CUT-TO-LENGTH OPERATION BUSINESS PLAN FOR ALGONQUIN PARK AND OTTAWA VALLEY FORESTS

By

Avery Nagora

An undergraduate thesis submitted in partial fulfillment of the requirements for the degree of Honors Bachelor of Science in Forestry

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Major Advisor Second Reader

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ABSTRACT

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Keywords: Cut-to-length, Maximum forwarding distance, Cost models, Revenue calculators, Profitability, Ottawa Valley Forest, Algonquin Park, AFA.

This undergraduate thesis is a business plan for cut-to-length operations in the Ottawa Valley and Algonquin Park forests. The purpose of the thesis is to construct a business plan with the necessary costing models that contractors need to develop a successful cut-to-length harvesting business. This will equip contractors and license holders with the necessary costing models to understand important variables in the operation and how these variables impact net profitability. This thesis uses multiple costing and revenue models to project the costs involved in extended forwarding distant applications and determine whether these conditions are economically feasible.

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INTRODUCTION

It is an exciting time to be involved in the forest industry. There is much change and development within the industry including new technologies. However due to an aging workforce and low profit margins in the industry, logging contractors are falling behind in their ability to keep up with these advancements. Mills are increasingly looking towards cut-to-length systems in forestry to keep up with current demands. Also, foresters are beginning to harvest more sensitive areas that have been missed and left behind by previous harvesting operations. The current tree-length harvesting operations are too disruptive compared to the cut-to-length operation to harvest in these delicate areas leaving large areas of land unharvested. With these changes, more companies are beginning to become obsolete in the industry due to the lack of investment in cut-to-length technology. This is mostly due to the contractor's inability to understand the computers and software now used in these cut-to-length machinery and high initial capital cost.

With this lack of computer and software knowledge, older forest contractors are beginning to get out of the industry and retire. This opens many positions in the industry and suggest that the future of forestry contracting is a young loggers game. Although these advancements in forestry propose a lot of potential for the younger generation it also proposes a problem. Young contractors lack the experience to launch a cut-to-length and succeed. Therefore, a business plan for younger contractors to follow is required to increase the chances of success in this relatively new advanced operation.

The purpose of this thesis is to construct a business plan with the necessary costing models that contractors need to develop a successful cut-to-length operation business in the Ottawa Valley and Algonquin park region. This will allow contractors and license holders who are interested in cut-to-length applications to better understand the cost involved in a cut-to-length operation. The business plan will be based in the Algonquin Park Forest under the Algonquin Forestry Authority (AFA). The AFA is the Crown Agency responsible for Sustainable Forest Management in Algonquin Provincial Park the only provincial park in Ontario that allows and was specifically set aside for harvesting operations. Creating a business plan to encourage more contractors to convert to the cut-to-length system would not only reduce the ecological foot-print on the park but also boost local mills competitiveness. By allowing mills to be more competitive for the current demand on the market, contractors could earn more revenue from better log quality and more diverse product sorts. Cut-to-length harvesting operations could be the answer for the future in Eastern Ontario to regain a competitive edge within the forest industry.

This thesis focuses on the systems analysis side of a cut-to-length operation business plan. Through the operational research, costing and revenue models have been developed to determine the feasibility of cut-to-length operations. Three main models have become the focus for determining feasibility. These models are as listed; 1. Optimal road spacing model, 2. Equipment costing model, 3. Product revenue calculator.

With the use of all three models the potential revenue of the hypothetical cut block using the same equipment as A.J. Nagora Logging Ltd. can be determined. This will provide the necessary information to determine whether a cut-to-length operation can be feasible in application with extended forwarding distances. If the extended forwarding applications are determined to not be feasible the business plan will state that compensation from the license holder is required to the contractors for these operations to continue.

LITERATURE REVIEW

DEVELOPING A BUSINESS

To create and develop a successful business can be rather difficult and is no small feat. Countless amounts of books and papers have been written to help guide new and the old entrepreneurs to such success in a new business. “You’ve got to have the ‘fire in your belly,’ or you will fail. There are long hours, hard work, and incredibly frustrating and stressful times ahead. But the rewards — being your own boss, being able to work on a variety of projects, feeling that proverbial sense of accomplishment — these are all very real results.” (Potts 2003).

One of the first and most important things an entrepreneur starting out can do is develop a business plan. Although a business plan requires a lot of time and energy it also forces a person to remain focused. Focus is key in determining the first steps in a successful business plan. The decision of how the owner will generate income, what their expenses are, who their competitors are, and what their company exactly does are just some of the questions an entrepreneur must first ask themselves (Potts 2003).

Planning is everything when it comes to developing a successful business. Before an entrepreneur can begin to apply for business loans and other type of funding the businesses plan must first be complete and well thought through (McKay 2016). Along with planning must come management. A successful business contains management that maximizes the utilization of income, people, and other resources that lead to a successful business (McKay 2016).

The business plan is the essential tool and base to developing a business. The plan is essentially a report on all the company's sources and use of funds. The plan also reports on the management of personnel, marketing strategies, products, labor relations production techniques and research (Ministry of Industry Trade and Technology 1986). Once the business plan is complete the goal turns to finding banks and government agencies to help fund the new business.

CUT-TO-LENGTH HARVESTING SYSTEM

A harvesting system refers to the equipment and machinery used in the harvest area (Pulkki n.d.). The cut-to-length harvesting system uses the fewest but most complex equipment. In this harvesting system there would commonly be seen just one single grip harvester and one forwarder (Pulkki n.d.). Cut-to-length harvesting requires the most skilled operators due to the equipment's high tech complex operating system.

A harvesting method refers to how the wood is processed and delivered to roadside (Pulkki n.d.). In the cut-to-length or "short wood" method the trees are "felled, delimbed, and bucked to individual product lengths directly in the stump area and then transported to the landing or roadside" (USDA 2006). The processed wood is transported to roadside by a forwarder; however, cable skidders are sometimes used. The cut-to-length method is well suited for use in all silvicultural systems. The size of landings (if any) are very small because no roadside processing equipment is needed, and wood can be piled in small cleared areas or directly off the access road (USDA 2006). The minimal amount of road required over the harvest areas is also quite unique to the cut-to-length system. With a productive skid distance of over 600 metres the forwarder has a much longer forwarding capability compared to the common grapple forwarding operations which average only approximately 300 metres. Due to this large forwarding capability only 20 m./ha of roads are needed creating more productive area in each harvest block and less environmental disturbance created during road construction (Pöyry, 1992).

This system is unique because the wood is carried off the ground avoiding the risk of breakage and dirt contamination which often occurs with the full tree and tree-length systems (Pulkki n.d.). With the system's ability to carry wood off the ground the system is also the best for the protection of residual trees and regeneration. This is because the residual trees are no longer being used as bumpers (as seen in any tree-length or full-tree operation) and with the logs being in neat piles minimal regeneration damage is present due to no dragging of any logs and just straight lifts instead (Pöyry, 1992). Even in stands with small diametre trees the cut-to-length method is still able to succeed (Pulkki n.d.). This method is well suited for sensitive areas because it has a low environmental impact by driving on top of the brush piles to disperse weight reducing the risk of rutting (Sugg n.d.). Over-all ground disturbance categories (dry, frozen, wet), the cut to length systems have the least amount of ground disturbance when compared to other harvesting systems (Pöyry, 1992).

DETERMINING OPTIMAL ROAD SPACING

Optimum road spacing (ORS) is an important factor to optimize the cost of any harvesting operation (Reza et al. 2007). Forwarding distance is the largest effect on ORS. As seen in the study from Pulkki (n.d.), as forwarding distance increase the cubic metre of road per hectare decrease and vice versa. However, many factors such as load volume, taxation policies, landing costs, overhead costs, slope and topography all have a significant influence on determine optimal road spacing (Reza et al. 2007).

The amount of volume the forwarding equipment can move at one time has the largest effect on optimal road spacing. As forwarding distance increase so does the need for larger load capability of the forwarders. If a logging contractor does not have equipment that is capable of forwarding the cubic metres needed for long distance skids that contractor would need more roads (Thompson, 1988).

Sessions 1986, has proved there is a significant connection between taxation polices and ORS. In mainly private land owner situations the increase of roads across their forest will increase the properties taxes. This creates another factor in minimizing road costs and suggests that in many private land owner’s cases longer forwarding distances offset the potential increasing in property taxes (Sessions, 1986).

Another important factor brought up by Peters (1978), is the cost of landings and its effect on ORS. Depending on the harvesting system being used either large or potentially no landings are required. Systems requiring large landings to process logs have an increased cost compared to systems that do not. This may have a large effect on optimal road spacing where longer forwarding distances are required to minimize roads to offset landing costs (Peters, 1978).

Another important factor effecting ORS is overhead costs. Overhead costs are fixed cost like payments and insurance on equipment and they are affected by timing which effects cubic metres of wood brought to road side per hour. This suggest that overhead cost and how there effect to skid trail distance should be considered when determining ORS. If shorter forwarding distances can substantially increase volume/dollars per hour then the cost for more roads may be more profitable (Thompson, 1992).

Optimal road spacing can also be heavily effected by terrain and slope. In an area with relatively flat and uniform ground this does not apply. However, in areas where the terrain and slope are quite intense ORS changes from the more common liner model (Heinimann, 1998). Sever slope and terrain cause the cycle time of forwarding equipment to increase drastically even over short forwarding distances. To keep an operation with such terrain productive without changing to a yarding system, more roads are needed to keep skid distances low (Henimann, 1998).

FORESTRY IN THE OTTAWA VALLEY

Since the early 1800's there has been logging in the Ottawa valley (Cultural Heritage n.d.). "In 1892 a Royal Commission recommended creation of a park, and in 1893 the Legislative Assembly of the Province of Ontario passed the Algonquin National Park Act. Objectives listed for establishment of the Park were: to preserve the headwaters of the watersheds; to preserve the native forest; to protect game and fur bearing animals, fish and birds; to provide an area for forestry experimentation; to serve as a health resort and pleasure ground for the benefit, advantage and enjoyment of the people of the province" (Algonquin Forestry Authority 2018). Still to this day many communities surrounding Algonquin Park rely heavily on the forest industry. There are three major forest management groups in the Ottawa Valley; the Algonquin Forestry Authority (AFA), Ottawa Valley Forest Group (OVF), and the Renfrew County Forest (RCF). The AFA is in charge of the entire Algonquin park and has managed all harvesting and operations within the park limits since 1974 (Algonquin Forestry Authority 2018). With the park being located only 250 kilometres north of Toronto the AFA is under constant pressure from environmental and many other social groups to prevent logging in the park. The OVF covers land from as far west as Bissett Creek to just east of Arnprior and as far south as Palmer Rapids (Ottawa Valley Forest 2018). Renfrew County forest owns 53 tracts of land covering 6527 hectares throughout the county. Of these 6527 hectares 84% is productive forest with the smallest tract of land being 10 hectares and the largest being 545 hectares (County of Renfrew 2018). The Ottawa Valley has a healthy competition of sawmills that offer a range of different prices and acceptable specie types and specs. However, the valley does lack local pulp mills, although there are four mills local contractors haul to (Thurso, Temiscaming, Trenton, Espanola) each are at an expense due to high mileage hauling costs.

MATERIALS AND METHODS

STUDY AREA

The study area for the thesis was the Ottawa Valley and Algonquin Park forests, Figure 1. These two forest areas are located along the boarder of eastern Ontario and western Quebec. The Ottawa Valley forest area begins approximately 67 kilometres west of Ottawa in the town of Arnprior. The Algonquin Park Forest most southern border is located 250 kilometres (km) north of Toronto in the township of Dysart

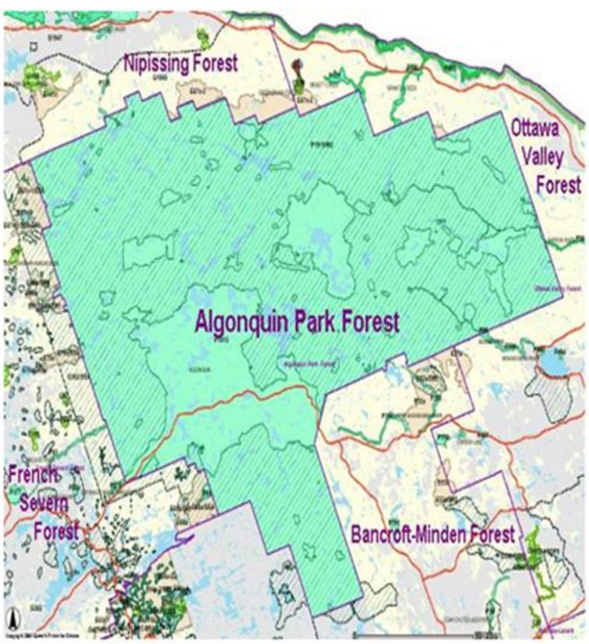


Figure 1 Study Area for the Thesis

The Algonquin Park Forest is controlled by the Algonquin Forestry Authority (AFA) Crown Agency. Being so close to the city of Toronto the AFA deals with constant pressure from ENGO's and other social groups. These group put a negative pressure on the park and believe logging should be banned from the park. To help satisfy these social groups the AFA must constantly create new ways to lower the effect of operations on the environment. To do this the AFA has brought more cut-to-length operations into the park which a capable of working in more sensitive areas with limited stress on the environment and increase skid trail distances. The new maximum skid trail distances have reached over 1000 metres in length. By increasing the length of the skid trail the contractors are having are harder time staying productive and thus feasible and essentially the AFA has met a fork in the road.

DATA SOURCES

Market research was completed through meeting with the logging businesses in the Algonquin Park and surrounding areas. Information was obtained by talking to other local forest management companies (Ottawa Valley Forest, Renfrew County Forest). Mill prices were determined by contacting the many local mills in the area. The prices were used to calculate potential revenues that can be achieved through cut-to-length harvest operations in the areas. Through an economic analysis, the most profitable mills and other local wood buyers will be determined. To determine whether or not this style of operation can be feasible in this area a feasibility analysis was preformed with regard to production and cost.

Production will be determined with the use production models built during past courses at Lakehead University which can have values from forwarders in Algonquin Park input in to them to determine production. These models will also determine how the speed of the forwarder loaded and empty information are used to calculate average cycle times. Cycle times with volume will be used to determine average productivity of logging contractors in the Algonquin Park. While observing the cycle times of this equipment the Productive Machine Hours (PMH) will also be able to be determined from the Scheduled Machine Hours (SMH). Utilization and other important calculations can be determined from SMH and PMH allowing the determination of which areas (human or mechanical) of the system can be improved to increase utilization percentages. Information found from these test to increase machine utilization will then be added to the business plan as some suggestions to improving the productivity.

Knowing that the AFA's average forwarding distance is longer then normal skids preformed by a forwarded, load size modifications are needed to remain productive. Examples of these forwarding distances and modifications have been provided by A.J. Nagora Logging. The comparison between factory load sizes and modified load sizes have been preformed by calculating the load size of a forwarder and its productivity over extended forwarding distances.

Forwarder load sizes were determined using John Deere forwarder models found online from the John Deere website. The forwarder model used specifically in this thesis was the John Deere forwarder 1410D. The reason for this model is because it is the model of forwarder owned by A.J. Nagora Logging Ltd.

Being that the terrain factor is unknown it will need to be determined. These terrain factors will be taken from the same area as the forwarding equipment to determine the effect it has on the cycle times. Further more, the business plan will include how to determine these terrain factors as the Algonquin park and Ottawa valley harvest sites will always have a different terrain factor due to it rugged terrain.

Forest Resource Inventory (FRI) data was collected by Leo Hall from Renfrew Ontario located in the Ottawa valley and the cuts he studied. This data will provide necessary information to help determine potential wood supply for creating models and scenarios. This FRI data will also be used to determine the average amount of stems harvested from a site through before and after Basal Area (BA) records.

This FRI data combined with the productivity data and cost analysis will be used to create models. These models will be used to determine harvest times and revenues for every harvest block a contractor will encounter working in this area.

With the completion of these models a clear understanding on the cost of owning and operating a cut-to-length operation will be known. These numbers can then be used in determining the size of loans needed to initially start up this type of operation. Also by understanding the cost and revenue that can be achieved by using this type of operation, a bank loan can more easily be obtained as the research will show the profitability of the business.

All costing models were created during harvesting courses taken at Lakehead University. These models are run using Excel spreadsheets and inputting the required data from the site being evaluated. Three different models were used to determine the total cost and revenue of a hypothetical cut block from the Ottawa Valley. These models were the road spacing costing model, equipment costing model, and a products revenue calculator developed by a fellow undergrad student Alex Emond.

OPTIMAL ROAD SPACING

The road spacing model, Table 1, was used to demonstrate how the length of skid ways largely effects the over all cost of a cut block. Many different inputs also have a large effect of how the costing model reacts to these increased forwarding distances. There were three main input focused on during this model. These inputs were; volume removed which effects the amount of merchantable timber per hectare, average load size effecting productivity over large skid distances, and road spacing which directly effects the maximum forwarding distance.

Optimum road spacing probably has the largest impact on the forwarding cost in a harvest area. This value is developed from an equation which uses inputted data from the current harvest block. Figure 2 below shows how the optimal road spacing effects the maximum forwarding distance. The optimal road spacing is represented by “S” if this spacing was divided in two it provides the maximum forwarding distance “S2” if the S2 distance is again divided by two the average forwarding distance is provided “S4”.

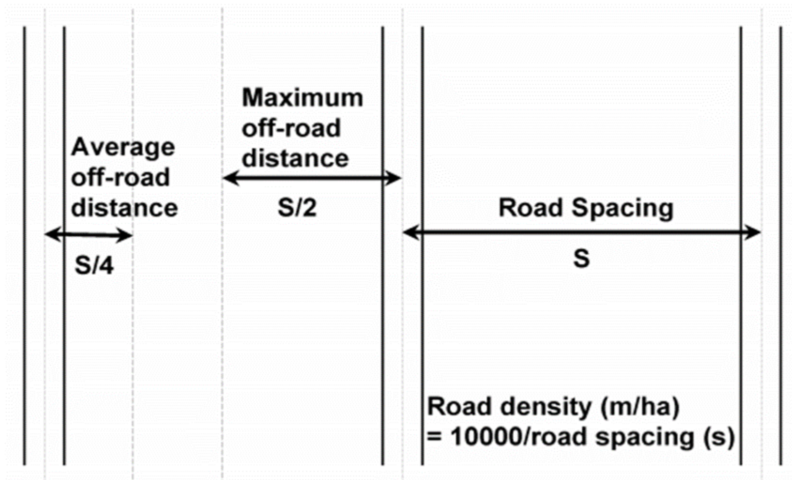


Figure 2 Optimal Road Spacing Diagram

Table 1 Optimal Road Spacing Model

Road Spacing Cost Per m^3					
		Factory Optimal Spacing	Modified Optimal Scaping	Factory Maximum Requested Dist.	Modified Maximum Requested Dist.
Road Coinstruction Cost ($/km)	Rc=	10000	10000	10000	10000
Volume Removed (m^3/ha)	V=	198	198	198	66
Off-Road Transport Machien Cost ($/min)	Mc=	1.85	1.85	1.85	1.85
Loaded Off-Road Driving Speed (m/min)	Dl=	66.667	66.667	66.667	66.667
Empty Off-Road Driving Speed (m/min)	De=	100	100	100	100
Average Load (m^3)	L=	22.4	41.3	22.4	41.3
Fixed Off-Road Transport Time (min)	Tf=	=J20	=K20	=L20	=M20
Terrain Factor	p=	1.1	1.1	1.1	1.1
Road Spacing	S=	=((40*J6*J11*J10*J9)/(J8*J7*J13*(J10+J9)))^0.5	=((40*K6*K11*K10*K9)/(K8*K7*K13*(K10+K9)))^0.5	3000	2000
Max. Skid Distance (m)		=J14/2	=K14/2	=L14/2	=M14/2
Forwarder cycle time (min)	Variable time, min	=(J14*J13)/(4*J10)+(J14*J13)/(4*J9)	=(K14*K13)/(4*K10)+(K14*K13)/(4*K9)	=(L14*L13)/(4*L10)+(L14*L13)/(4*L9)	=(M14*M13)/(4*M10)+(M14*M13)/(4*M9)
	Fixed time, min	=J21-J19	=K21-K19	=L21-L19	=M21-M19
	Total time, min	=J19/(B7/100)	=K19/(C7/100)	=L19/(D7/100)	=M19/(E7/100)
Veriable Cost (m^3)	Cv=	=J8*(J14/(4*J10)+J14/(4*J9))*J13/J11	=K8*(K14/(4*K10)+K14/(4*K9))*K13/K11	=L8*(L14/(4*L10)+L14/(4*L9))*L13/L11	=M8*(M14/(4*M10)+M14/(4*M9))*M13/M11
Fixed Cost (m^3)	Cf=	=J8*J12/J11	=K8*K12/K11	=L8*L12/L11	=M8*M12/M11
Road Cost (m^3)	Cr=	=10*J6/(J7*J14)	=10*K6/(K7*K14)	=10*L6/(L7*L14)	=10*M6/(M7*M14)
Total Cost (m^3)	Ct=	=J24+J25+J26	=K24+K25+K26	=L24+L25+L26	=M24+M25+M26
Harvest Block Cost Comparison ($)	Total Cost Over Block	=(198*144)*J27	=(198*144)*K27	=(198*144)*L27	=(198*144)*M27
	Cost Difference Factory Vs. Modified	=J28-K28		=L28-M28	
	Cost Difference Optimal Vs. Requested Max	Factory		Modified	
		=L28-J28		=M28-K28	

EQUIPMENT COSTING MODEL

The equipment costing model, Table 2, investigated how cost per cubic metre were affected multiple fixed and variable cost and equipment scheduling. Three major factors also were observed through this model to see how they affected the cost per m^3. These factors were; cubic metres produced per scheduled machine hour (SMH), number of SMH worked per day, and number of working days per year. To determine how these factors effected the cost per cubic metre multiple equations were used to determine different variables. These variables were then used to further add to the cost until calculating a final cost per cubic metre, Table 2.

Table 2 Equipment Costing Model

Equipment	Single Grip Harvester	Forwarder	Log Truck	Crew vehicle
Number of working days/year	242	242	242	242
Number of SMH/day	10	10	12	3
Machine Utilization	0.95	0.95	0.95	0.95
Annual Production Estimate,m^3 /a	=D4*D5*D49	=E4*E5*E49	=(F4*F5*F49)*F22	30976
Installed or Purchase price, $ (P)	695000	495000	300000	70000
Future Salvage Value, % (FSV)	10	12	12	12
Future Salvage Value, $ (FSV)	=D8*0.1	=E8*0.12	=F8*0.12	=G8*0.12
Expected Economic Life-Years(EL)	4	4	5	8
Interest rate %	5	5	5	4
Fuel consumption, L/PMH	25	15	60	12
Fuel cost, $/L	1.1	1.1	1.1	1.1
Engine oil consumption, (L/PMH)	0.1	0.1	=0.1*F22	=0.1*G22
Oil cost, $/L	4.32	4.32	4.32	4.32
Hydraulic oils and/or lube L/PMH	1.8	0.2	=0.2*F22	0
Hydrualic oils and/or lube cost $/L	2.84	2.84	2.84	2.84
Annual repair and maintenance cost, % of initial purchase price	5	5	5	5
Operator wage, $/SMH	25	20	20	0
Fringe benefits cost, % of wage	30	30	30	0
Number of operators required/shift	1	1	1	1
Insurance/risk cost, % of purchase price	3.1	2.4	0	2.4
Licence cost, $/a	0	0	=14000*F22	2900
SYSTEM COST SUMMARY				
Inerest rate, decimal	=D12/100	=E12/100	=F12/100	=G12/100
Present value of salvage vaue, $	=(D10/((1+D27)^D11))	=(E10/((1+E27)^E11))	=(F10/((1+F27)^F11))	=(G10/((1+G27)^G11))
Scheduled hours per year, SMH/a	=D4*D5	=E4*E5	=F4*F5	=G4*G5
Productive hours per year, PMH /a	=D29*D6	=E29*E6	=F29*F6	=G29*G6
FIXED COSTS				
Annual capital cost, $/a	=(D8-D28)*((D27*((1+D27)^D11))/(((1+D27)^D	=(E8-E28)*((E27*((1+E27)^E11))/(((1+E27)^E	=(F8-F28)*((F27*((1+F27)^F11))/(((1+F27)^F11)-1))+(F28*F27)	=(G8-G28)*((G27*((1+G27)^G11))/(((1
Capital Cost, $/SMH	=D33/D29	=E33/E29	=F33/F29	=G33/G29
License and insurance cost, $/a	=((D8*D23)+D24)/100	=((E8*E23)+E24)/100	=((F8*F23)/100)+F24	=((G8*G23)/100)+G24
VARIABLE COSTS				
Energy, oil and lube cost, $/PMH	=(D13*D14)+(D15*D16)+(D17*D18)	=(E13*E14)+(E15*E16)+(E17*E18)	=(F13*F14)+(F15*F16)+(F17*F18)	=(G13*G14)+(G15*G16)+(G17*G18)
Repair and maintenance cost, $/a	=(D8*D19)/100	=(E8*E19)/100	=(F8*F19)/100	=(G8*G19)/100
LABOUR COSTS				
Operator Cost, $/SMH	=(((D20*D21)/100)+D20)*D22	=(((E20*E21)/100)+E20)*E22	=(((F20*F21)/100)+F20)*F22	=(((G20*G21)/100)+G20)*G22
TOTAL COST				
Annual operating cost, $/a	=D33+(D38*D30)+(D42*D29)+D35+D39	=E33+(E38*E30)+(E42*E29)+E35+E39	=F33+(F38*F30)+(F42*F29)+F35+F39	=G33+(G38*G30)+(G42*G29)+G35+G3
Hourly operating cost, $/SMH	=D45/D29	=E45/E29	=F45/F29	=G45/G29
PRODUCTION				
m3 produced per SMH, m^3/SMH	12.8	22.4	7.5	0
m3 produced per PMH, m3/PMH	=D7/D30	=E7/E30	=F7/F30	0
Cost per m^3, $/$m^3$	**=D45/D7**	**=E45/E7**	**=F45/F7**	**=G45/G7**
TOTAL COST PER M^3				**=SUM(D51:G51)**

PRODUCT REVENUE CALCULATOR

The product revenue calculator, Table 3, developed by Alex Emond was used to calculate the potential revenue of the site by each available species. This was completed by gathering the current prices of produce from the local mills in the area. All prices were offered in gross metric tons, therefore a weight calculation from cubic metre of each species by their density was needed to obtain the species metric weight in metric tons. Having the price from each mill and the weight in metric tons of each species a calculation for the gross revenue of each species by load or harvest block was determine. This combined with the costing models in tables 1 and 2 could determine the estimated profit of the cut area.

Table 3 Product Pricing Calculator

Gross Revenue Calculator					
	Mill:	Hokum (Killaloe)			
	Species	Volume (m3)	GMT	Price/GMT	Revenue
Species 1	Pw	36	44.96	49.55	2227.78
Species 2			0	0	0.00
Species 3			0	0	0.00
Species 4			0	0	0.00
Species 5			0	0	0.00
Species 6			0	0	0.00
Totals		36	44.964		$ 2,227.78

RESULTS

OPTIMAL ROAD SPACING MODEL

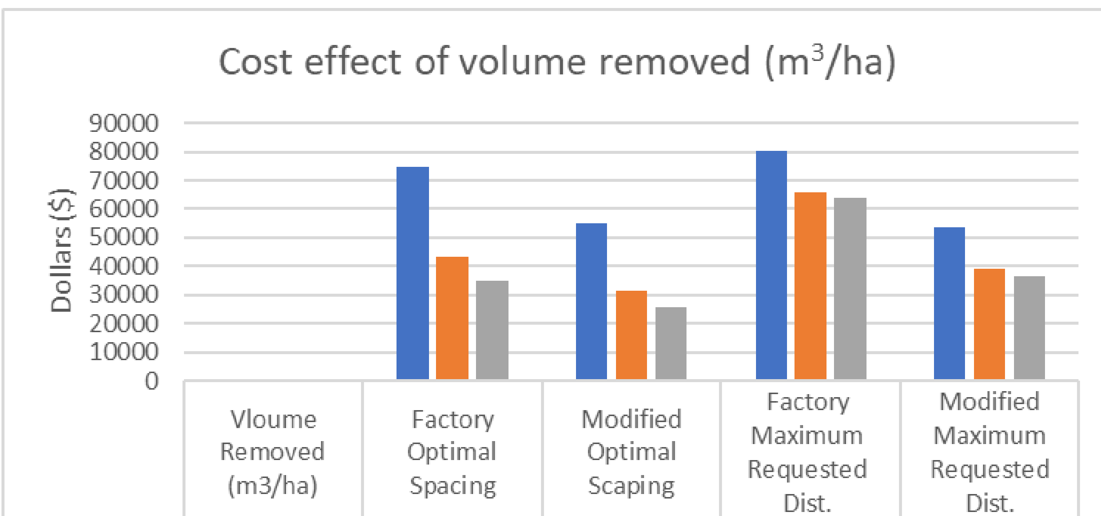
As stated in the materials and methods, the optimal road spacing model is important because it displays how extended forwarding trails effects the overall cost of a cut-to-length operation. In this model there are three main inputs that largely effect the end cost, Table 4, volume removed per hectare, average load size, and road spacing.

Table 4 Inputs Effecting End Costs of the Optimal Road Spacing Model

Road Spacing Cost Per m^3					
		Factory Optimal Spacing	Modified Optimal Scaping	Factory Maximum Requested Dist.	Modified Maximum Requested Dist.
Road Coinstruction Cost ($/km)	Rc=	10000	10000	10000	10000
Volume Removed (m^3/ha)	V=	198	198	198	198
Off-Road Transport Machien Cost ($/min)	Mc=	1.85	1.85	1.85	1.85
Loaded Off-Road Driving Speed (m/min)	Dl=	66.67	66.67	66.67	66.67
Empty Off-Road Driving Speed (m/min)	De=	100	100	100	100
Average Load (m^3)	L=	22.4	41.3	22.4	41.3
Fixed Off-Road Transport Time (min)	Tf=	5.31	7.20	16.87	11.25
Terrain Factor	p=	1.1	1.1	1.1	1.1
Road Spacing	S=	943	1281	3000	2000
Max. Skid Distance (m)		471.6	640.3	1500.0	1000.0
Forwarder cycle time (min)	Variable time, min	6.48	8.80	20.62	13.75
	Fixed time, min	5.31	7.20	16.87	11.25
	Total time, min	11.79	16.01	37.50	25.00
Veriable Cost (m^3)	Cv=	0.54	0.39	1.70	0.62
Fixed Cost (m^3)	Cf=	0.44	0.32	1.39	0.50
Road Cost (m^3)	Cr=	0.54	0.39	0.17	0.25
Total Cost (m^3)	Ct=	1.51	1.11	3.27	1.37
Harvest Block Cost Comparison ($)	Total Cost Over Block	$ 43,029.04	$ 31,689.15	$ 93,104.20	$ 39,129.20
	Cost Difference Factory Vs. Modified	$ 11,339.89		$ 53,975.00	
	Cost Difference Optimal Vs. Requested Max	Factory		Modified	
		$ 50,075.16		$ 7,440.05	

<u>Volume Removed per Hectare</u>

The volume removed per hectare is an inputted value in the optimal road costing model. This means that this value is dependent on the harvest block being harvested and will change between each harvest block. As seen in Table 4 the volume removed was set at 198 m^3/ha. However, this value would be used more appropriately in a clear cutting application and being that in the Algonquin park and Ottawa Valley this is not a common practice a new value needed to be added. A selection cutting method remove one third of the basal area in a cut block and therefore 66 m^3/ha would be a more common value in this study area. Figure 3 shows how the change in volume removed per hectare effects the cost of forwarding over the harvest area.



	Vloume Removed (m3/ha)	Factory Optimal Spacing	Modified Optimal Scaping	Factory Maximum Requested Dist.	Modified Maximum Requested Dist.
Series1	66	$74,528.48	$54,887.22	$80,469.47	$53,529.20
Series2	198	$43,029.04	$31,689.15	$66,069.47	$39,129.20
Series3	300	$34,956.96	$25,744.39	$63,621.47	$36,681.20

Figure 3 Effects of volume Removed per Hectare Over the Harvest Area

As clearly shown above the cost increases substantially when the volume removed value changes from 198 m^3/ha to 66 m^3/ha. This Figure also shows that if the volume per hectare was to increase to 300 m^3/ha the cost would decrease substantially.

Load Size and the Effect it has on Optimal Road Spacing

Load size is another inputted data which changes depending on the size of forwarder being used and any modifications they might have, Table 5. As shown below, each size of forwarder carries a different volume then the other. The difference one may notice looking at the model numbers is the 1410D machine compared to all the other G models this is just the difference in years and the 1410 model no longer exists in a new machine. The maximum cubic metre by exact dimension would be the cubic metres the equipment could carry if they were essentially hauling a liquid with no spaces of air. However, these are not realistic numbers when comparing number to the “real world”. To adjust the number to a more correct volume the maximum load rating was divided by the volume per cubic metre of the average eastern white pine. This calculation allowed for more accurate numbers when dealing with production and the amount of cubic metres the equipment can move per hour.

Table 5 List of Common Sized Forwarders

Common Forwarder Load Sizes			
John Deere equipment models	Max. cubic meters by exact dimensions	Estimated actual max. cubic meters using white pine ($1249 kg/m^3$)	Max. load rating (kg)
1110G	19.2	9.6	12000
1210G	20.8	10.4	13000
1410D	22.4	11.2	14000
1510G	24	12.0	15000
1910G	30.4	15.2	19000
Modified 1410D	40.75	20.4	25470

Load size compare to the maximum forwarding distance is expressed in Figure 4 below. The max forwarding distance chart assumes the conditions are relatively perfect and exactly the same for all load sizes. This chart again uses cubic metre that would be seen if the dimensions of the equipment were hauling a liquid. For every $1m^3$ of wood more a forwarder can haul the machine can productively travel another 26.8 metres in distance. The reason this chart is important is because as shown above in Table 5 the largest size forwarder holds only 30.4 m^3 by it dimensions and this would only allow the 1910G a max skid distance of 800 metres to stay productive. This does not satisfy the AFA's desire to have these over 1000 metre skidways while satisfy production demands.

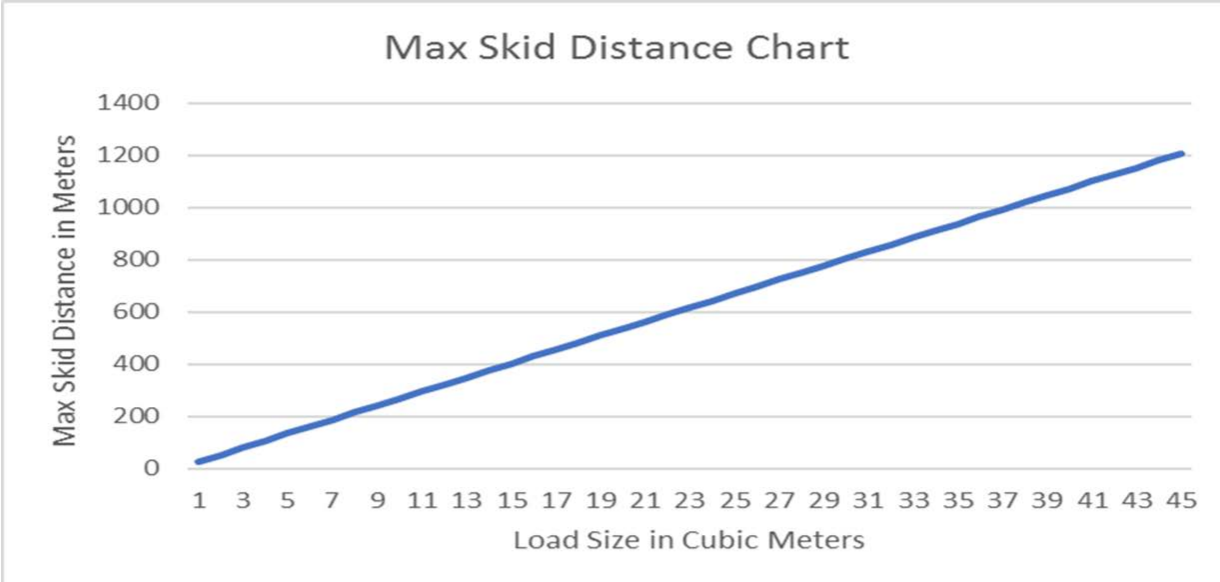


Figure 4 Maximum Forwarding Distance Chart

Proving that the largest factory sized bunks are unable to achieve the 1000 metre forwarding distance productively it is clearly seen a bunk modification is required. Figure 5, 6, and Table 6 below show the difference in a factory 1410D forwarder and a modified 1410D forwarder and the load size difference between the two. The log stakes in Figure 4 on the factory forwarder appear just slightly taller then the bulk head on the machines log bunk. Figure 5 shows a picture of A.J. Nagora Logging Ltd.'s 1410D forwarder, although the picture is of poor quality the yellow log stake extensions are clearly seen which extend 3 feet higher then the bulk head. This modification to the bunks is a simple way to allow contractors to gain more volume per load. As shown in Table 5, the volume is almost doubled in size. Comparing maximum forwarding distances before and after the modification is where the largest impact occurs. Prior to the modification a factory 1410D had a max skid distance of only 600 metres however after the forwarder could productively work on a max skid distance of almost 1100 metre satisfying the AFA's 1000m skid way threshold.

Figure 5 Factory 1410D Forwarder

Figure 6 A.J. Nagora Logging's Modified 1410D Forwarder

Table 6 Factory Forwarder Bunk Size Compared to Modified Bunk Size

Common Forwarder Load Sizes				
John Deere equipment models	Max. cubic meters by exact dimensions	Estimated actual max. cubic meters using white pine (1249kg/m3)	Max. load rating (kg)	Max skid distance (m)
1410D	22.4	11.2	14000	600.32
Modified 1410D	40.75	20.4	25470	1092.1

Table 7 below shows the effect load size has on the cost of an entire harvest block. Using the optimal road spacing the factory 1410D has a forwarding cost of $43,029.04 for the entire block. Using that same road spacing with the 1410D modified bunk size the cost over $10,000 less costing $31,689.15. The large cost difference is note when the factory 1410D forwarder is pushed beyond its productive limit to the 1000 metre requested forwarding distance. Here the cost increases to $66,069.47 a cost difference of over $20,000 increasing the overall forwarding cost by over a third. However, the increase in price is not as large with the modified bunk size. The cost increase for this bunk size is less than $10,000 when pushed to the 1000 metre requested distance. The reason the cost difference is not as large is because at 1000 metre the modified bunk size is still within is productive working limits whereas the factory bunk size has become very unproductive at this distance due to extend travel time.

Table 7 Load Size Cost Difference Over the Entire Block

Total Cost for Entire Block			
Factory 1410D (22.4m^3) Optimal Spacing	Modified 1410D (40.75 m^3) Optimal Scaping	Factory 1410D (22.4 m^3) Maximum 1000m Requested Dist.	Modified 1410D (40.75m^3) Maximum 1000m Requested Dist.
$ 43,029.04	$ 31,689.15	$ 66,069.47	$ 39,129.20

Optimum Road Spacings Effects on Forwarding Costs

The equation used to determine the optimal road spacing is best described in Table 8. The table shows the equation used in Excel and the inputted data required to solve for it.

Table 8 Optimum Road Spacing Equation

Optimum road spacing = S =(40*Rc*L*De*Dl)/(Mc*V*p*(De+Dl))^0.5

Inputted Data:

Inputted Data	Symbology
Road Coinstruction Cost ($/km)	Rc
Volume Removed (m^3/ha)	V
Off-Road Transport Machien Cost ($/min)	Mc
Loaded Off-Road Driving Speed (m/min)	Dl
Empty Off-Road Driving Speed (m/min)	De
Average Load (m^3)	L
Fixed Off-Road Transport Time (min)	Tf
Terrain Factor	p
Road Spacing	S

Figure 7 and Table 9 show the effect road spacing has on the total cost of an operation using a factory 1410D forwarder. The cost for the 1410D forwarder to operate at a road spacing of 500 metres is $43,517.37 and only increase by just over $300 to forward a distance of 1000 metres. However, as both the Figure and the table show there is a large increase in cost once the road spacing reaches 1500 metres. This cost increase continues in a linear action increasing by over $13,000 for each 500-metre increase in road spacing.

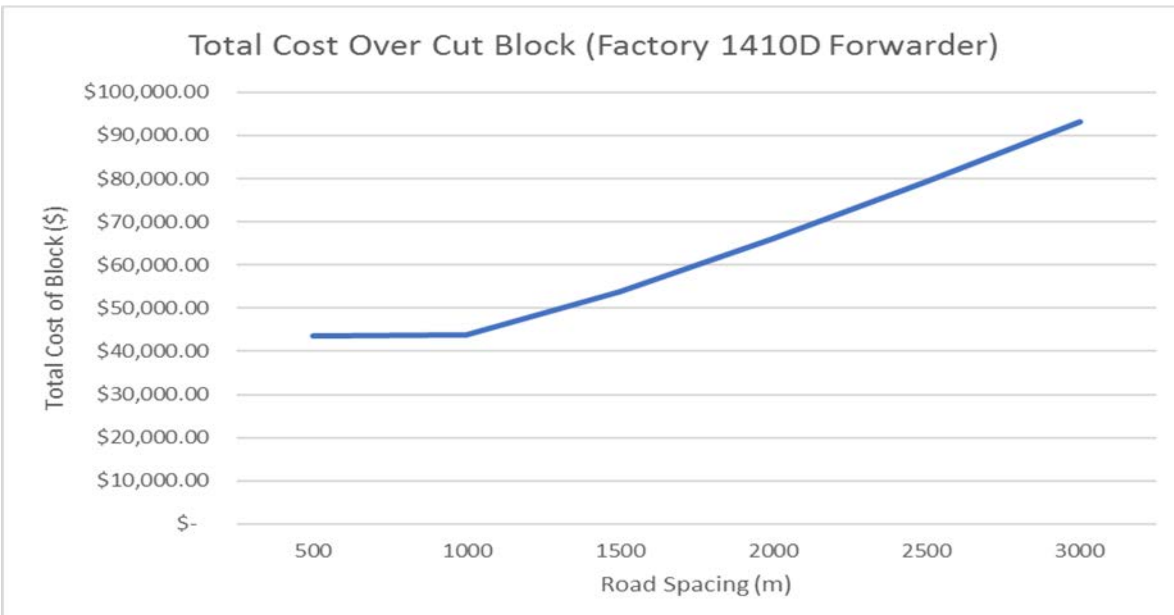


Figure 7 Road Spacings Effect on Cost over the Harvest Block

Table 9 Cost Effect of Road Spacing on 1410D Forwarder

Road Spacing (m)	Maximum Skidding Distance (m)	Total Cost Over Cut Block ($) (Factory 1410D Forwarder)
500	250	43517.37
1000	500	43834.73
1500	750	53752.10
2000	1000	66069.47
2500	1250	79346.83
3000	1500	93104.20

EQUIPMENT COSTING MODEL

The equipment costing model is used to determine the cost of the equipment per cubic metre of wood. This is completed by inputting current variable and fixed cost and calibrating them to equipment productivity. This is important in determining if the equipment being used on the harvest area will be a feasible option given the equipment’s expenses. The model is also useful for determining the areas of the system that could be better utilized to increase the production whether it be mechanical or operator error. Table 10 is the accurate equipment costing model for this hypothetical harvest area using production and costing value from A.J. Nagora Logging Ltd.

Table 10 A.J. Nagora Logging Equipment Costing Model

Equipment	Single Grip Harvester	Forwarder	Log Truck	Crew vehicle
Number of working days/year	242	242	242	242
Number of SMH/day	10	10	12	3
Machine Utilization	0.95	0.95	0.95	0.95
Annual Production Estimate,m^3 /a	30976	54208	21780	30976
Installed or Purchase price, $ (P)	695000	495000	300000	70000
Future Salvage Value, % (FSV)	10	12	12	12
Future Salvage Value, $ (FSV)	69500	59400	36000	8400
Expected Economic Life-Years(EL)	4	4	5	8
Interest rate %	5	5	5	4
Fuel consumption, L/PMH	25	15	60	12
Fuel cost, $/L	1.1	1.1	1.1	1.1
Engine oil consumption, (L/PMH)	0.1	0.1	0.1	0.1
Oil cost, $/L	4.32	4.32	4.32	4.32
Hydraulic oils and/or lube L/PMH	1.8	0.2	0.2	0
Hydraulic oils and/or lube cost $/L	2.84	2.84	2.84	2.84
Annual repair and maintenance cost, % of initial purchase price	5	5	5	5
Operator wage, $/SMH	25	20	20	0
Fringe benefits cost, % of wage	30	30	30	0
Number of operators required/shift	1	1	1	1
Insurance/risk cost, % of purchase price	3.1	2.4	0	2.4
Licence cost, $/a	0	0	14000	2900
SYSTEM COST SUMMARY				
Inerest rate, decimal	0.05	0.05	0.05	0.04
Present value of salvage vaue, $	57177.82	48868.53	28206.94	6137.80
Scheduled hours per year, SMH/a	2420	2420	2904	726
Productive hours per year, PMH /a	2299	2299	2758.8	689.7
FIXED COSTS				
Annual capital cost, $/a	182732.29	128257.78	64187.69	9730.83
Capital Cost, $/SMH	75.51	53.00	22.10	13.40
License and insurance cost, $/a	21545.00	11880.00	14000.00	4580.00
VARIABLE COSTS				
Energy, oil and lube cost, $/PMH	33.044	17.5	67	13.632
Repair and maintenance cost, $/a	34750	24750	15000	3500
LABOUR COSTS				
Operator Cost, $/SMH	32.5	26	26	0
TOTAL COST				
Annual operating cost, $/a	393645.45	268040.28	353531.29	27212.82
Hourly operating cost, $/SMH	162.66	110.76	121.74	37.48
PRODUCTION				
m3 produced per SMH, m^3/SMH	12.8	22.4	7.5	0
m3 produced per PMH, m3/PMH	13.47	23.58	7.89	0
Cost per m^3, $/$m^3$	**12.71**	**4.94**	**16.23**	**0.88**
TOTAL COST PER M^3				**34.76**

The scheduled machine hours (SMH) on this site were 10hrs for the harvester and the forwarder. When hauling two loads a day of logs to the local mills from these sites it would take the driver 12 SMH a day. The crew vehicle was use 1.5hrs to get to the harvest site and 1.5hrs to return home for a total of 3 SMH a day. Operators using the crew vehicle are not paid when driving and the crew vehicle does not contribute to the cubic metres in anyway so it only contributes a cost on the operation. During one SMH Nagora's harvester is capable of producing 12.8 m^3 and the forwarder can haul 22.4m^3 an hour. By dividing the two loads by 12 hours assuming the truck is hauling white pine logs the truck is averaging approximately 7.5 m^3 an hour. Given the variable and fixed costs of these pieces of equipment the cost per cubic metre was determined as seen above in Table 10 for a total equipment cost of 34.76 $\$/m^3$.

In this equipment costing model there are two factors that have a large effect on the overall cost per cubic metre. The first being the number of shifts and working hours per day. Although the variable cost will remain the same for every work schedule the fixed cost will fluctuate largely by the cubic metre. The second factor is the amount the operation can produce per hour. This is largely dependent on the size and species of trees being harvested. Small diametre trees with a higher pulp production will lower production while large diametre trees yield more logs will increase production.

Table 11 below shows the equipment cost difference if the Nagora crew was to operate using two 10hr shifts. By operating with a double shift the variable cost of operating remain the same. However, doubling the shift does not increase the yearly fixed cost but does doubles the yearly production of the equipment and therefore lowers the cost per cubic metre. Comparing Table 10 to Table 11 the total cost per cubic metre including all of the equipment is lowered by 7.21 $\$/m^3$. The only increase in cost is the crew vehicle, being that this vehicle does not contribute to the cubic metres the cost doubles by adding a second shift.

Table 11 Cost Difference for Nagora's Operation if a Second Shift was Implemented

Equipment	Single Grip Harvester	Forwarder	Log Truck	Crew vehicle
Number of working days/year	242	242	242	242
Number of SMH/day	10	10	12	3
Machine Utilization	0.95	0.95	0.95	0.95
Annual Production Estimate,m^3 /a	30976	54208	21780	30976
Installed or Purchase price, $ (P)	695000	495000	300000	70000
Future Salvage Value, % (FSV)	10	12	12	12
Future Salvage Value, $ (FSV)	69500	59400	36000	8400
Expected Economic Life-Years(EL)	4	4	5	8
Interest rate %	5	5	5	4
Fuel consumption, L/PMH	25	15	60	12
Fuel cost, $/L	1.1	1.1	1.1	1.1
Engine oil consumption, (L/PMH)	0.1	0.1	0.1	0.1
Oil cost, $/L	4.32	4.32	4.32	4.32
Hydraulic oils and/or lube L/PMH	1.8	0.2	0.2	0
Hydrualic oils and/or lube cost $/L	2.84	2.84	2.84	2.84
Annual repair and maintenance cost, % of initial purchase price	5	5	5	5
Operator wage, $/SMH	25	20	20	0
Fringe benefits cost, % of wage	30	30	30	0
Number of operators required/shift	1	1	1	1
Insurance/risk cost, % of purchase price	3.1	2.4	0	2.4
Licence cost, $/a	0	0	14000	2900
SYSTEM COST SUMMARY				
Inerest rate, decimal	0.05	0.05	0.05	0.04
Present value of salvage vaue, $	57177.82	48868.53	28206.94	6137.80
Scheduled hours per year, SMH/a	2420	2420	2904	726
Productive hours per year, PMH /a	2299	2299	2758.8	689.7
FIXED COSTS				
Annual capital cost, $/a	182732.29	128257.78	64187.69	9730.83
Capital Cost, $/SMH	75.51	53.00	22.10	13.40
License and insurance cost, $/a	21545.00	11880.00	14000.00	4580.00
VARIABLE COSTS				
Energy, oil and lube cost, $/PMH	33.044	17.5	67	13.632
Repair and maintenance cost, $/a	34750	24750	15000	3500
LABOUR COSTS				
Operator Cost, $/SMH	32.5	26	26	0
TOTAL COST				
Annual operating cost, $/a	393645.45	268040.28	353531.29	27212.82
Hourly operating cost, $/SMH	162.66	110.76	121.74	37.48
PRODUCTION				
m3 produced per SMH, m^3/SMH	12.8	22.4	7.5	0
m3 produced per PMH, m3/PMH	13.47	23.58	7.89	0
Cost per m^3, $/$m^3$	**12.71**	**4.94**	**16.23**	**0.88**
TOTAL COST PER M^3				**34.76**

Table 12 below increases the production numbers by $6m^3$ for the harvester and forwarder as the hauling and crew vehicle will remain the same. This represents the equipment working in a very productive site and showing how the cost is effected given the higher production numbers. As shown in Table 12 the cost of the equipment has lowered by 4.01 $\$/m^3$ compare to the original value 34.76 \$/m3 in Table 10.

Table 12 Equipment Cost Difference with Higher Production Numbers

Equipment	Single Grip Harvester	Forwarder	Log Truck	Crew vehicle
Number of working days/year	242	242	242	242
Number of SMH/day	10	10	12	3
Machine Utilization	0.95	0.95	0.95	0.95
Annual Production Estimate,m^3 /a	30976	54208	21780	30976
Installed or Purchase price, $ (P)	695000	495000	300000	70000
Future Salvage Value, % (FSV)	10	12	12	12
Future Salvage Value, $ (FSV)	69500	59400	36000	8400
Expected Economic Life-Years(EL)	4	4	5	8
Interest rate %	5	5	5	4
Fuel consumption, L/PMH	25	15	60	12
Fuel cost, $/L	1.1	1.1	1.1	1.1
Engine oil consumption, (L/PMH)	0.1	0.1	0.1	0.1
Oil cost, $/L	4.32	4.32	4.32	4.32
Hydraulic oils and/or lube L/PMH	1.8	0.2	0.2	0
Hydraulic oils and/or lube cost $/L	2.84	2.84	2.84	2.84
Annual repair and maintenance cost, % of initial purchase price	5	5	5	5
Operator wage, $/SMH	25	20	20	0
Fringe benefits cost, % of wage	30	30	30	0
Number of operators required/shift	1	1	1	1
Insurance/risk cost, % of purchase price	3.1	2.4	0	2.4
Licence cost, $/a	0	0	14000	2900
SYSTEM COST SUMMARY				
Inerest rate, decimal	0.05	0.05	0.05	0.04
Present value of salvage vaue, $	57177.82	48868.53	28206.94	6137.80
Scheduled hours per year, SMH/a	2420	2420	2904	726
Productive hours per year, PMH /a	2299	2299	2758.8	689.7
FIXED COSTS				
Annual capital cost, $/a	182732.29	128257.78	64187.69	9730.83
Capital Cost, $/SMH	75.51	53.00	22.10	13.40
License and insurance cost, $/a	21545.00	11880.00	14000.00	4580.00
VARIABLE COSTS				
Energy, oil and lube cost, $/PMH	33.044	17.5	67	13.632
Repair and maintenance cost, $/a	34750	24750	15000	3500
LABOUR COSTS				
Operator Cost, $/SMH	32.5	26	26	0
TOTAL COST				
Annual operating cost, $/a	393645.45	268040.28	353531.29	27212.82
Hourly operating cost, $/SMH	162.66	110.76	121.74	37.48
PRODUCTION				
m3 produced per SMH, m^3/SMH	12.8	22.4	7.5	0
m3 produced per PMH, m3/PMH	13.47	23.58	7.89	0
Cost per m^3, $/$m^3$	**12.71**	**4.94**	**16.23**	**0.88**
TOTAL COST PER M^3				**34.76**

Revenue Calculation

The product revenue calculator designed by fellow undergraduate student Alex Emond was used to compare cost of the operation to potential gross revenue to determine whether these operations can be feasible. The gross revenue calculator calculations can be seen in Appendix 4. Nagora's hypothetical site was a 21-hectare selection cut with 66 m^3 removed per hectare. Table 13 below displays the profits of the operation given the harvest areas species composition and an equipment cost of 34.76 $/$m^3$.

Table 13 A.J. Nagora Logging Ltd. Potential Profits

Nagora's Hypothetical Current Harvest Site				
Species	Species Comp.	Total m^3	logs m^3	pulp m^3
Sw	30%	415.8	207.9	207.9
By	20%	277.2	27.72	249.48
Ms	20%	277.2		277.2
Bf	10%	138.6		138.6
BW	10%	138.6	13.86	124.74
Pw	10%	138.6	110.88	27.72
ConMix				374.22
hectares		21		
Volume removed (m^3/ha)		66		
total volume removed		1386		
Total Volume of Logs		360.36		
Total Volume of Pulp		1025.64		
Cost for Logs		$ 12,527.26		
Cost for Pulp		$ 35,654.51		
Total costs		$ 48,181.76		
Gross Revenue Logs (Hokum's)		$ 14,648.25		
Gross Revenue Pulp (Jovalco)		$ 26,914.71		
Total Gross Revenue		$ 41,562.96		
Total profit		-$ 6,618.80		

Given the species composition of the site and the cost of the equipment to harvest this site A.J. Nagora Logging Ltd. would lose $6,618.80. This cost is if Nagora

Logging hauled all of its own wood and delivered their logs to Hokum's sawmill in Killaloe and delivered their pulp to Jovalco Pulp mill in Litchfield Quebec.

DISCUSSION

UNDERSTANDING THE IMPORTANCE OF MANAGEMENT

Owning a cut-to-length harvesting system is a demanding management roll all on its own. The equipment used in the system require highly trained and competent operators whom are not easily found in the current industry of these forests. Managing these crews requires enhanced planning to ensure all areas of the system remain productive and satisfied. As shown above through all the models there are numerous factors which can make or break a harvesting operation; for example, if the Nagora operation was to work a double shift lowering the cost per cubic metre the revenue calculator would have shown a profit on the operation instead of a $6000 loss. The full understanding of these factors is necessary for success on each individual harvest block as no block is ever the same.

As stated by Potts and McKay the management and planning of income, people, resources, and expenses are all key in developing a successful business. The models depicted above are great tools in the process of planning and management because they will allow a business owner to understand their income on every harvest block and faults in their system slowing production. This allows owners to refuse or accept harvests blocks depending on the estimated profits before moving a single piece of equipment to the job site. Through figuring out faults in the system owners can strategically target areas to improve to and regain maximum production. To remain effective these models should be updated regularly to match the current harvest area and the current operating expenses.

The understanding of expenses such as fuel, oil, and even insurance and how they can change year to year and more importantly day to day is very important in managing these models. If these factors are not updated prior to bidding on or accepting harvest areas, weeks or even months of work could all be performed at a cost to the operation.

ALGONQUIN PARK FORESTS SKIDWAYS

With the location of the park being only 250 km north of Toronto the pressure from environmental groups and other social groups is inevitable and a struggle every day for the AFA. Due to satisfying these environmental groups large areas of unharvested land has been left behind due to over lapping buffered areas. These areas now needing to be harvested are requiring over 1000-metre skidways to access these blocks.

The problem occurring in these areas is many also have a low cubic metre per hectare or the trees in the stand are so large production is slowed to process them with cut-to-length equipment. Also, the cost to forward these requested distances to harvest these areas is to large for the average forwarder most companies have. Table 7, provides the cost of a factory bunks size to a modified bunk when attempting to skid these distances and this shows almost a $30,000 cost increase for the factory bunk sized equipment. Although these stands are without a doubt in need of harvesting, they run a fine line between keeping social groups satisfied and keeping logging contractors in business.

OPTIMAL ROAD SPACING

Volume Removed per Hectare

As seen in Figure 3, there are large cost differences when the volume removed per hectare in increase or decrease. The reason for the change in cost is the effect volume removed has on the forwarders production ability. When the volume removed value lowered to 66 m3/ha the wood became sparse for the forwarder and the forwarder needed to work more area to reach the same load size. This requires more time to load the forwarder which lowers the production and increases cost per cubic metre for the wood. The opposite occurs if the volume removed per hectare was to increase to 300 m^3, this would increase the productivity as the forwarder would have more wood in less area increasing load times which provides a large increase in productivity and decrease in costs.

Load Size and Optimal Road Spacing

Load size has a large impact on forwarding cost especially over large forwarding distances. The reason for the results in table 7 where the factory load size has an almost $30,000 increase in cost is due to the productivity of the forwarder at that distance. Compared to the modified 1410D forwarder the factory bunk needs to make more trips to haul the same volume. The large increase in cost is due to travel time, with the factory size bunk needing to make more trips productivity is lost in the amount of time it takes the forwarder to travel between the landing area and the harvest block.

The same applies in the optimal road spacing scenario. With larger forwarding distances production decreases and thus cost increases. If there were more roads and landings cycle times would be shorter due to less travel time and therefore production would increase. This same trend would also be seen across all forwarder sizes because the cost in this case is impacted by travel time due to distance and not load size.

EQUIPMENT COSTING MODEL

Looking at Table 12, equipment cost is largely dependent on the equipment's productivity. Production in a harvest block is largely dependent on the size class and species of wood being harvested. Small diametre wood can be processed quickly but does not amount to a lot of cubic metres per hour. Oversized white pine and hardwoods are known in the study region for their high cubic metre values per stem. However, these larger trees are heavy and are slow to process as the equipment struggles with their immense size thus the production numbers per hour continue to remain low. When in a harvest block where the trees average a diametre class of 30-60 centimetres the production numbers can increase substantially. This is because the size of tree can be processed quickly without requiring a large amount of labor from the equipment.

NAGORA'S HARVESTING MODEL

As stated earlier the cut from Nagora Logging was a hypothetical example of a realistic cut block one might find in this area. The costing model in table 10 show the cost per cubic metre to harvest this site to be 34.76 $\$/m^3$. With this cost it is very clear that the model of Nagora's harvesting block in table 13 would not be a successful cut and the company would surly lose money. This is due to the high cost of hauling the wood to the mills and the low profit from pulp products.

Given the location of this cut block the shortest hauling distance would be 166 kilometres to the Holkums Sawmill located in Killaloe Ontario. For a log truck to perform this round trip including loading and unloading times it would take 6hrs allowing only two trips a day to be delivered into this mill. Seen in the equipment costing model in table 10, the relatively low cubic metres and hour during hauling of the wood raises the dollar cost of cubic metre of wood to 16.23 $\$/m^3$ accounting for almost half of the cost. However, as seen in Nagora's model if the company was to only haul its own logs the company would still turn a profit on that site.

The company loses money when it hauls its own pulp to the mill Jovalco in Litchfield Quebec. In addition to hauling to Quebec an additional license that was not included in the costs would need to be added, further increasing the cost of hauling pulp. With the combined cost of hauling and the low revenue from products the cost of hauling pulp would ultimately bankrupt a company on this site.

CONCLUSION

The cost involved in using these cut-to-length operations depends on the area being harvested. If the same models were run on a more productive site with shorter skid ways and hauling distances the profitability of the system would greatly improve. However, understanding what can cause the profitability of a harvest is an important learning process when choosing to develop a business.

The models have proven that cut-to-length operations in certain blocks with long forwarding distances and low cubic metres a hectare are very costly in the Algonquin Park Forest.

If the AFA wishes to hire cut-to-length operations on these sites to increase forest quality, they must consider the costs to the contractors involved. To continue to increase forwarding distances capable of reaching these areas the AFA needs to consider compensating the contractor's expenses for sub optimal road density. The tools developed in this thesis can be useful to model cut-to-length feasibility with variable road density and inform forest managers and contractors on the additional costs incurred through long-forwarding.

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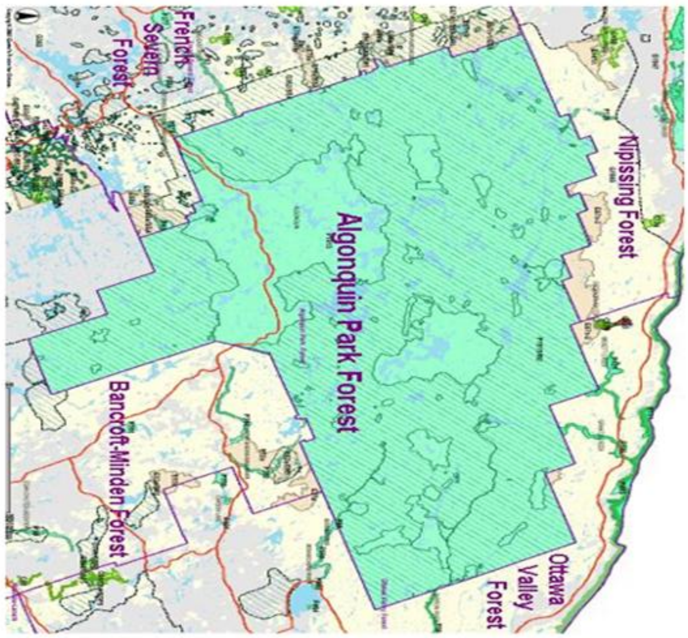
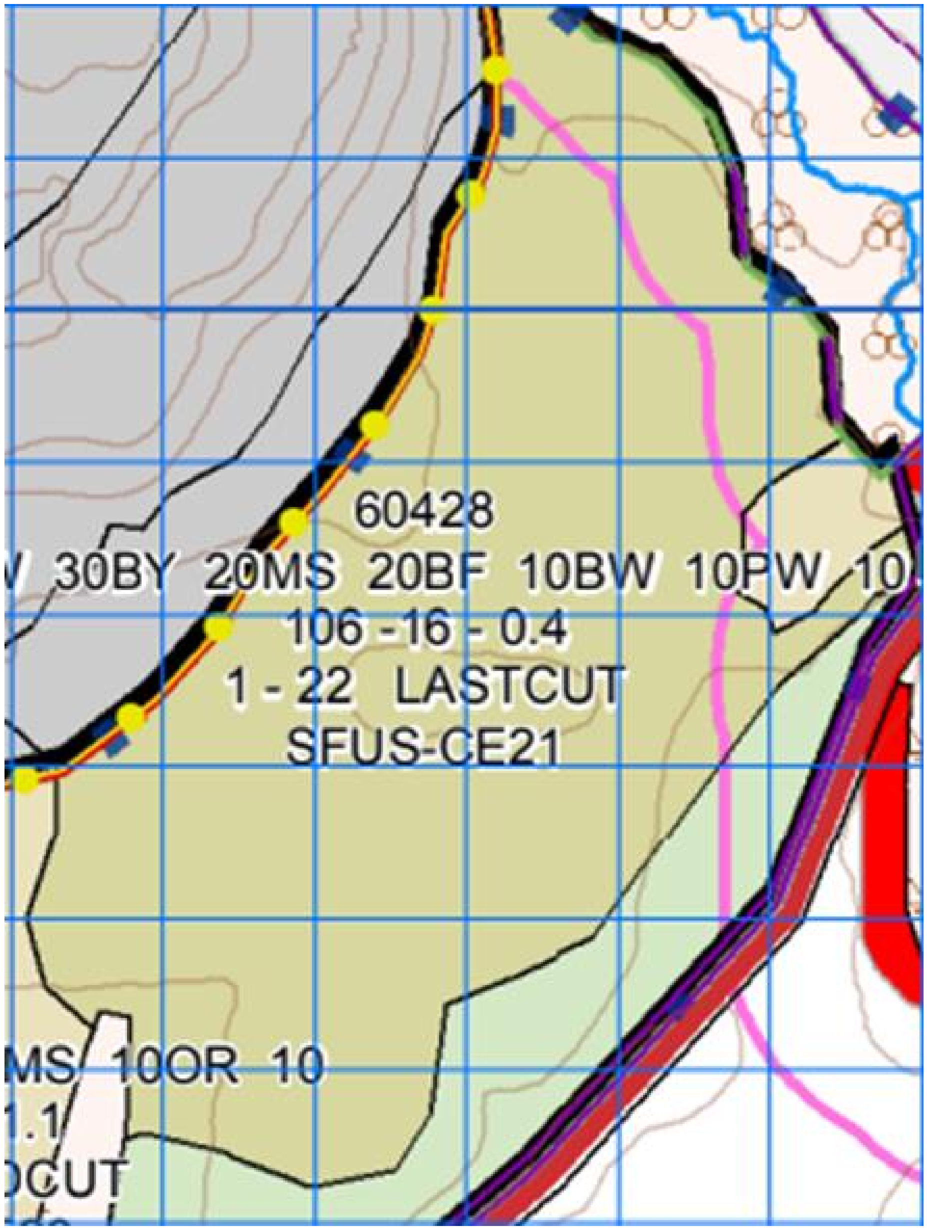
APPENDIX 1

AREA OF STUDY




60428
30BY 20MS 20BF 10BW 10PW
106 - 16 - 0.4
1 - 22 LASTCUT
SFUS-CE21
MS 10OR 10

APPENDIX 2

OPTIMAL ROAD SPACING MODEL CALCULATIONS

Road Spacing Cost Per m^3					
		Factory Optimal Spacing	Modified Optimal Scaping	Factory Maximum Requested Dist.	Modified Maximum Requested Dist.
Road Coinstruction Cost ($/km)	Rc=	10000	10000	10000	10000
Volume Removed (m^3/ha)	V=	198	198	198	66
Off-Road Transport Machien Cost ($/min)	Mc=	1.85	1.85	1.85	1.85
Loaded Off-Road Driving Speed (m/min)	Dl=	66.67	66.67	66.67	66.67
Empty Off-Road Driving Speed (m/min)	De=	100	100	100	100
Average Load (m^3)	L=	22.4	41.3	22.4	41.3
Fixed Off-Road Transport Time (min)	Tf=	5.31	7.20	16.87	11.25
Terrain Factor	p=	1.1	1.1	1.1	1.1
Road Spacing	S=	943	1281	3000	2000
Max. Skid Distance (m)		471.6	640.3	1500.0	1000.0
Forwarder cycle time (min)	Variable time, min	6.48	8.80	20.62	13.75
	Fixed time, min	5.31	7.20	16.87	11.25
	Total time, min	11.79	16.01	37.50	25.00
Veriable Cost (m^3)	Cv=	0.54	0.39	1.70	0.62
Fixed Cost (m^3)	Cf=	0.44	0.32	1.39	0.50
Road Cost (m^3)	Cr=	0.54	0.39	0.17	0.76
Total Cost (m^3)	Ct=	1.51	1.11	3.27	1.88
Harvest Block Cost Comparison ($)	Total Cost Over Block	$ 43,029.04	$ 31,689.15	$ 93,104.20	$ 53,529.20
	Cost Difference Factory Vs. Modified	$ 11,339.89		$ 39,575.00	
	Cost Difference Optimal Vs. Requested Max	Factory		Modified	
		$ 50,075.16		$ 21,840.05	

Road Spacing Cost Per m³					
		Factory Optimal Spacing	Modified Optimal Scaping	Factory Maximum Requested Dist.	Modified Maximum Requested Dist.
Road Coinstruction Cost ($/km)	Rc=	10000	10000	10000	10000
Volume Removed (m^3/ha)	V=	198	198	198	66
Off-Road Transport Machien Cost ($/min)	Mc=	1.85	1.85	1.85	1.85
Loaded Off-Road Driving Speed (m/min)	Dl=	66.667	66.667	66.667	66.667
Empty Off-Road Driving Speed (m/min)	De=	100	100	100	100
Average Load (m^3)	L=	22.4	41.3	22.4	41.3
Fixed Off-Road Transport Time (min)	Tf=	=J20	=K20	=L20	=M20
Terrain Factor	p=	1.1	1.1	1.1	1.1
Road Spacing	S=	=((40*J6*J11*J10*J9)/(J8*J7*J13*(J10+J9)))^0.5	=((40*K6*K11*K10*K9)/(K8*K7*K13*(K10+K9)))^0.5	3000	2000
Max. Skid Distance (m)		=J14/2	=K14/2	=L14/2	=M14/2
Forwarder cycle time (min)	Variable time, min	=(J14*J13)/(4*J10)+(J14*J13)/(4*J9)	=(K14*K13)/(4*K10)+(K14*K13)/(4*K9)	=(L14*L13)/(4*L10)+(L14*L13)/(4*L9)	=(M14*M13)/(4*M10)+(M14*M13)/(4*M9)
	Fixed time, min	=J21-J19	=K21-K19	=L21-L19	=M21-M19
	Total time, min	=J19/(B7/100)	=K19/(C7/100)	=L19/(D7/100)	=M19/(E7/100)
Veriable Cost (m^3)	Cv=	=J8*(J14/(4*J10)+J14/(4*J9))*J13/J11	=K8*(K14/(4*K10)+K14/(4*K9))*K13/K11	=L8*(L14/(4*L10)+L14/(4*L9))*L13/L11	=M8*(M14/(4*M10)+M14/(4*M9))*M13/M11
Fixed Cost (m^3)	Cf=	=J8*J12/J11	=K8*K12/K11	=L8*L12/L11	=M8*M12/M11
Road Cost (m^3)	Cr=	=10*J6/(J7*J14)	=10*K6/(K7*K14)	=10*L6/(L7*L14)	=10*M6/(M7*M14)
Total Cost (m^3)	Ct=	=J24+J25+J26	=K24+K25+K26	=L24+L25+L26	=M24+M25+M26
Harvest Block Cost Comparison ($)	Total Cost Over Block	=(198*144)*J27	=(198*144)*K27	=(198*144)*L27	=(198*144)*M27
	Cost Difference Factory Vs. Modified	=J28-K28		=L28-M28	
	Cost Difference Optimal Vs. Requested Max	Factory		Modified	
		=L28-J28		=M28-K28	

Vloume Removed (m^3/ha)	Total Cost for Entire Block			
	Factory Optimal Spacing	Modified Optimal Scaping	Factory Maximum Requested Dist.	Modified Maximum Requested Dist.
66	$ 74,528.48	$ 54,887.22	$ 80,469.47	$ 53,529.20
198	$ 43,029.04	$ 31,689.15	$ 66,069.47	$ 39,129.20
300	$ 34,956.96	$ 25,744.39	$ 63,621.47	$ 36,681.20

Vloume Removed (m^3/ha)	Total Cost for Entire Block			
	=J5	=K5	=L5	=M5
66	74528.4824325043	54887.2233902756	80469.4662490973	53529.2020334087
198	43029.0393947007	31689.1531994468	66069.4662490973	39129.2020334087
300	34956.9568557142	25744.3897602698	63621.4662490973	36681.2020334087

Total Cost for Entire Block			
Factory 1410D (22.4m^3) Optimal Spacing	Modified 1410D (40.75 m^3) Optimal Scaping	Factory 1410D (22.4 m^3) Maximum 1000m Requested Dist.	Modified 1410D (40.75m^3) Maximum 1000m Requested Dist.
$ 43,029.04	$ 31,689.15	$ 66,069.47	$ 39,129.20

Road Spacing (m)	Maximum Skidding Distance (m)	Total Cost Over Cut Block (Factory 1410D Forwarder)
500	250	$ 43,517.37
1000	500	$ 43,834.73
1500	750	$ 53,752.10
2000	1000	$ 66,069.47
2500	1250	$ 79,346.83
3000	1500	$ 93,104.20

Road Spacing (m)	Maximum Skidding Distance (m)	Total Cost Over Cut Block (Factory 1410D Forwarder)
500	=K37/2	43517.3665622743
1000	=K38/2	43834.7331245487
1500	=K39/2	53752.099686823
2000	=K40/2	66069.4662490973
2500	=K41/2	79346.8328113717
3000	=K42/2	93104.199373646

APPENDIX 3

EQUIPMENT COSTING MODEL

Equipment	Single Grip Harvester	Forwarder	Log Truck	Crew vehicle
Number of working days/year	242	242	242	242
Number of SMH/day	10	10	12	3
Machine Utilization	0.95	0.95	0.95	0.95
Annual Production Estimate,m^3 /a	30976	54208	21780	30976
Installed or Purchase price, $ (P)	695000	495000	300000	70000
Future Salvage Value, % (FSV)	10	12	12	12
Future Salvage Value, $ (FSV)	69500	59400	36000	8400
Expected Economic Life-Years(EL)	4	4	5	8
Interest rate %	5	5	5	4
Fuel consumption, L/PMH	25	15	60	12
Fuel cost, $/L	1.1	1.1	1.1	1.1
Engine oil consumption, (L/PMH)	0.1	0.1	0.1	0.1
Oil cost, $/L	4.32	4.32	4.32	4.32
Hydraulic oils and/or lube L/PMH	1.8	0.2	0.2	0
Hydrualic oils and/or lube cost $/L	2.84	2.84	2.84	2.84
Annual repair and maintenance cost, % of initial purchase price	5	5	5	5
Operator wage, $/SMH	25	20	20	0
Fringe benefits cost, % of wage	30	30	30	0
Number of operators required/shift	1	1	1	1
Insurance/risk cost, % of purchase price	3.1	2.4	0	2.4
Licence cost, $/a	0	0	14000	2900
SYSTEM COST SUMMARY				
Inerest rate, decimal	0.05	0.05	0.05	0.04
Present value of salvage vaue, $	57177.82	48868.53	28206.94	6137.80
Scheduled hours per year, SMH/a	2420	2420	2904	726
Productive hours per year, PMH /a	2299	2299	2758.8	689.7
FIXED COSTS				
Annual capital cost, $/a	182732.29	128257.78	64187.69	9730.83
Capital Cost, $/SMH	75.51	53.00	22.10	13.40
License and insurance cost, $/a	21545.00	11880.00	14000.00	4580.00
VARIABLE COSTS				
Energy, oil and lube cost, $/PMH	33.044	17.5	67	13.632
Repair and maintenance cost, $/a	34750	24750	15000	3500
LABOUR COSTS				
Operator Cost, $/SMH	32.5	26	26	0
TOTAL COST				
Annual operating cost, $/a	393645.45	268040.28	353531.29	27212.82
Hourly operating cost, $/SMH	162.66	110.76	121.74	37.48
PRODUCTION				
m3 produced per SMH, m^3/SMH	12.8	22.4	7.5	0
m3 produced per PMH, m3/PMH	13.47	23.58	7.89	0
Cost per m^3, $/$m^3$	**12.71**	**4.94**	**16.23**	**0.88**
TOTAL COST PER M^3				**34.76**

Equipment	Single Grip Harvester	Forwarder	Log Truck	Crew vehicle
Number of working days/year	242	242	242	242
Number of SMH/day	10	10	12	3
Machine Utilization	0.95	0.95	0.95	0.95
Annual Production Estimate,m^3/a	=D4*D5*D49	=E4*E5*E49	=(F4*F5*F49)*F22	30976
Installed or Purchase price, $ (P)	695000	495000	300000	70000
Future Salvage Value, % (FSV)	10	12	12	12
Future Salvage Value, $ (FSV)	=D8*0.1	=E8*0.12	=F8*0.12	=G8*0.12
Expected Economic Life-Years(EL)	4	4	5	8
Interest rate %	5	5	5	4
Fuel consumption, L/PMH	25	15	60	12
Fuel cost, $/L	1.1	1.1	1.1	1.1
Engine oil consumption, (L/PMH)	0.1	0.1	=0.1*F22	=0.1*G22
Oil cost, $/L	4.32	4.32	4.32	4.32
Hydraulic oils and/or lube L/PMH	1.8	0.2	=0.2*F22	0
Hydraulic oils and/or lube cost $/L	2.84	2.84	2.84	2.84
Annual repair and maintenance cost, % of initial purchase price	5	5	5	5
Operator wage, $/SMH	25	20	20	0
Fringe benefits cost, % of wage	30	30	30	0
Number of operators required/shift	1	1	1	1
Insurance/risk cost, % of purchase price	3.1	2.4	0	2.4
Licence cost, $/a	0	0	=14000*F22	2900
SYSTEM COST SUMMARY				
Inerest rate, decimal	=D12/100	=E12/100	=F12/100	=G12/100
Present value of salvage vaue, $	=(D10/((1+D27)^D11))	=(E10/((1+E27)^E11))	=(F10/((1+F27)^F11))	=(G10/((1+G27)^G11))
Scheduled hours per year, SMH/a	=D4*D5	=E4*E5	=F4*F5	=G4*G5
Productive hours per year, PMH /a	=D29*D6	=E29*E6	=F29*F6	=G29*G6
FIXED COSTS				
Annual capital cost, $/a	=(D8-D28)*((D27*((1+D27)^D11))/(((1+D27)^D	=(E8-E28)*((E27*((1+E27)^E11))/(((1+E27)^E	=(F8-F28)*((F27*((1+F27)^F11))/(((1+F27)^F11)-1))+(F28*F27)	=(G8-G28)*((G27*((1+G27)^G11))/(((1
Capital Cost, $/SMH	=D33/D29	=E33/E29	=F33/F29	=G33/G29
License and insurance cost, $/a	=((D8*D23)+D24)/100	=((E8*E23)+E24)/100	=((F8*F23)/100)+F24	=((G8*G23)/100)+G24
VARIABLE COSTS				
Energy, oil and lube cost, $/PMH	=(D13*D14)+(D15*D16)+(D17*D18)	=(E13*E14)+(E15*E16)+(E17*E18)	=(F13*F14)+(F15*F16)+(F17*F18)	=(G13*G14)+(G15*G16)+(G17*G18)
Repair and maintenance cost, $/a	=(D8*D19)/100	=(E8*E19)/100	=(F8*F19)/100	=(G8*G19)/100
LABOUR COSTS				
Operator Cost, $/SMH	=(((D20*D21)/100)+D20)*D22	=(((E20*E21)/100)+E20)*E22	=(((F20*F21)/100)+F20)*F22	=(((G20*G21)/100)+G20)*G22
TOTAL COST				
Annual operating cost, $/a	=D33+(D38*D30)+(D42*D29)+D35+D39	=E33+(E38*E30)+(E42*E29)+E35+E39	=F33+(F38*F30)+(F42*F29)+F35+F39	=G33+(G38*G30)+(G42*G29)+G35+G3
Hourly operating cost, $/SMH	=D45/D29	=E45/E29	=F45/F29	=G45/G29
PRODUCTION				
m3 produced per SMH, m^3/SMH	12.8	22.4	7.5	0
m3 produced per PMH, m3/PMH	=D7/D30	=E7/E30	=F7/F30	0
Cost per m^3, $/$m^3$	**=D45/D7**	**=E45/E7**	**=F45/F7**	**=G45/G7**
TOTAL COST PER M^3				**=SUM(D51:G51)**

APPENDIX 4

REVENUE CALCULATION

Gross Revenue Calculator					
	Mill:	Jovalco (Litchfield)			
	Species	Volume (m^3)	GMT	Price/GMT	Revenue ($)
Species 1	Mr	277.2	311.30	30.80	9587.90
Species 2	ConMix	374.22	336.80	23.30	7847.39
Species 3	By	249.48	265.6962	23.8	6323.57
Species 4	Bw	124.74	132.5986	23.8	3155.85
Species 5			0	0	0.00
Species 6			0	0	0.00
Totals		1025.64	1046.39		$ 26,914.71

Gross Revenue Calculator					
	Mill:	Hokum (Killaloe)			
	Species	Volume (m^3)	GMT	Price/GMT	Revenue ($)
Species 1	Pw	110.88	94.69	49.55	4691.56
Species 2	Sp	207.90	158.63	44.41	7045.10
Species 3	By	27.72	29.5218	72.4035423	2137.48
Species 4	Bw	13.86	14.73318	52.5418674	774.11
Species 5			0	0	0.00
Species 6			0	0	0.00
Totals		360.36	297.57		$ 14,648.25

Nagora's Hypothetical Current Harvest Site				
Species	Species Comp.	Total m3	logs m3	pulp m3
Sw	30%	415.8	207.9	207.9
By	20%	277.2	27.72	249.48
Ms	20%	277.2		277.2
Bf	10%	138.6		138.6
BW	10%	138.6	13.86	124.74
Pw	10%	138.6	110.88	27.72
ConMix				374.22
hectares		21		
Volume removed (m3/ha)		66		
total volume removed		1386		
Total Volume of Logs		360.36		
Total Volume of Pulp		1025.64		
Cost for Logs		$ 12,527.26		
Cost for Pulp		$ 35,654.51		
Total costs		$ 48,181.76		
Gross Revenue Logs (Hokum's)		$ 14,648.25		
Gross Revenue Pulp (Jovalco)		$ 26,914.71		
Total Gross Revenue		$ 41,562.96		
Total profit		-$ 6,618.80		

Nagora's Hypothetical Current Harvest Site				
Species	Species Comp.	Total m3	logs m3	pulp m3
Sw	0.3	=$P$13*O4	=$P$4/2	=$P$4/2
By	0.2	=$P$13*O5	=P5*0.1	=P5*0.9
Ms	0.2	=$P$13*O6		=P6
Bf	0.1	=$P$13*O7		=P7
BW	0.1	=$P$13*O8	=P8*0.1	=P8*0.9
Pw	0.1	=$P$13*O9	=P9*0.8	=P9*0.2
ConMix				=R9+R4+R7
hectares		21		
Volume removed (m3/ha)		66		
total volume removed		=P11*P12		
Total Volume of Logs		=SUM(Q4:Q9)		
Total Volume of Pulp		=SUM(R4:R9)		
Cost for Logs		=P14*'Equipment Cost'!G52		
Cost for Pulp		=P15*'Equipment Cost'!G104		
Total costs		=SUM(P16:R17)		
Gross Revenue Logs (Hokum's)		14648.25		
Gross Revenue Pulp (Jovalco)		26914.71		
Total Gross Revenue		=SUM(P19:R20)		
Total profit		=P21-P18		

APPENDIX 5

ADDITIONAL FORWARDER INFORMATION

Forwarder Winter Travel Information With Tracks On				
Travel Speed				
Empty	6	km/h		
Loaded	4	km/h		
Empty	100	m/min		
Loaded	67	m/min		
Skidding Distance (m)	480			
Factory Load Size	22.4	Cubic Meters		
Modified Load Size	40.75	Cubic Meters		
Factory Max Skid Distance (m)	600.0			
Modified Max Skid Distance (m)	1091.5			
per 1 m3 the machien can travel		26.79	meters	

1410D load specs
22.4 cu/meters or 6.2 cord load size of factory size machine
1,366,931.87 volume cubic inches
214 length of log bunk in inches
109 width of log bunk in inches
58.6 height of log stakes in inches
4ft 10inches height of stakes
18.35 cu/meters or 5.06 cords additional volume per load with stake extensions of 4ft
40.75 cu/meter or 11.26 cord load size with modified stake lengths

WOOD BUNK

Deck Length	17-ft 10-in *5,4 m* or	18-ft 3-in *5,56 m*
Optional	13-ft 10-in *4,2 m*	
Load Stake Width	9-ft 1-in *2,76 m*	9-ft 8-in *2,95 m*
Optional	9-ft 10-in *3,0 m* for 13-ft 10-in deck	
Maximum Cross Section	49.5 sq-ft *4,6 m^2*	58 sq-ft *5,4 m^2*
Optional	53.5 sq-ft *5,0 m^2* for 13-ft 10-in deck	
Headboard	Fixed with hydraulic extension	Fixed with hydraulic extension
Log Bunks	4 pair with 8 stakes, moveable	4 pair with 8 stakes, moveable
Payload	6.2 cords *22,4 m^3* stacked	7.3 cords *26,3 m^3* stacked
Optional	6.7 cords *24,4 m^3* stacked for 13-ft 10-in deck	
Max. Load Rating	30,865 lb *14 000 kg*	37,480 lb *17 000 kg*

Common Forwarder Load Sizes			
John Deere equipment models	Max. cubic meters by exact dimensions	Estimated actual max. cubic meters using white pine (1249kg/m^3)	Max. load rating (kg)
1110G	19.2	9.6	12000
1210G	20.8	10.4	13000
1410D	22.4	11.2	14000
1510G	24	12.0	15000
1910G	30.4	15.2	19000
Modified 1410D	40.75	20.4	25470

Common Forwarder Load Sizes			
John Deere equipment models	Max. cubic meters by exact dimensions	Estimated actual max. cubic meters using white pine (1249kg/m^3)	Max. load rating (kg)
1110G	=O26/625	=O26/1249	12000
1210G	=O27/625	=O27/1249	13000
1410D	=O28/625	=O28/1249	14000
1510G	=O29/625	=O29/1249	15000
1910G	=O30/625	=O30/1249	19000
Modified 1410D	40.75	=O31/1249	25470

Common Forwarder Load Sizes				
John Deere equipment models	Max. cubic meters by exact dimensions	Estimated actual max. cubic meters using white pine (1249kg/m3)	Max. load rating (kg)	Max skid distance (m)
1410D	22.4	11.2	14000	600.32
Modified 1410D	40.75	20.4	25470	1092.1

Common Forwarder Load Sizes				
John Deere equipment models	Max. cubic meters by exact dimensions	Estimated actual max. cubic meters using white pine (1249kg/m3)	Max. load rating (kg)	Max skid distance (m)
1410D	=T26/625	=T26/1249	14000	=R26*26.8
Modified 1410D	40.75	=T27/1249	25470	=R27*26.8