PO Box 1127
Rotorua 3040
Ph: + 64 7 921 1883
Fax: + 64 7 921 1020
Email: forestgrowersresearch@fgr.nz
Web: www.fgr.nz

Programme: Harvesting & Logistics

Project No: 5.3
Milestone Number:

Report No. H047

Harvesting Automation Value Chain Modelling

Authors:
Karen Bayne, Melissa Welsh, Michael Wang, Scion,
Rob Radics, Lincoln University, and
Bùi Việt Hà, Massey University

Research Provider:
Scion
Christchurch

Date: 23 April 2021

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EXECUTIVE SUMMARY

This report details the development of an easy-to-understand simulation model that quantifies the efficiency and economic benefits of new automated processes, so that forestry companies can make management decisions around whether to adapt their harvesting practices to include new automated harvesting value chain technology. Using the ExtendSim software, a discrete event simulation package, which provides visual display of products (in this case logs) through a range of value chains, forestry companies can input their own data and easily model what happens if changes are made.

The long-term purpose for the Value Chain Optimisation project is to provide a base model that can be customised by firms looking to examine the implications on production cost and efficiency when considering converting to a new value chain system. Major project activities have involved:

- Establishing a spreadsheet of operational parameters for the ExtendSim modelling
- Logistic input parameters. Establishing and refining from simulation runs, the baseline timings, machine costs and production operation flows for the various eight value chain options.
- Conducting simulation runs to estimate yield and operating times
- Creation of a benefits and cost spreadsheet, and machinery costs to account for operating costs, depreciation, maintenance and personnel hours.
- Establishing an economic model to incorporate the simulation parameters and validate economic benefits to a hypothetical forest company.

Progress to date has provided a base simulation model for eight various harvesting value chain configurations. The economic costings for the process, based on the simulated outputs, have also been modelled. The initial outputs have produced an economic model from the process simulations that indicates large potential worth for new automated harvesting processes, from an economic and higher yield perspective.

The simulation runs, using ExtendSim software, estimate an increase in process yield from 1,103 tonnes per day using the conventional process supply chain, to 1,945 tonnes per day when the process utilises proposed new automated harvesting machinery through the log sort supply chain, increasing the annual system throughput by 78%.

However, there are social and economic factors to consider also – the new process reduces the crew requirements by 11 workers and has capital outlay requirements of more than $50 million. The economic modelling indicates the new supply chain configuration would cost $51 million in total plant investment and has a Net Present Value (NPV) of $83 million. Total benefits result in a Return on Investment (ROI) of 31%, an Internal Rate of Return (IRR) of 24% and a payback period of 1.5 years.

In the absence of specific forestry company data, the accuracy of the current model cannot be assessed. Therefore, the model is also currently being validated against ‘best case’ industry knowledge to identify any potential errors or anomalies before being used with ‘real’ company data. This will provide an estimation for the model’s accuracy, and any supply chain aspects needing refinement.

INTRODUCTION

Primary Growth Partnership Harvesting Automation Programme

Harvesting operations in New Zealand face some big challenges now and in the future. The programme aims to address the challenges by developing a new forestry value chain. These challenges include: labour shortages; rising costs reducing competitive advantage and increasing barriers to long term sustainability; and unviable small holdings. Additionally, log security, high inventory levels, limited port storage space and to date the limited use of High Productivity Motor Vehicles (HPMV) are also issues this programme will help solve.

All companies and harvesting operations work to minimise the impact of such challenges however often the various parts of the value chain work independently to improve their sphere of operation invariably impacting on efficiency and therefore cost of another part of the value chain.

The Value Chain Optimisation project within the Harvesting PGP investigates the economic benefits from new simulated supply chain models that incorporate automated log sort yard capabilities. In particular, the value chains that allow harvesting businesses to move from the current harvesting process (Figure 1) to a new process incorporating an automated sort yard (Figure 2).

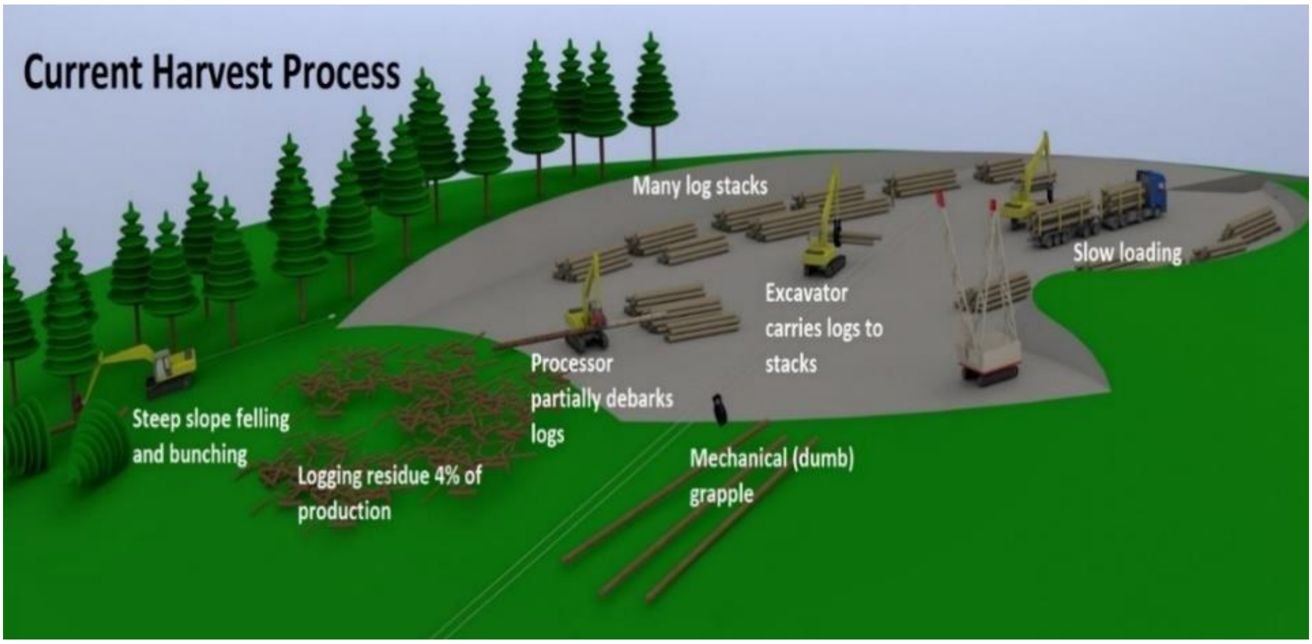


Figure 1: The current conventional harvesting process

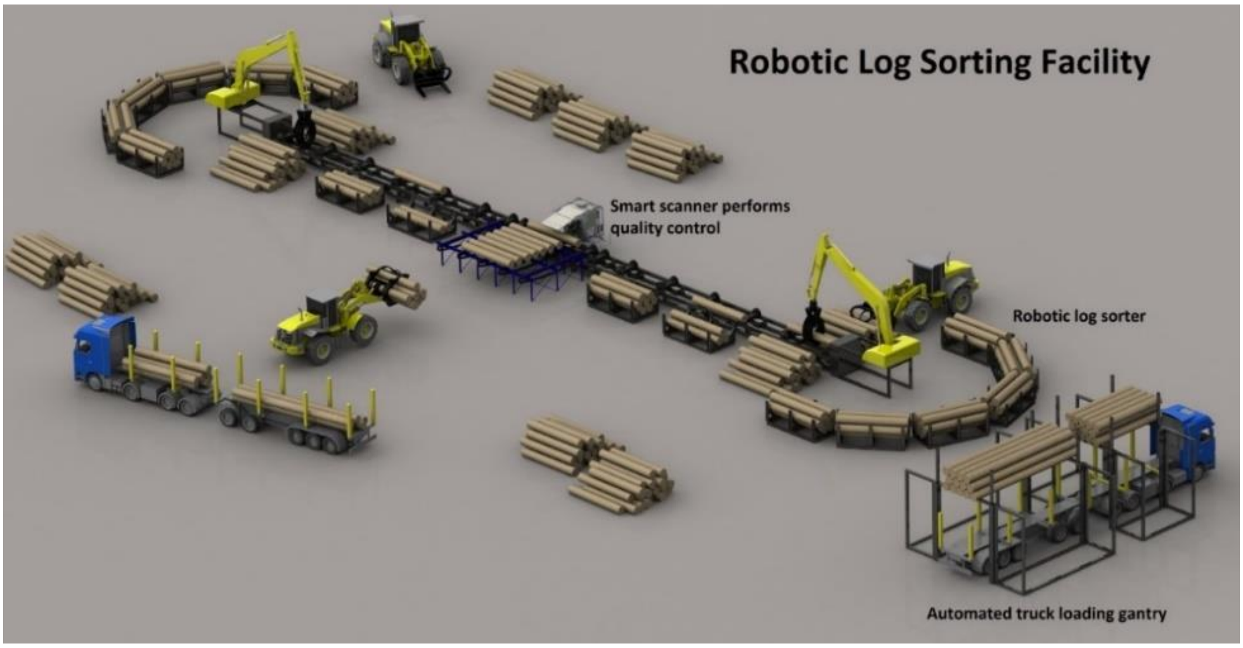


Fig 2: Proposed robotic log sorting facility

PROJECT OBJECTIVE AND MILESTONES

Background to Value Chain Optimisation model

'Te Mahi Ngahere i te Ao Huruhuri – Forestry Work in the Modern Age' aims to reduce the delivered cost of logs to customers by developing a new more efficient value chain. An earlier spreadsheet model was developed for a 10-year period, to calculate the potential economic benefits of moving to a new more efficient value chain. This simple model estimated savings of a new value chain where logs would be removed from a landing in mixed grades and taken to another location for sorting, Quality Control, weighing, scaling and labelling using robots and automated processors. The results of this work showed a $9/tonne cost reduction of the delivered log cost to the port or mill customer [1]. The spreadsheet was very detailed but difficult to understand and difficult to explain or present to an audience. Therefore, a simple visual model needed to be developed so that the Te Mahi Ngahere i te Ao Hurihuri work programme could be presented to the wider logging industry to ensure complete industry understanding of the programme. It is important that the industry understands the new value chain, the cost implications, and is on-board with the new technical development.

Project Milestones

This report relates to the first of three milestones (Figure 3) within the Value Chain Optimisation objective of "Forestry in the Modern Age" Harvesting PGP: *Validating the costs and benefits used for the business case* contributing to Milestone 1.3 Technical and Economic Feasibility of the PGP Agreement, specifically: Complete the initial design for each product, optimise the value chain using Scion simulation software, review alternatives and competing products in international markets, conduct economic feasibility, incorporation of market situation report, and prepare technical and economic feasibility report for sign off to progress project to prototype development.

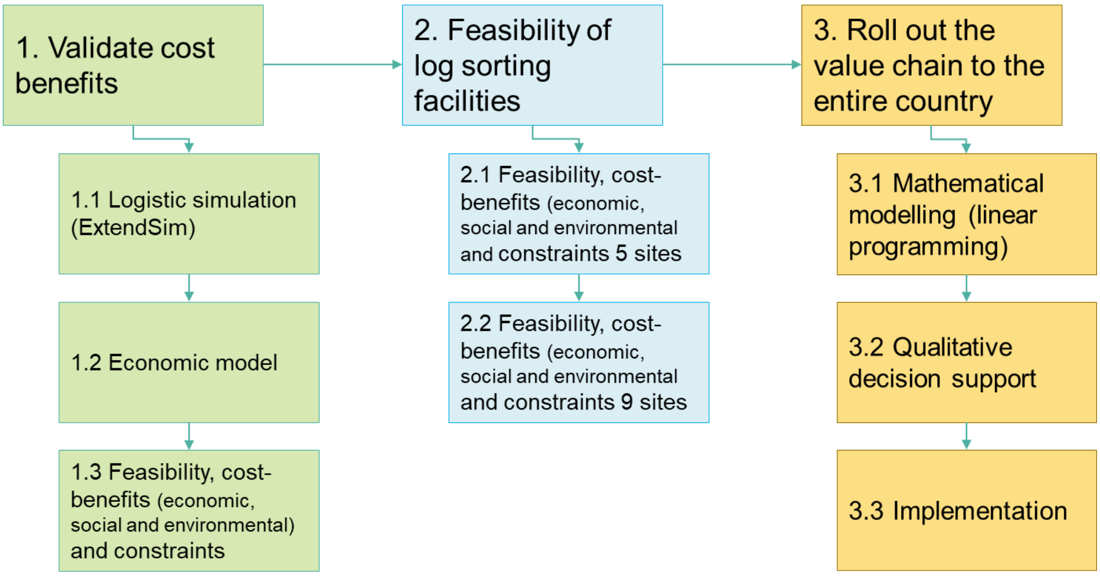


Figure 3: Project Milestones

Two main objectives from the first milestone were to:

a) Establish the logistics of the new value chain, which incorporates automated processes and the new robotic sorting yard, and simulate this new process to establish process parameters for economic modelling.

b) Investigate the cost benefits to forest business from incorporating new automated log sorting into current value chains.

RESULTS

Using ExtendSim software developed for discrete event modelling, simulation models of the two value chains were built highlighting the cost differences (efficiencies) at each point in time.

Figure 4 below is an example of a forestry simulation. Through discussions with TST members and FGR, a series of eight different value chain configurations were determined, along with the new log sort yard supply chain and current trucking parameters. Sensitivities around machine breakdowns, truck delays, truck queues, high and low production for each simulation were run, showing benefits or additional costs for each segment of the value chain.

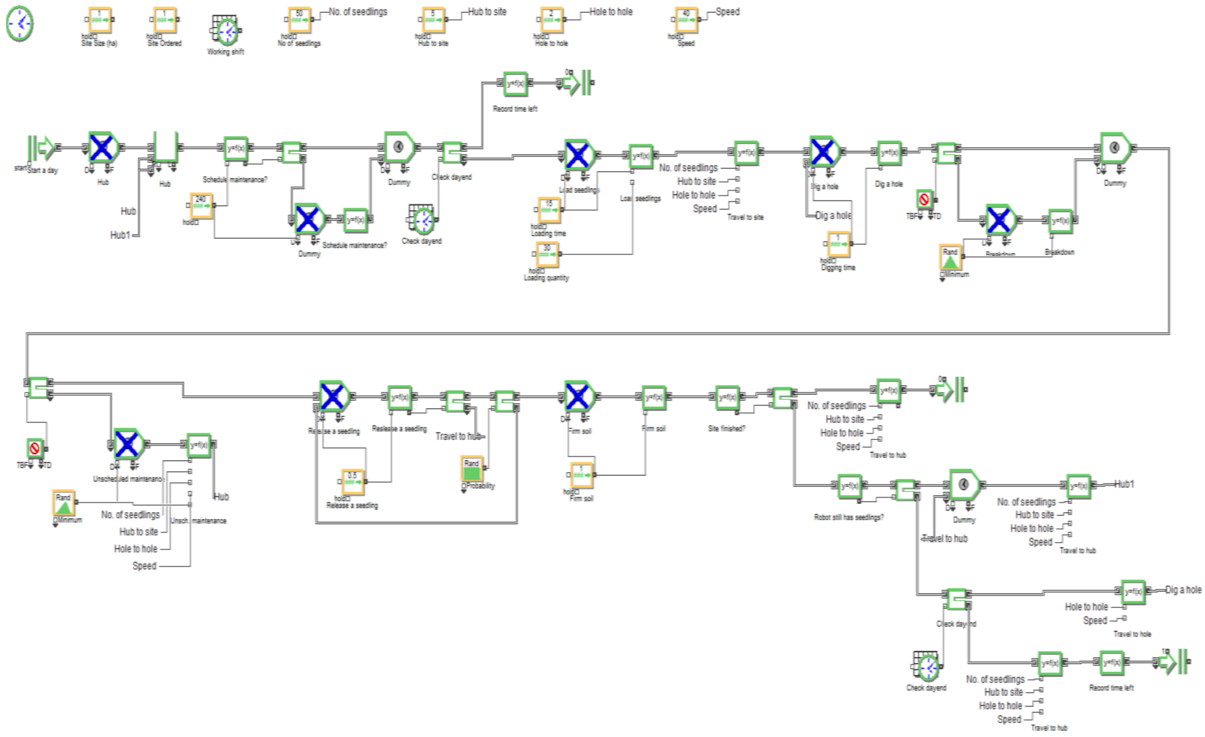


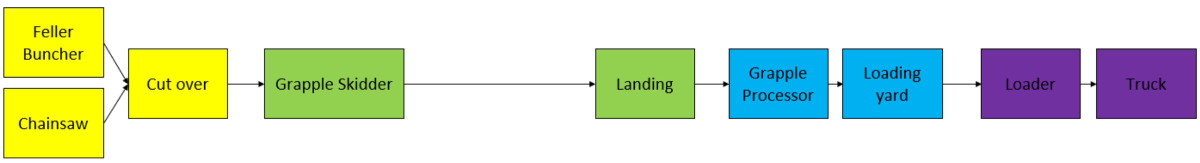
Figure 4: Basic Forestry Value Chain Model

Project scope

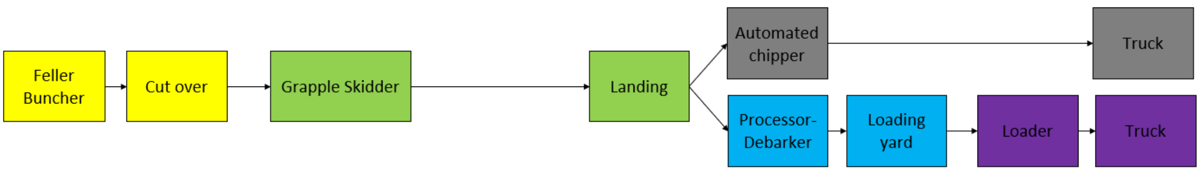
Simulation Model development

The parameters for the initial programme expanded to include a range of potential processing value chains, taking into account different Hauler and Mechanised versus Ground based operations. A total of eight potential options have been developed, with input parameters for each dependent on the log flow, machine operating times and labour requirements. Eight value chains have been modelled using the software ExtendSim. These consist of the existing manual and mechanised systems, as well as incorporation of an automated sort yard into both the manual and mechanised systems:

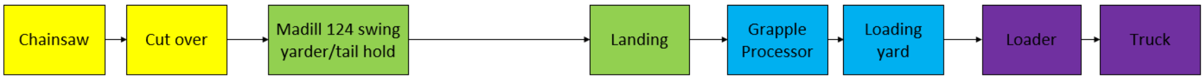
Conventional Ground-based (CGB)



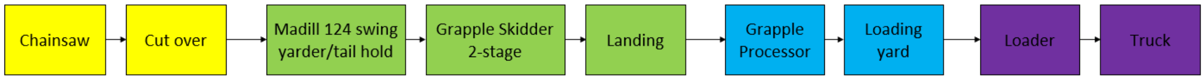
Automated Ground-based (AGB)



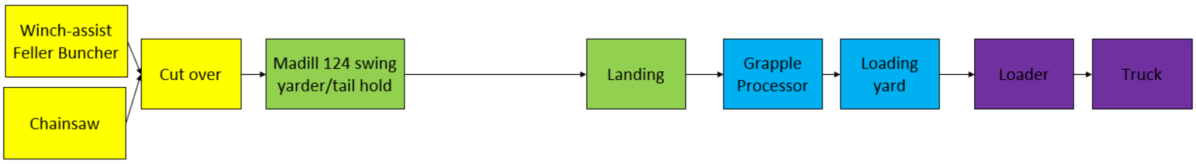
Conventional Hauler (CH1)



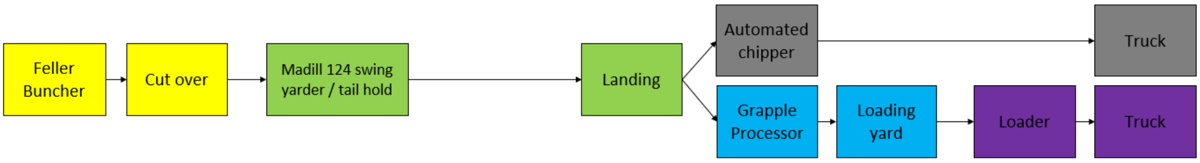
Conventional Hauler with 2 stage (CH1-2)



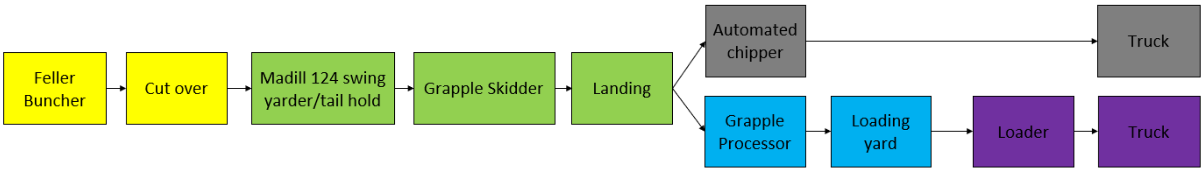
Mechanised Hauler (CH2)



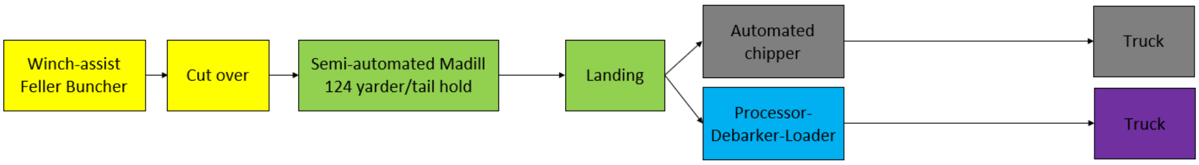
Automated Hauler (AH1)



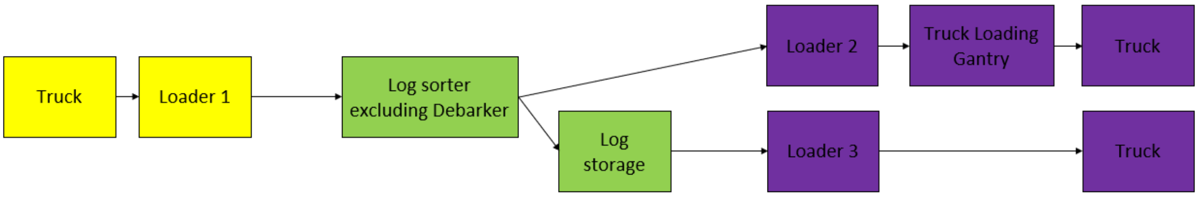
Automated Hauler with 2 stage (AH1-2)



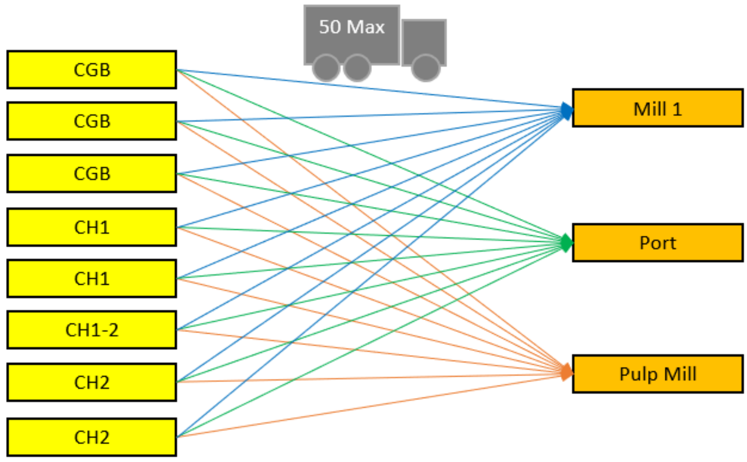
Automated Hauler 2 (AH2)



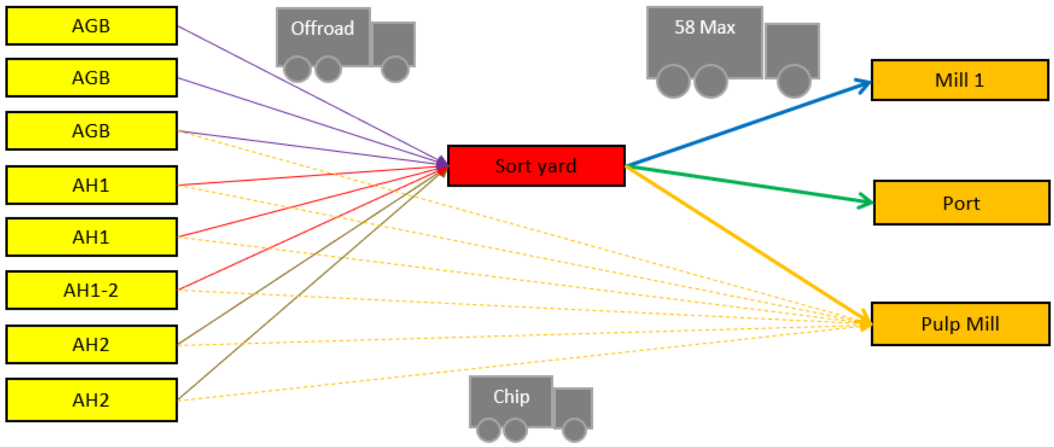
Sort yard



Trucking current process



Trucking new process



Weekly team meetings assisted in the logic for development of the ExtendSim simulation for each of these processes, in order to establish both the yield and working hours per machine for input into the economic model. These discussions centred on establishing parameters for the machinery throughputs, costs, and estimated cycle times. The Excel sheet inputs and process maps were iterated over time (latest version is V23), following revised assumptions around trucking, processor capacity due to conventional to automated supply chains, including the incorporation of debarker, log sorter and a truck loading gantry.

During iteration V16, the inclusion of ability to send waste directly to a chipper was added, and the capacity for loaders revised given the waste volumes had been adjusted, as well as estimated log volumes passing through the sort yard, given new automated harvest crew capacity and production volume. Further iterations accounted for corrections in daily machine working times and truck unloading times. The current simulation models 22 runs of 5 days each to provide a predicted yield distribution value.

Economic model development

Using the results of the ExtendSim modelling, an economic model (fig 5) has been developed to estimate the net benefits of the two operation scenarios. The initial economic model was based on fundamental economic input data, and later the yield and working hours from the ExtendSim runs were added.

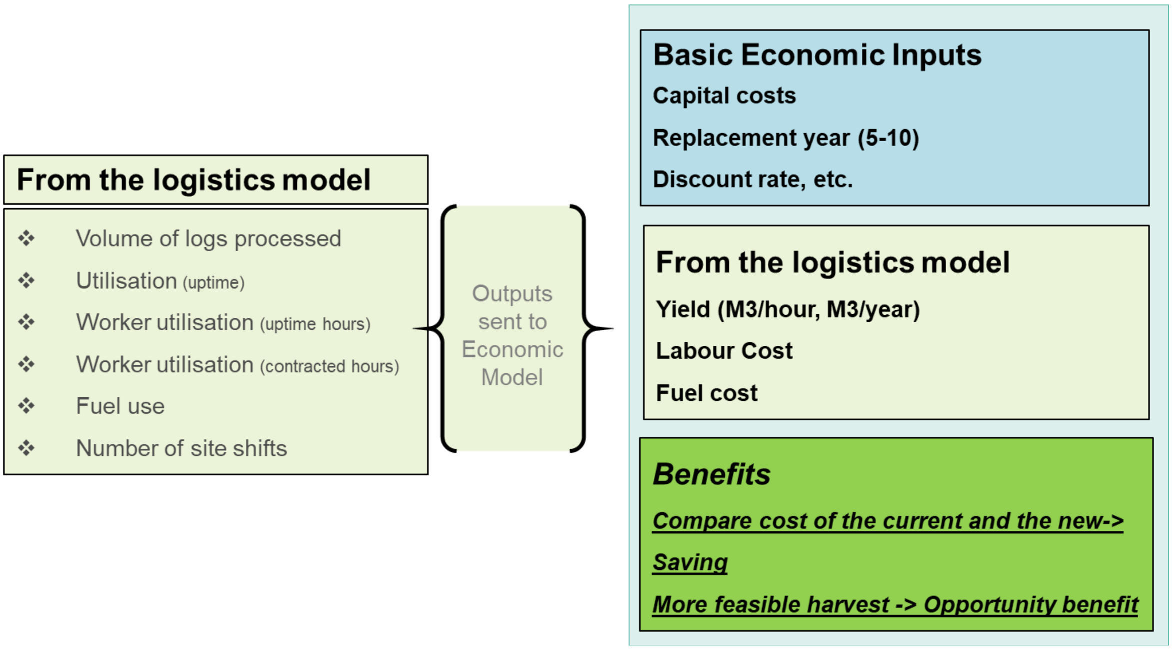


Figure 5: An overview of the economic modelling inputs, to determine cost benefits from the new automated process

The economic model currently evaluates the scenarios over a 20 year period, taking into account depreciation, maintenance and replacement of machinery over that time. We are now in the process of validating this model, using pre-existing tools and information. A questionnaire to elicit estimates from forestry companies was developed,and circulated to the industry however we had no responses. An alternative source of data was found using data from the FGR Benchmarking database [2].

The table below summarised the number each crew type and total personnel required under the current, conventional scenario and he the new proposed operation scenario.

Table 1: Crew requirements for value chain configurations

Crew types		
	Current number	New number
Conventional GB Crew CGB	3	0
Conventional Hauler Crew CH1	2	0
Conventional Hauler 2 stage CH1-2	1	0
Conventional Hauler Mech Crew CH2	2	0
Automated GB Crew AGB	0	3
Auto Hauler Crew (PGP1) AH1	0	2
Auto Hauler Crew (PGP1) 2 stage AH1-2	0	1
Auto Hauler Crew (PGP2) AH2	0	2
Sort Yard	0	1
Personnel	64	53

The following table (Table 2) shows the amount of time each piece of machinery ran for in a single ExtendSim run. These are the values used to produce the estimates of machinery related costs in the economic model, including daily running costs, maintenance and replacement.

Table 2: Process simulation times

Current process simulation	
Machinery	**Process time (hours per day)**
Chainsaw	23.70
Feller buncher	6.74
Feller buncher winch	5.37
Grapple skidder	7.96
Grapple skidder 2 stage	2.04
Loader	57.13
Madill 124 grapple	5.47
Madill 124 swing	6.80
Processor	20.92
Truck 33	82.99

The yield output by each crew type in this conventional operation simulation is given in Table 3 below. These are the values used to estimate the annual income of such an operation, as well as the costs of handling this volume of logs.

Table 3: Conventional yield output

Site	Total yield (tonnes per day)
CGB	129.01
CGB	129.01
CGB	129.01
CH1	143.34
CH1	143.34
CH1-2	143.34
CH2	143.34
CH2	143.34
Total	**1,103.73**

The daily operation time of each piece of machinery under the new process scenario is shown in Table 4.

Table 4: Daily operation times

New Process simulation	
Machinery	**Process time (hours per day)**
Auto chipper	1.98
Feller buncher	17.02
Feller buncher winch	30.21
Grapple skidder	16.26
Grapple skidder 2 stage	6.72
Loader 1	6.67
Loader 2	5.28
Loader 3	6.80
Loader large	43.46
Madill 124 grapple	16.75
Madill 124 semi auto grapple	9.24
Processor - Debarker	36.82
Processor - Debarker - Loader	12.36
Sorter	7.68
Truck 22	18.37
Truck 28	79.44
Truck 40	25.36
Truck Loading Gantry	4.11

The simulated average daily output in Table 5 suggests greater efficiency under the new process. Though the greater volume of logs does lead to increased operation costs in their handling.

Table 5: Automated yield output

Site	Total yield
AGB	227.70
AGB	245.57
AGB	252.59
AH1	246.16
AH1	241.70
AH1-2	260.84
AH2	233.90
AH2	236.85
TOTAL	**1945.32**

The summary of financial measures (Table 6) would support incorporation of the new automated process, but requires further validation and refinement (next stage of project).

Table 6: Summary of Economic comparison between conventional and new automated process

Summary of Financial Measures		
Current		**New**
$23.437	Net Present Value ($m)	$82.229
0.3%	Internal Rate of Return (%)	27.3%
5.2%	Return on Invested capital (%)	30.9%
8.4	Payback period (years)	1.5

Other Financial Information		
$43.474	Plant total installed cost ($m)	$51.689
$3.998	Initial working capital required ($m)	$7.079
$47.472	Total start-up cost ($m)	$58.768
$18.989	Initial equity investment ($m)	$23.507
($3.425)	Periodic loan payments ($m)	($4.240)
2.0%	Equivalent annual loan interest rate (%)	2.0%
0.5%	Equivalent annual deposit interest rate (%)	0.50%
$3.595	Standard annual repairs & maintenance ($m)	$5.156
1,840	Standard productive time (hours/year)	1,840
253,857	System throughput (tonnes/year)	449,485
138	System throughput (tonnes/standard annual operating hour)	244

CONCLUSION / NEXT STEPS

The economic model is still being validated and refined, with the plan for the elaborated model to handle user inputs in a flexible and user-friendly manner.

In the absence of any particular company data, the accuracy of the current model cannot be assessed. Therefore, the model is also currently being validated against ‘best case’ industry knowledge to identify any potential errors or anomalies before being used with ‘real’ company data from the five sites. This will provide an estimation for the model’s accuracy, and any supply chain aspects needing refinement. Once we are able to access industry data we intend to undertake sensitivity analysis in order to identify the most important drivers of the mode, input combinations that lead to the model breaking even and necessary constraints and trade-offs. As an initial step in this process, data from the Benchmarking study will be used as a proxy for actual company data in initial validation.

To date the programme has been discussed with the TST, and some early adopter firms. For this programme to succeed the industry must understand the expected outcomes and see the need for change. We plan to collaborate with the operational and financial experts of the forestry companies we work with to teach the use of the model and refine it as necessary to the company and their customised feasibility study. Further milestones in this project will run real-time data from firms looking to estimate the benefits of adopting the automated supply chain into their own production processes, and are dependent on the PGP programme’s success in attracting interest in the transition to automation.

Next steps: Once we are able to access industry data we intend to undertake sensitivity analysis in order to identify the most important drivers of the mode, input combinations that lead to the model breaking even and necessary constraints and trade-offs. As an initial step in this process, data from the Benchmarking study will be used as a proxy for actual company data in initial validation.

ACKNOWLEDGEMENTS

The team wishes to thank TST members for data, and FGR staff, particularly Don Scott and Keith Raymond for their weekly project contribution via our video calls to test the logic and provide suggestions to improve the model. We also thank Paul Childerhouse (Massey University) for his student supervision.

Our thanks also to Rien Visser (University of Canterbury) for providing harvesting benchmarking data that will assist in validating and refining the model.

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1. Radics, R., *Planterbot Value Chain Model*, Scion, 2018.
2. Obi, F. and R. Visser, *10 yr Benchmarking data envelope analyses*, in *FGR H042*, Forest Growers Research, 2020.