturn has been produced calculations are relatively simple. Risk remains with the data available to feed in to the analysis rather than with the process and framework.

Environmental

Currently there are a number of projects in other programs that attempt to model ecosystems services and their economic benefits. So the risks in getting a viable model are dependent or their success. However, some of the key environmental factors like CO_2 sequestration are already modelled and implemented into the "Calculators". Also sedimentation, water quantity and quality are reasonably well modelled at a catchment scale.
Risks – Except for CO_2, risks are dependent on other programs but generally they could be assessed as moderate compared to other areas in the Framework.

Resolution / Detail

The pilot study (FFR R04) clearly highlighted the differences between usage of a system for current industry decision support and usage for evaluating end-product performance. In the approach used for the latter, the quantity of data and processing time were several orders of magnitude larger than that required for, say, generating yield tables.
As an example, Figure 2 shows the level of detail of a modelled stem that is adequate for predicting yield by log type. The stem has a circular cross-section, sweep is considered in only two dimensions, branch shapes are very simplistic, and wood properties are known only as average values on a disc.

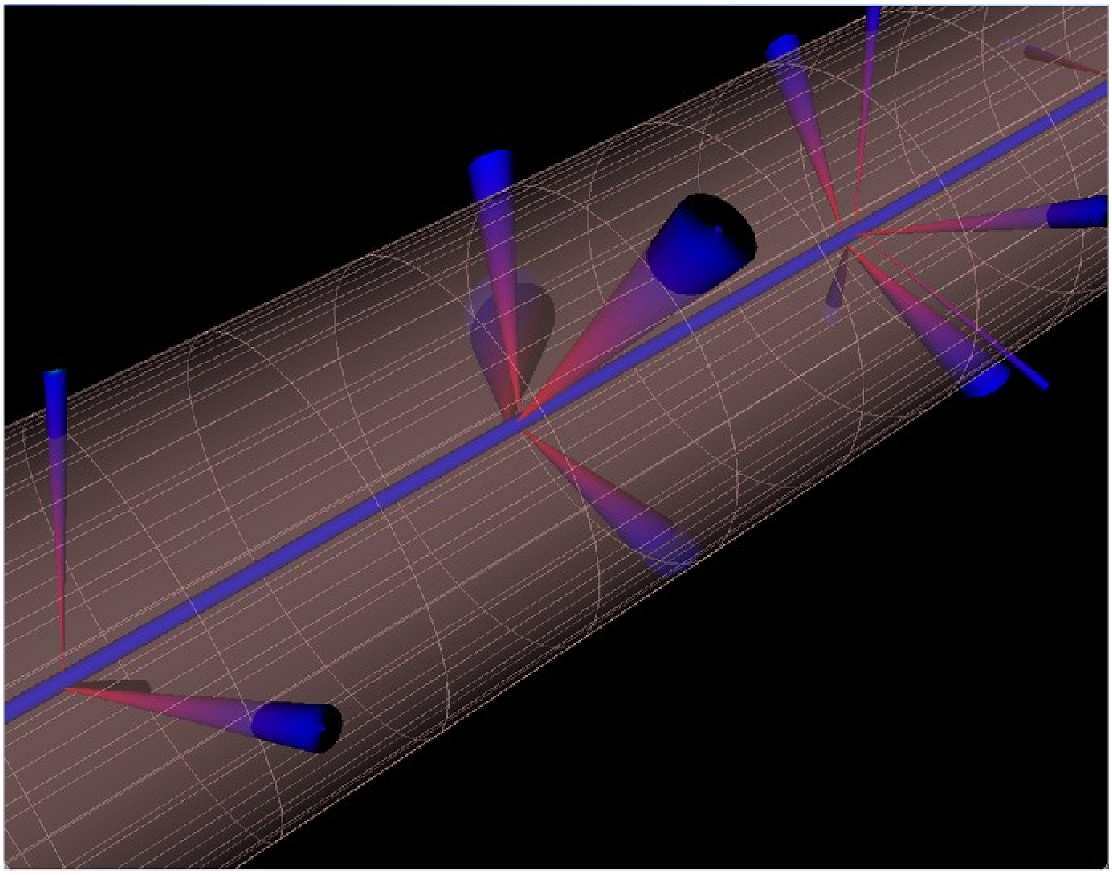


Figure 2. Modelled stem prior to bucking, showing three branch clusters

Key Entities

Within a simulation, each possible outcome is called a ***scenario***. A scenario is a sequence of events that could happen in practice, and so corresponds to one **crop, site, function set, regime, clearfell** and **cutting strategy,** together with wood processing options. In reality a stand can only

be grown in one way to a clearfell date, and can only be merchandized to one set of log products which can supply a given mix of end-product processes.
The user will be able to set up projects that represent a set of scenarios. These projects will be able to be saved, copied, edited, and organized in a folder-like structure.

Stand Growth Modelling

The models of the growth and development of a stand of trees remain core building blocks of the system, so the architecture must support current best practice as well as older approaches that are still useful. Using a list of stems[2] (tree list) as the basic stand entity is the most common approach (Garcia 2002), and can also underpin stand-level models by having utilities which generate stem lists and summarize and scale them to conform to stand-level growth predictions. Radiata pine plantations are usually managed at a level of intensity that provides actual measured lists of stems at several points in the stand's life, so this approach is a reasonably natural fit.
In Table 1 below the first few rows of a stem list are shown. Other attributes may include stem-level attributes such as prune height, outer-wood density, acoustic velocity, etc. The weighting is a scaling factor which indicates how much each stem in the list contributes to the per hectare totals. The sum of the weightings equals the stocking (stems per hectare), so if a stem list was derived from a bounded plot of 0.05ha the stems would all have the same weighting of 1/0.05 = 20. If six plots were combined, the stem weighting would be 20/6 = 3.3333.

Table 1. Stem list (example rows)

Stem ID	DBH	Height	Weighting	Other Attributes
2	218	18.4	2.0152	
8	220	18.26	3.3024	
12a	238	20.63	3.3024	
...	...	...	...	

Stem lists also allow for spatially explicit models (distance-dependent) if these models are found to be effective in improving the accuracy of predictions or extending our understanding of growth and product quality.
The time step used in forest growth modelling depends on the application. Models have been produced with daily time step (Battaglia *et al.* 2004) right through to multi-year steps (Hann and Larsen 1991). This framework will be based around an annual time step, but will interpolate to a monthly step using tables of monthly growth proportions. This approach is flexible, as it supports within-year decision making such as silvicultural scheduling, and can include any model that can produce an annual statement of the growth parameters it supports. Additional detail from models such as CABALA can be indexed to rings/shoots within logs, and hence to boards and fibre if required.

Deterministic / Stochastic

The framework will allow for stochastic models, i.e., models that include random effects to simulate natural variability. However, as most users base their decisions on a single run, certain rules will be required to ensure that it is possible to test how close the run is to an average, or most likely, outcome:

- Repeatability. All random generators are started from a single seed in a determined order, so the same inputs will produce the same outputs in a subsequent run.
- The user can vary the seed and so explore the distribution of outcomes that can be produced.

Under this approach, the scenario can be re-run using a different seed in order to examine the variation inherent in the simulation, but if the seed is unchanged then the same results will be produced regardless of how the scenario is introduced to the system.

[2] "Stem" is used rather than "tree" to identify the leader with a distinct bole at breast-height which contributes to the stand stocking (stems/ha). A tree may comprise more than one stem.

Silviculture and Other Events

Growth simulation will be controlled by commands - a combination of a trigger and an event, as specified in the Regime entity. A regime command consists of an event trigger that defines when the events will occur (for example, Mean DOS > 170mm) and one or more events which describe what will occur. The latter may also include stem selection. An example of classes describing events is shown in Figure 3, with details of the fields, properties, etc expanded. Interfaces are used to abstract the functionality safely away from the implementation.

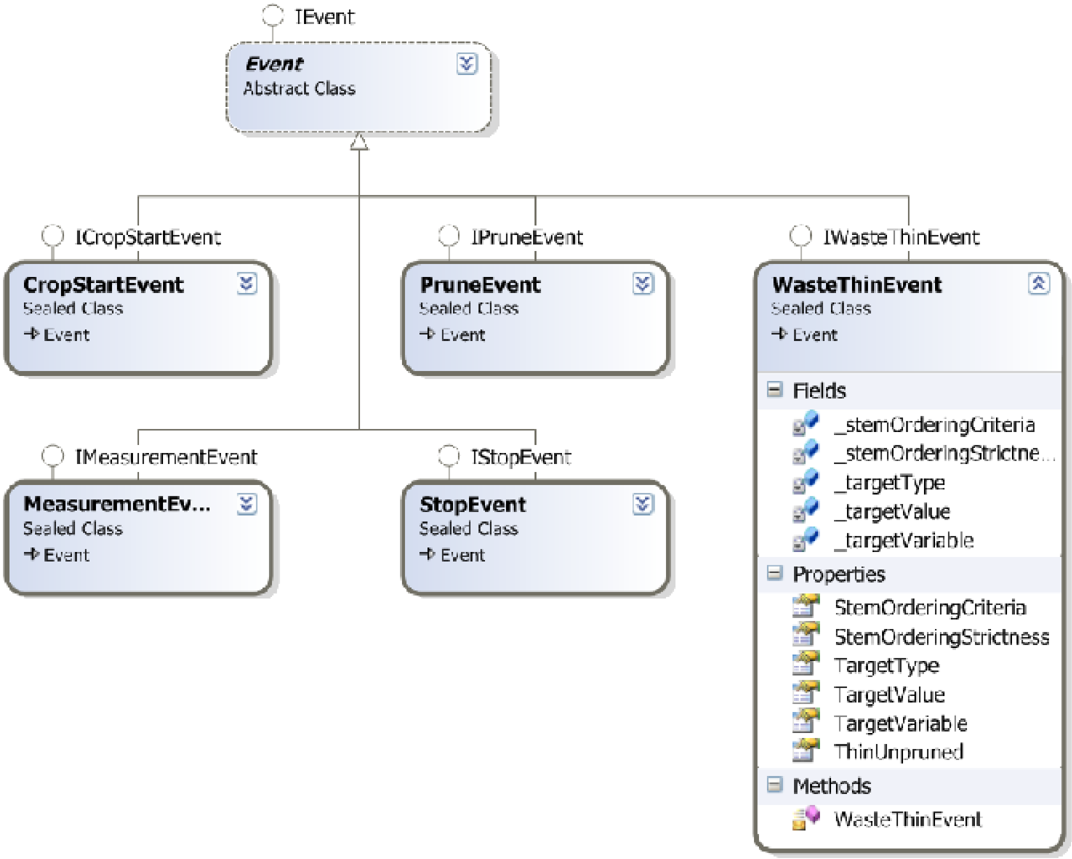


Figure 3. Example of Event Classes.

Supporting Supplementary requirements

These factors need to be considered to ensure that they can be provided for under the architecture.

Extensibility: The system must be extensible to allow it to grow both in scope and in detail. The obvious extensions are the addition of new models (growth, wood properties, etc) which may model different characteristics using different driving variables and producing different outputs. Models may need to be wrapped in a compatible outer-layer before being introduced to the system. It is essential to allow the input data to be augmented without needing to change the data models, especially with regard to persistence. This requires a level of resilience (fault tolerance) built into the system, so that components do not assume they have the information they need, but ask for it, and if the information is not available, they can degrade gracefully and with detailed feedback to the user. The use of informal parameters (through property strings for example) will make it easier to add new models which have "non-standard" requirements.

Usability: There is a range of potential uses, from the research scientist through a number of commercial requirements. To cater for the more detailed analysis, the system will have a detailed user interface that provides access to all entities in multiple non-modal windows. The user will be able to

- Define entities (crops, regimes,...) interactively by filling in the on-screen forms;
- Define a Project as a combination of entities, and more than one instance of each entity so that multiple scenarios are generated;
- Control the scenarios to be analysed via the Scenario list;
- Analyse multiple scenarios in a single simulation run;
- Allow for detailed and complex scenarios to be modelled from greenfields through to advanced processing.

For forest management decision support, user-interfaces will be written to assist specific business processes. For example, the silvicultural scheduling interface will be purpose-built so it can be used with simplified inputs for the modules required. Outputs will focus on what is necessary for commercial use via simple reports which leave out any detail that is not required. It is an industry requirement that the system be designed to allow easy processing of large volumes of data quickly (West *et al*., 2008).

Reliability: (testability) Three levels of testing should be supported: unit, regression and UI. Unit tests ensure that functional building blocks perform as specified, and produce the same answers as the reference solutions or reference implementation. Testing at the unit level must be automated so that maintenance work (extensions, re-factoring, and corrections) can be quickly verified. Regression tests attempt to exercise a large proportion of the pathways through the whole system, and are particularly aimed at verifying that the whole system has not regressed while under maintenance. Automation is essential. UI testing cannot be usefully automated, and is dependent on release candidates being exercised and evaluated by testers who ideally are not part of the development team.

Performance: This is not a transaction-based system. The main performance bottlenecks are likely to be processor-intensive modelling algorithms. These can be tackled on a case-by-case basis, but the decision-support interfaces will not rely on slow models or algorithms.

Supportability: The system will run on “industry-standard” Wintel computers. The run-time environment will be Microsoft .NET. All development will be done in C# to ensure it will remain supportable for its full life-cycle, while providing the productivity of a modern object-oriented language with garbage collection.

Scalability: All entities will be stored in a relational database allowing for the possibility of multiple concurrent users in any one installation. Simulation code will run on the user’s PC so the limiting factor will be PC processing capacity.

Available Software

World-wide there is a range of software programs and systems that are aimed specifically at the forest industry. The issue with reviewing such software is that in most instances there is limited information about the functionality of the software unless you get close to the producer as a potential purchaser. Further, there is usually little public information about underlying design.

In New Zealand, we have a long history of producing forest industry software, both as a framework around growth models, functions and algorithms, and in areas of forest management. There is a range of software from different producers (both domestic and from overseas) that is commonly used within the industry. These include products from Forestech Research and Development Ltd, Silmetra Ltd, Remsoft, Management and Technology Systems Ltd and NZ Forest Research Ltd. These organisations produce a range of tools that span forest management requirements and may be integrated to a greater or lesser degree. Growth modelling tools that are available are based on existing models, algorithms and functions that have been developed over the last four decades in New Zealand. These are both proprietary and public domain.

Examples of integrated systems used in forest industries internationally have been showcased in recent technology events. These include Cenega Solutions Inc, Remsoft, Finnish in-forest optimisation systems, Remsoft, Finnish in-forest optimisation systems and various systems used in South America. While these systems offer various levels of integration, they are all focused on forest management, covering various areas of the value chain. No commercial system that has been sourced has modelled from site through to primary or secondary processing outturn. While examples of forest management systems can be sourced covering despatch systems, transportation logistics, GIS integrated land management systems, forest estate modelling, log bucking and breakdown simulators, digital processing, lumber management and stock management systems, it is difficult without seeing a demonstration of such systems to know whether they will add to the knowledge already held in the relevant areas of modelling.

The more critical steps in the VFS will revolve around improved modelling techniques from site selection through to final crop internal wood properties and the processing of the resulting logs. The underlying science will be New Zealand-specific in terms of species and site performance.

Framework Prototype

A test framework overlying existing models has been chosen that will give immediate benefits to industry and will demonstrate some of the concepts in completing the VFS. When discussing existing use and requirements of decision-making systems (West *et al*., 2008), it was highlighted that from the same framework, both detailed analysis options and simpler, quicker modelling options were required by industry, depending on the problem being addressed.

The test prototype addresses operation scheduling and provides an underlying automated set up to speed the process of inputs currently required. This then performs the calculation, and produces a report that details options for scheduling over a range of months, with the predicted outcome shown, highlighting the date when the desired outcome is achieved. This allows the impact of moving the operation forward or back from the optimal timing to be seen.

Underlying this is a more complex modelling framework. The inputs have been simplified down to a regional selection, driving default parameters to populate required attributes and model / function sets. This allows a simple and efficient set-up and run for the operator. The output reports have been tailored to supply all required information to support the operation scheduling decision.

Inputs

The inputs required for scheduling a pruning operation are region, a crop file, and the pruning lift information. This includes target DOS, lift height, pruned stocking, minimum green crown length and stem selection criteria (for example largest DBH and height). All of these data should be easily accessed by the resource forester.

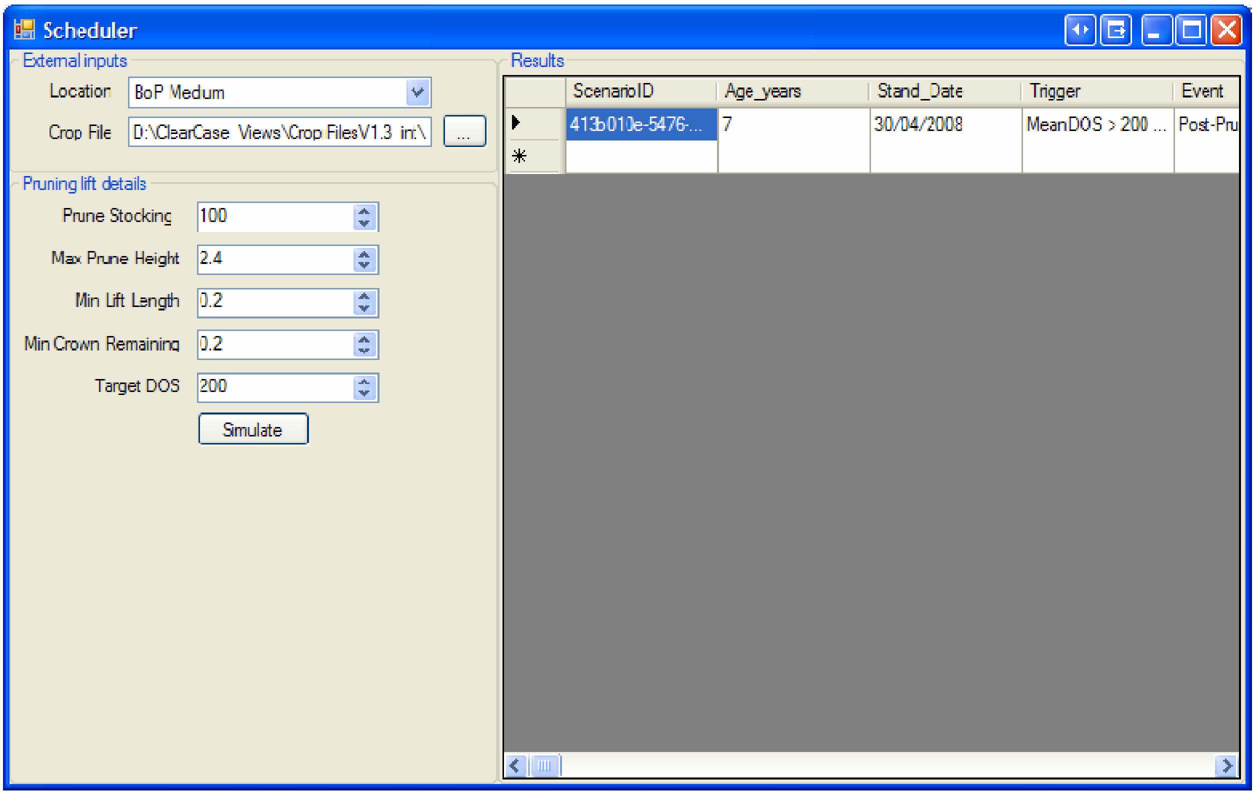
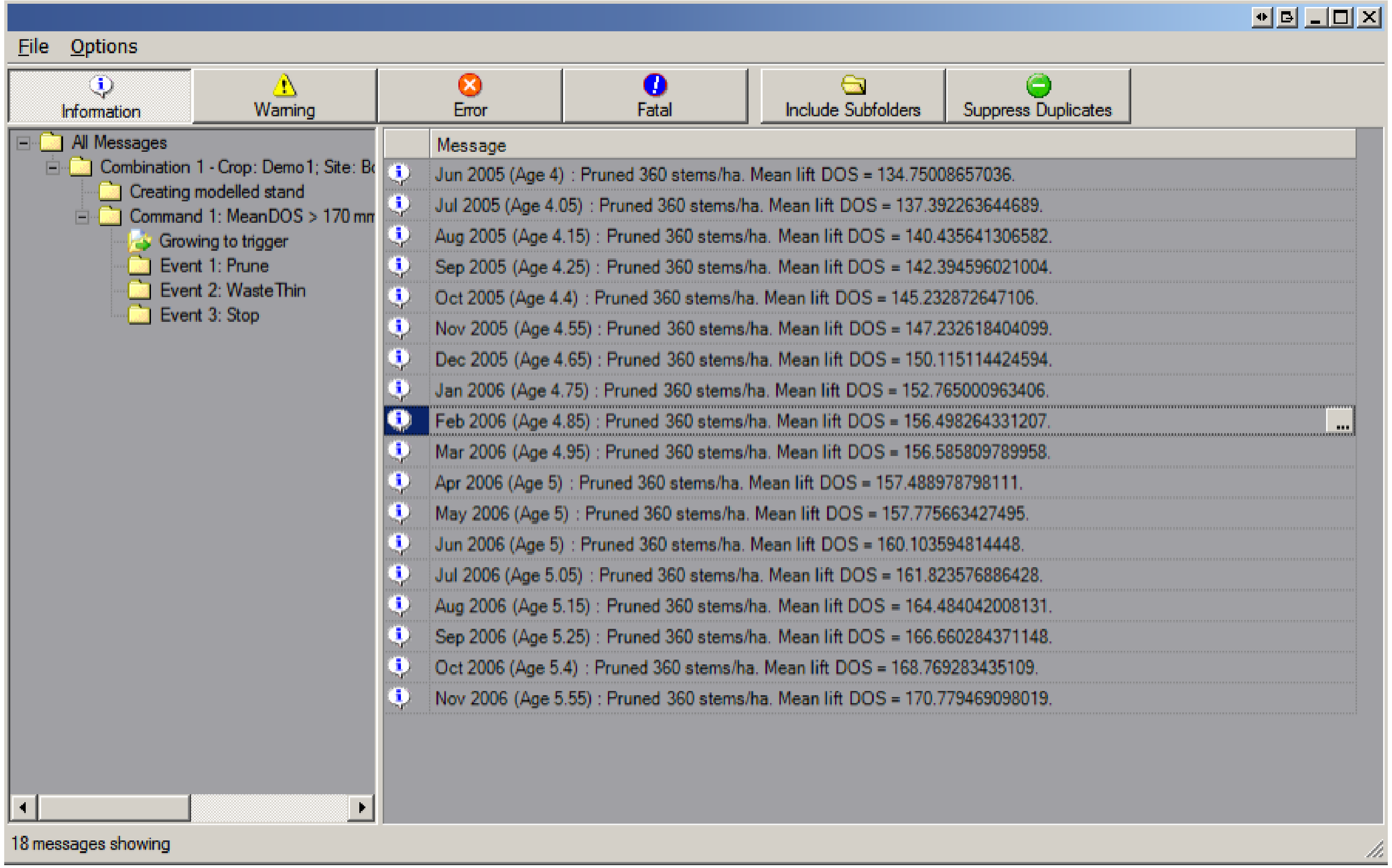


Figure 4. Data Entry and Report Screen

Outputs

The date at which the required pruned stocking will be reached, meeting the defined criteria, will be calculated. This will be detailed in the output report, listing mean DOS, height and date of pruning, from the date the target stocking is reached, through the target DOS, to several months beyond. This is to allow the user to view the impact of flexibility around the scheduling date. It is also possible to view the underlying stem list to see the range of DOS and heights around the mean.



	Prune 1
Month Year	November 2006
Age (years	5.6
Scheduled On	MeanDOS > 170 mm
Stem Ordering	LargestDbhxHeight,3
Prune Strategy	Ht<2.4 C>0.2 L>0.2
Prune Stocking	(s/ha) 360
Crop Height (m)	(CV%) 6.7 (6%)
Crop Q.Mean Diam (mm)	121
DOS (mm) (CV%)	170 (5%)
Lift DOS (mm) (CV%)	170 (5%)
Mean Top DOS (mm)	181
Max Branch (mm) (CV%)	33 (9%)
DOS Height (m) (CV%)	0.9 (14%)
Prune Height (m) (CV%)	2.2 (6%)
Prune Lift (m) (CV%)	2.2 (6%)
Stand Stocking (s/ha)	885
Mean Top Height (m)	6.5
Basal Area (m²/ha)	9.63
Q Mean Diameter (mm)	117.7
Mean Top Diameter (mm)	128.0
Total Length Pruned (m/ha)	797.5
Catchup Pruning (%)	0

Figure 5. Pruning summary report

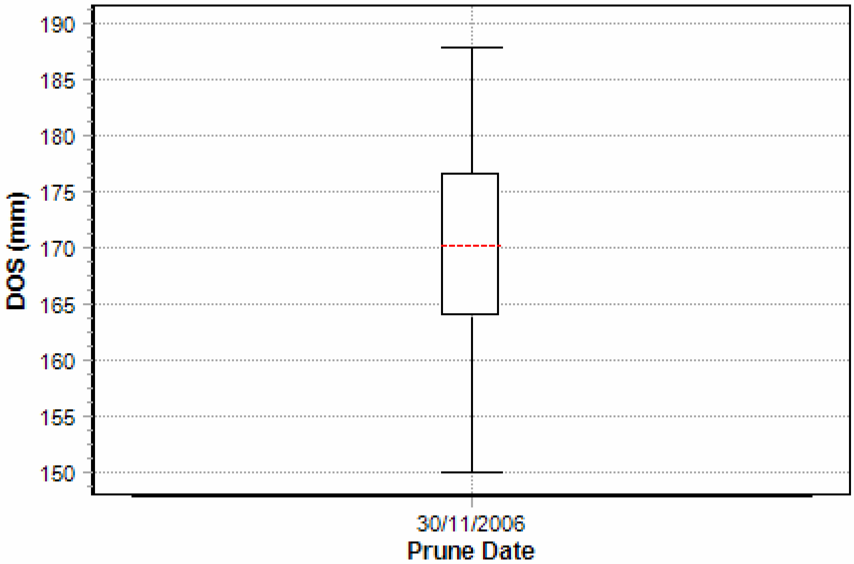


Figure 6. DOS range report

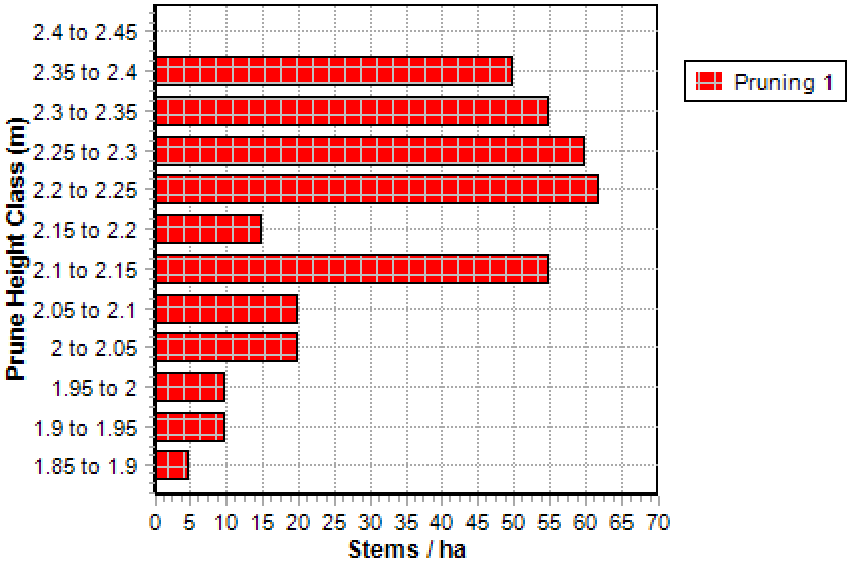


Figure 7. Distribution of pruned height

Example of detailed stem listing

Name,	DBH mm,	Height m,	Weighting stems ha,	Pruned Height m,	Lift Length m,	Lift DOS mm,	Lift DOSHt m,	Lift DOS Max Brnch,	Reason Not Pruned
Stem 142,	107,	5.97,	4.98,	2.12,	2.12,	152,	1.06,	31,	
Stem 22,	104,	5.98,	4.98,	2.12,	2.12,	154,	0.79,	30,	
Stem 127,	111,	5.78,	4.98,	2.07,	2.07,	166,	0.77,	33,	
Stem 162,	107,	5.96,	4.98,	2.12,	2.12,	152,	1.05,	31,	
Stem 167,	107,	5.66,	4.98,	2.21,	2.21,	162,	0.76,	32,	
Stem 88,	101,	5.99,	4.98,	2.32,	2.32,	144,	1.05,	29,	
Stem 83,	103,	6.02,	4.98,	2.14,	2.14,	148,	1.06,	30,	
Stem 81,	103,	6.07,	4.98,	2.14,	2.14,	146,	1.07,	30,	
Stem 3,	111,	6.46,	4.98,	2.29,	2.29,	162,	0.76,	30,	
Stem 104,	94,	6.35,	4.98,	2.25,	2.25,	137,	0.83,	25,	
Stem 136,	07,	5.52,	4.98,	2.35,	2.35,	164,	0.73,	33,	
Stem 17,	110,	5.26,	4.98,	2.24,	2.24,	164,	0.94,	36,	
Stem 118,	110,	5.82,	4.98,	2.26,	2.26,	164,	0.77,	33,	
Stem 76,	104,	6.00,	4.98,	2.33,	2.33,	154,	0.79,	30,	
Stem 43,	104,	5.41,	4.98,	2.30,	2.30,	155,	0.94,	33,	
Stem 148,	104,	5.67,	4.98,	2.25,	2.25,	152,	1.01,	32,	
Stem 123,	109,	5.57,	4.98,	2.27,	2.27,	160,	0.98,	34,	
Total:									

Figure 8. Underlying Stem List

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APPENDICES

Appendix A - Model Inputs and Outputs

These are primarily examples. The design will be open to additions, and the final list will be determined by the design team and the requirements of the models at implementation.

Genotype Selection

Inputs:	Species Stock options - Seedlings - Cuttings - Clonal GF Ratings GF plus ratings Breeding Values
Outputs	Impact on growth Productivity Improvements in - form - branching (grade outturn) - disease resistance - internal wood properties - other Infeed into resource assessment module

Site Management

Inputs:	Pre-plant - Ripping - Mounding - Roller crushing - V-blading - Burn off - Mechanised land prep - Windrowing - Oversowing - Dessication - Spray - Spot spray Post-plant - Spot spray - Animal control - Blanking - Fertilise
Outputs	Growth impact Productivity Improvements in form Improvements in mortality Infeed into resource assessment module

Site

Inputs:	Site description - Altitude - Soil type/class - Exposure to wind - X and Y co-ordinates - Site index - 300Index value - Frost prone - Aspect - Fertiliser history - Previous crop - Rainfall - Average temperature - Location - Potentially upload data from GIS linked map or database
Outputs	Productivity impact Impact on form, branching (grade outturn) Impact on internal wood properties Infeed into resource assessment module

Stand Management

Inputs:	Crop description - Species - GF rating/Breeding Value - Regime - Operation to be scheduled - Plant date - month and year - Stand information / stem list / stand list - Initial stocking - Final crop stocking - Stem selection order Event properties - Maximum pruned height - Maximum green crown remaining - Minimum lift length - Date Event trigger - Age - Date - Basal area - Mean dbh - Mean green crown height - Mean height - Mean top height - Mean DOS - Stocking
Outputs	Range of dates for scheduling with resulting calculated DOS Impacts of stocking Impacts of silviculture Infeed into resource assessment module

Resource Assessment

Inputs:	Inventory data - Dictionary - Basal area - Height - Branching - Density - Defects - Species - User-defined variables Stocking Method of sampling Growth models Taper and volume functions Stand area Tree counts Individual tree locations Plot locations Stratification Standing tree scans Harvesting head data LIDAR, radar and optical remote sensing imagery Hyperspectral imagery Processing plant scan data
Outputs	Stem volume Stem description (2D vs 3D) - DBH - Height - Crown height - Internal wood properties (task 1.3, 1.5, 1.7) - Basal area Infeed for bucking module

Bucking

Inputs:	Grades grade description - Allowable branch size - Branch frequency - Nodal swelling - Min / max SED - Max LED - Length / fixed or random - Sweep - Spike knots - Defects not permitted - Density Grade prices Harvesting head data Cut patterns Strategy (maximise value vs priority)

Outputs	Yield tables Yield cubes Infeed for primary processing module

Primary Processing

Inputs:	log description (2D vs 3D) - SED - LED - Length - Taper - Shape - Branching - Growth rings (task 1.5) - Density distribution - Spiral grain - Heartwood - Grain orientation around branches - MFA - Pith Cut patterns
Outputs	Grade and grade output Board description Infeed for secondary processing module

Economics

Inputs:	Yield tables Yield cubes Log prices Discount rate Operational costs Land costs Carbon values Other non-traditional forest values Land opportunity cost
Outputs	Gross returns Net returns Scenario comparisons

Environmental

Inputs:	Carbon values Carbon calculators Recreational returns Land opportunity cost
Outputs	Water quality Carbon benefits Recreation Land improvement Financial benefits

Appendix B - Summary of Feedback

Responses were received from a number of TST members, and the time, effort and thought that went in to these is gratefully acknowledged. There was some good constructive feedback.

Make it modular

Acknowledge that there is no point in building the system as one big framework, for a number of reasons. One of the most important is the need to be able to separate out modules to allow analysis in specific areas to be carried out independently. Outputs from one module can form the output of another to allow the system to work interactively. The second reason is to control the complexity.

Make it capable of handling "commercial size" data sets

Agree that bulk data needs to be handled, and that where applicable inputs and outputs should be able to feed directly from / to a variety of existing software (not just ATLAS products).

Good growth models are fundamental

Agree that good growth forecasting will form the backbone of the system, but the idea will be to develop the framework in conjunction with the improvement of existing, and the development of new, models, rather then waiting until all development is completed before building models into the framework. This will allow developments to be made available to industry as they progress. The DSS component is only a part of the total IFS bid (15% over the six years) and the development of a delivery framework will not impact on the work planned in other objectives on existing and new model development.

Do not replicate existing work / systems

There is no intention anywhere within the DSS development to replicate work that exists. If tools are in place from other sources then these should be used in the DSS where possible (IP issues notwithstanding). The basis for listing the modules was to identify the possible inputs and outputs of a complete DSS tool, rather then to list modules that we would necessarily be actively developing. If information from disparate sources is utilised, the work will need to focus on allowing the information to flow through the modules to give the right answers, based on the predicted interactions. It has been mentioned by a number of people – don't reinvent the wheel. This was taken on board from the industry survey and there is no intention of doing so – obviously this was not made clear in the report. (This applies to, among other areas, stand management, resource assessment and log bucking). It will be a matter of prioritising the development to achieve the maximum value for industry along the development process. All modules need to be developed not only to keep pace with existing and new science, but also with enough flexibility to utilise alternative sources of information that may become available in the future.

Focus on the achievable first

Agree that it will be impossible to create a system that allows modelling for all possible combinations of G*E*S, or that at best are too costly to attempt. Some work needs to be done to assess what is realistically achievable (80 / 20 rule).

Utilise all available information / systems

The focus of the DSS developed does not need to be all strictly "software development". Looking at available information that is currently not well utilised by industry and how such information / systems can be utilised to improve modelled outcomes, could be a good method for some short-term gains in modelling process. Another area of possible short-term benefits is some work on making the current "black box" more transparent so people have a better understanding of current models, their limitations, and assumptions made within software.

Whether primary processing should be included

The issue with the value of primary processing to those companies who don't do it, and who export reasonable volumes is a valid for some companies. However, it has been acknowledged that as a FRST-funded project, there need to be some "stretchy bits", and this part of the DSS tends to fill this criteria.

Whether an economic module should be included

The feedback received is unanimous in not supporting the need for an economic module. This may not be the view of the whole of membership as it needs to be remembered that the feedback is currently all from the big players who have systems and rules in place within their organisations. . There may be some requirement for a basic economic analysis module from some of the smaller members, and this needs to be gauged. If there is a perceived need, it is unlikely that such a module will need to be either costly or complicated, and is largely covered by work already undertaken by Scion in other areas.

Deterministic vs stochastic

The deterministic vs stochastic debate needs to be furthered, but it is probably something that can be part of the development process. The answer is likely to be a combination based on the existing range of models.

Resolution vs complexity (Calculators)

The resolution question has a number of sides. Attempting to maintain more then one tool to cater for different requirements in terms of level of resolution, rather then trying to develop one tool that performs at a number of levels, may be a cheaper and more effective option. This may reduce complexity, which is a big concern and can often introduce problems both in terms of development time and in performance of software. However there may also be opportunities for introducing fast options for processing within the more complex tool, such as the Scheduler. These opportunities need to be looked for and capitalised on as the development progresses.