The Use of Optimization Programs in the Canadian Wood Products Sector

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Abstract

The international wood products sector has historically been an extremely volatile and competitive which has forced companies to find ways to gain competitive advantages in order to succeed. The Canadian companies within the industry that have found the most international success are the ones who have been able to continually develop optimization programs to aid in reaching both their long- and short-goals. Applied optimization programs have been able to improve a company's operations by minimizing costs, increasing efficiency, and increasing output. Optimization programs, if structured and constructed properly, can be applied a variety of ways into many of the operations occurring within the wood products industry. This report aims to provide a breakdown of optimization models, an analysis of how they incorporated into operations, and an overview of what kind of optimization programs are used in the wood products sector.

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Index of Abbreviations

CPM- Critical Path Method

CT scan- Computed Tomography Scan

EOQ- Economic Order Quantity

FPAC- Forest Products Association of Canada

LP- Linear Programing

LVL- Laminated Veneer Lumber

OSB- Oriented Strand Board

PERT- Program Evaluation and Review Technique

SPF- Spruce/Pine/Fur

1.0 Introduction

1.1 What is an optimization program?

The Merriam-Webster Dictionary defines optimization as "an act, process or methodology of making something (as a design, system, or decision) as fully perfect, functional, or effective as possible." (Merriam-Webster, 2013) An applied optimization program attempts to strive for this definition by means of a variety of possible techniques in order to achieve a specific goal. Optimization programs are used in nearly every industry, ranging from the use in biomedical industry (Figueiredo, 2007) and the field of statistical analyses (Srivastava, Sylvester, & Blaauw, 2005) to factory development and industrial idealization (Nee & Long, 1988). Optimization programs can be as simple as real-life simulation of a situation, or as complicated as extremely complex algorithms. Researchers and industry members are interested in using and incorporating optimization programs since the programs are able to simulate tasks such as minimizing cost and time requirements and maximizing revenue and efficiency.

1.2 Brief History

The idea of using optimization programs falls within the larger and more general field of operations research. The origins of the modern idea of operations research were mainly derived from the industrial revolution. This general idea of optimizing jobs and scheduling really began to take off during the middle of the twentieth century; more particularly, during the Second World War. It was during this time that it became necessary for companies, factories, and even entire countries to essentially find the minimum amount of money and time to make the maximum volume of their particular output. (Hillier & Lieberman, 1980) Many would suggest that this goal of having a maximum output from a minimum input is simply human nature and has been incorporated in operations in product for ever; however, it was only recently that mathematical formulas, scientific methods, and complicated algorithms have been implemented and programmed into these operations.

1.4 The International Wood Products Sector

Not only in Canada, but also internationally, the forestry and wood products sectors have traditionally been relatively unpredictable and somewhat volatile industries. The large degree of uncertainty can be highly attributed to a variety of factors. The fact that wood is intermediary material used for the building and forming of other products means that its demand is fully based on the demand for these other particular products. (B2B Business News, 2012) Another large factor contributing to the variability in the industry is the fact that the forestry sector is a highly internationalized industry. Trading is done globally, and as such, it is no longer sufficient to only abide to the national standards, regulations, and practices. The ever-changing international currency rates are also large factors in adjusting the demand for wood products, since a large majority of the goods are being traded internationally.

1.5 Canada in the Wood Products Sector

The wood products sector can be roughly separated into two sectors; the primary industry and the secondary industry. Canada has traditionally had most of its success in the forestry industry through the primary industry; more specifically through the trading and exporting of our large amounts of material and raw logs. (Wynn, 2012) This was possible due to the fact that Canada has such vast amounts of high quality forest land. As more and more nations began developing, they found ways to produce direct substitutes for Canadian lumber through means such as fast growing plantation in Brazil (Garay, Pellens, Kindel, Barros, & Franco, 2008) and producing wood substitutes such as bamboo composites. (Verma & Chariar, 2011) This Canadian lumber has essentially become a commodity product, having to compete primarily on cost, against nations with much lower regulatory costs and labor costs for comparable products. Several of the larger and more notable Canadian companies have been able to find success through operational planning and optimization programs to stay competitive in the international market and have continually contributed to Canada's success in the industry.

1.6 Key Members of Canada's Wood Products Sector

Canfor Corporation- Canfor Corporation is a Canadian forestry company that is "one of the world's largest producers of sustainable wood building solutions." They are most reputable in their production of SPF dimensional lumber and pulp. (CANFOR, 2012) Canfor was established in the 1930s by John G. Prentice and has had a large number of owners since then including Jim Pattison (Davis, 2009)

Tolko Industries Ltd- Tolko Industries is a manufacturer of an assortment of wood products including lumber, OSB, and plywood for the international market. Tolko is a private company that was founded in 1956 in Lavington, British Columbia and its current president is Brad Thorlakson. (Tolko, 2013)

Western Forest Products Inc- Western Forest Products is a British Columbia based manufacturer of "Sustainable Coastal Wood." (Western Forest Products Inc., 2012) A large majority of their products are timber based products which are sold internationally. The current CEO of Western Forest Products Inc. is Don Demens.

West Fraser Co Ltd- West Fraser Corporation is an integrated forests company which had traditionally focused on the sales of SPF and pulp, but has since diversified their products by selling and manufacturing engineered wood products such as treated wood and LVL. West Fraser was founded in 1955 by the Ketcham brothers, and to this day has been based out of Quesnel, British Columbia. (West Fraser, 2013)

2.0 Optimization Programs

Attempting to find the ideal operations strategy is not as simple as merely picking any optimization program, plugging in corresponding variables, and finding the best solution. There are a large variety of model types, all of which can be further broken down by the types of variables and solutions existing within the model.

2.1 Optimization Classifications

Optimization systems can often be represented mathematically in which a mathematical formula, model, or equation, combined with a given set of criteria and constraints, is used to find a maximum or minimum value that abides to the constraints. Equation 1 represents a general mathematical optimization equation. The formula attempts to maximize the function f(x), with g(x) and h(x) being constrains that the function f(x) must abide too.

Equation 1- A General Mathematical Optimization Formula (Daztzig, 2010)

$$\text{Maximize } f(x): x \text{ in } X,\ g(x) <= 0,\ h(x) = 0$$

Optimization systems can be broken down into multiple classifications depending on the properties of the inputs and outputs of the solution.

2.1.1 Linear Vs. Non-Linear

Linear optimization consists of mathematical models containing functions and constraints that include only linear inequalities and relationships. A linear program in its most basic form contains three fundamental elements: a linear function to be maximized or minimized, constraints, and non-negative variables. (Hillier & Lieberman, 1980) Figure 1 is a graphical representation of a linear optimization model using equation 2 as a definition for its function and constraints. The green shaded region represents the solutions to the program and the white area represents non-feasible values.

Equation 2- Linear Modeling Example Equation

$$\text{Minimize } Z = 100(X2-X1^2)^2+(1-x1)^2; \ x1>=0, \ x2>=0$$

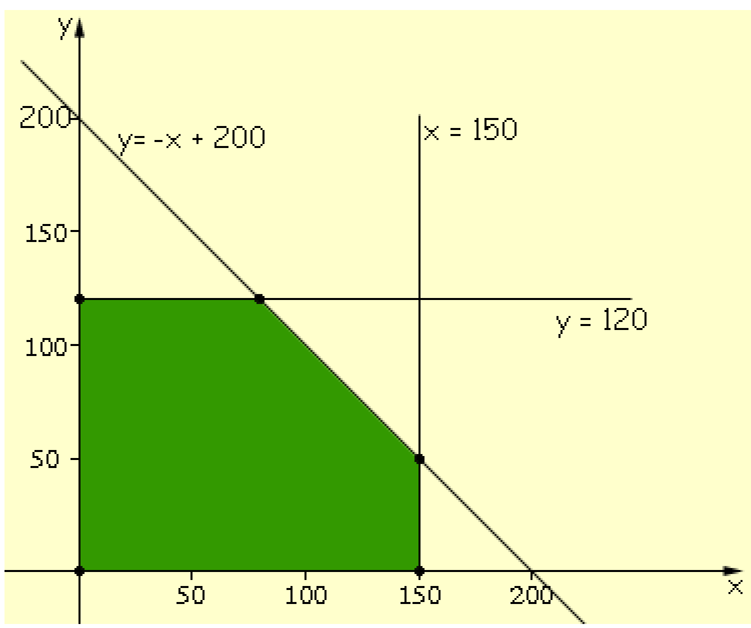

Figure 1- Simple Linear Programming Result (University of Regina, 2012)

Non-linear mathematical programming models are used in place of linear models when the assumptions of linearity for the entire set of equations and constraints cannot be made. A simple non-linear solution is represented in figure 2 using equation 3 to define its parameters.

Equation 3-Non-Linear Modeling Example Equation

Maximize f(x):y <= 120, y=-x+200,y>0, x>0

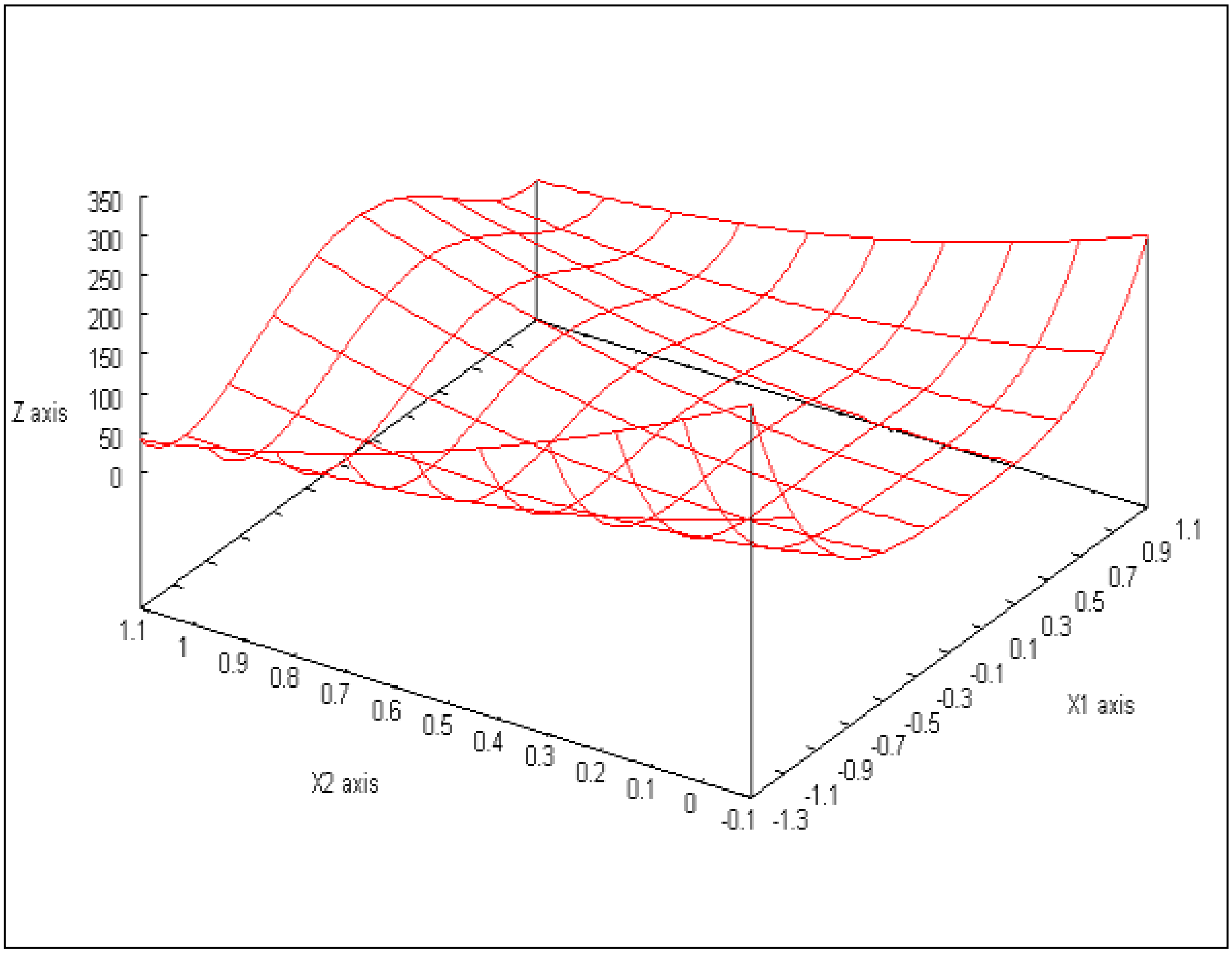

Figure 2- Example Non-Linear Programing Result

2.1.2 Static Vs. Dynamic

Whether a mathematical optimization model is static or if it is dynamic is the determining variable in whether it is solved at a particular point in time or over a time frame. Static models assume that factors do not change over time, and therefore any instantaneous point in time will be no different than at a different point in time. (Gershenfeld, 1998) A dynamic model suggests the opposite; that a multitude of factors may be different at any particular point in time. Dynamic models, being ever-changing, often require the use of calculus and differential equations.

2.1.2 Continuous Vs. Discrete

The fundamental goal of mathematical optimization programs is to theorize real world situations into a mathematical formula, calculate the formula, and then use that calculated value to determine what ideal decision to make. In reality; however, the entire set of real numbers are not always possible, thus the values and quantities often require integer values. For example, in a manufacturing operation where a manager must decide the ideal number of machines and workers to have on the shop floor, a non-integer value is not feasible thus the solution must be a whole number. Continuous models allow for any real number within the constraints of the model to be chosen including continuous values such as time or temperature, whereas discrete modes allow for only integer values to be chosen including discrete values such as number of workers or a number of machines.

2.1.3 Stochastic Vs. Deterministic

The level of randomness within a particular optimization model is often accounted for by whether the model is stochastic or deterministic. A deterministic model, with the same given inputs, should theoretically produce the same result every time. A stochastic model; however, has unknown variables and inputs to account for the randomness in the solutions. (Ladde & Sambandham, 2003). The majority of manufacturing processes are considered to be stochastic due to the large number of uncontrollable and random factors contributing to the final product.

2.1.4 Implicit Vs. Explicit

Describing an optimization model as either an implicit model or an explicit model refers to how a particular solution is found. An explicit model uses values at a current time to determine solution at a point in the future. Implicit models are much more complex relative to their counterparts and involve using values both at the current and the future time to determine the solution in the future.

3.0 Implementation of Optimization Programs

3.1 Optimization Procedure

All optimization programs, regardless of the type, have the same fundamental steps in order to reach their final goal or solution. The procedure is a generalized three step process where the problem must first be formulated, next the inputs must be determined, and finally it must be completed within a reasonable time frame.

3.1.1 Step One- Formulating a problem

The most elementary step of implementing an optimization program is to determine what problem wants to be solved. The problem can be as simple as finding the fastest route of travel for a single product from point A to point B, or as complicated as minimizing the total time of travel within an entire supply chain. An example five step process to aid in formulating a problem is (Smith, 2012):

1. **Specify the objectives-** The core goal that is hoping to be reached must be explicitly stated, and every step taken afterwards must contribute to this goal being reached.
2. **Review the environment**- As much as a particular task me be isolated, there is nearly always an effect on other factors when one task gets changed. For example; an entire operation must be looked at when one particular task is attempting to be optimized and there must be a net-gain in order for the optimization to be effective.
3. **Explore the nature of the problem-** In order to easily and effectively formulate the problem, as much knowledge on the particular topic, operation, or product must be gained.
4. **Define the variable relationships**- Any factor affecting the final outcome must be considered
5. **Determine the consequences of an alternative course of action**

3.1.2 Step Two- Identifying the proper inputs

The entire set of factors and inputs contributing to a final output must be precisely determined prior to attempting to formulate an optimization program for an operation. The amount of inputs contributing to a particular optimization program can be endless so factors that contribute minimally are often omitted from an optimization model.

3.1.3 Step Three- Solve within a reasonable time

There may exist a particular optimization program or model or program that returns the most ideal results, but unless the solution is achieved within a reasonable time, it cannot be used effectively.

3.2 Optimization Timelines

3.2.1 Strategic planning

Strategic planning encompasses the entire mission, vision, and value statement of an organization and is used to plan over five years into the future. Every decision in a company's lifetime should be catered towards reaching their strategic planning goals. Strategic planning is used to define who an organization wants to be and what they hope to accomplish in the long term. (McNamara, 2010) Strategic planning is often the focus of upper level management, all of whom attempt to set the goals for the rest of the organization to follow. A large amount of strategic planning is required in the start-up of new companies and new factories. Optimization programs can be integrated into these strategic planning decisions by forecasting demand and then engineering their factories to have the preliminary required capacity. As well as applying techniques to the factory aspect of strategic planning, the supply chain can also be optimized by means of optimization programs. The material sources and final production destinations can all be considered to find the optimal location for a plant to be situated within a supply chain.

3.2.2 Tactical planning

Tactical planning is used to analyze the everyday actions taking place within an operation and find ways to implement strategic planning into smaller, more specific areas of an organization. (Management Innovations, 2008) Tactical planning is considered a medium- to long-term planning method and usually lasts between twelve months and five years. Existing organizations focus the majority of their improvement and optimization planning on their tactical plans. Optimization programs can be implemented into an organization`s regular operations to achieve goals such as minimizing costs or increasing productivity.

3.2.3 Operative Planning

Operative planning is the planning of day to day activities within a particular operation. These activities can include daily actions such as administrative planning and employee scheduling; all of which are planned less than a year into the future. Operative planning is implemented by organizations in order to improve the likelihood of achieving their tactical and strategic plans. Optimization programs can be implemented into operative planning through means such as tracking production progress to find bottlenecks and ensuring routine quality checks.

4.0 Optimization Methods Used in the Industry

4.1 Economic Order Quantity

Economic Order quantity can be defined as the specific quantity of a particular good that should be ordered in order to minimize costs. The two costs contributing to the total cost are; the yearly costs to place the orders and the yearly costs to hold products as inventory. The EOQ is a method often used to help optimize and reach goals within an organization`s tactical planning. Equation 3 shows the standard formula used to define order quantity where Q is the optimal order quantity, D is units of annual demand, S is the order cost, and H is the cost to hold the product.

Equation 3- Economic Order Quantity Formula (ReadyRatios, 2013)

$$Q^* = \sqrt{\frac{2DS}{H}}$$

Determining the optimal order quantity requires an ideal balance to be found between the two costs, and the use of the optimal order quantity formula allows the order volume which will optimize their system. Figure 3 illustrates the total costs associated with order and holding inventory and the economic order quantity is represented at the point where the cost curves intersect. In the secondary industry, the EOQ varies largely based on the current product demand whereas in the primary industry there is a slightly more constant and predictable demand therefore the EOQ varies far less.

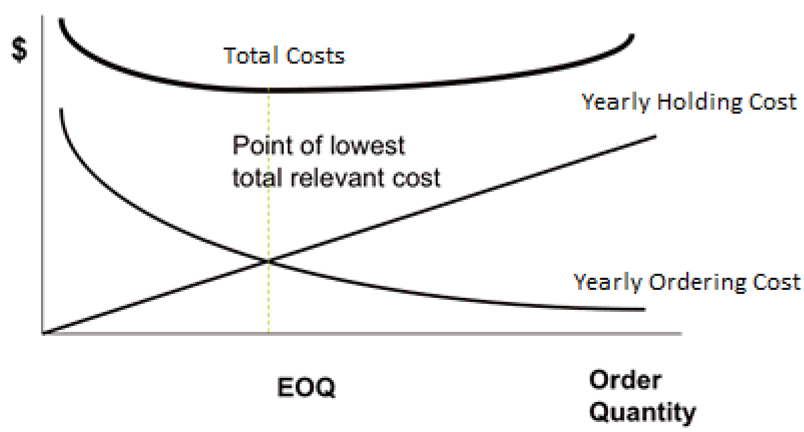

Figure 3- Economic Order Quantity (Cecil Bozarth, 2011)

4.2 Optimal Plant Capacity

Each machine and operation within a manufacturing plant or factory has a particular capacity or volume of output that can be produced in a given length of time. In the preliminary stages of deciding on a plant layout, approximations on the desired output must be considered in designing the layout. Time studies and simulation can be done to find the output capacity of particular machines in order to be suited for the plant's output requirements. As well as picking machines well suited for the operation, the entire facility must be designed to allow smooth flow from start to finish of the process. Depending on the intended operation occurring in the proposed factory, steps can be taken and techniques can be implemented to maximize the capacity for the given size.

4.3 Optimal Plant Throughput

In operations there are often bottlenecks within the entire process. Bottlenecks in an operation act the rate-determining step and completely depict the capacity of the plant. In the situation where one machines capacity was increased, the capacity of the entire operation may not increase if the bottleneck was left unchanged. One method that is used to reduce the effect of bottlenecks is by creating intermediate buffers between machines which minimize the potential downtime for any machine. Optimization techniques can be used to locate these particular bottlenecks and then find ways to minimize the effect of the bottle neck on the operation.

	Raw Data for the Panel Saw			
	description	fig.	unit	Notes
1	Average number of sheets per cutting cycle	**5.00**	Sh/Cy	
2	Basic time per cutting cycle	**0.30**	h/Cy	
3	Additional time machine (distribution time)	**15.00**	%	
4	Setting-up time per production / custom order	**0.30**	h/order	
5	Fixed setting-up time per production day	**0.50**	h/day	
6	Standard personal requirement including Forkliftdriver	**2.00**	Pers.	
7	Basic time for to stack/unload the cutted parts (person)	**0.20**	Min/part	
	Calculations			
	description	fig.	unit	Notes
	Machine / Panel saw			
1	Number of cutting cycles per day	**48.40**	Cycles/day	1,209.96 m2/d / (2.5 m 2.0 m) / 5 Sh/Cy
2	Total basic time per day	**14.52**	h/d	48.40 Cy/day x 0.3 h/Cy
3	Total setting up time per order	**1.80**	h/d	0.3 h/order x 6 orders/day
4	Fixed setting uptime per production day	**0.50**	h/d	
5	Total basic and setting up time	**16.82**	h/d	14.52 h/d + 1.80 h/d + 0.5 h/d
6	Additional time	**2.52**	h/d	16.82 h/d x 15 % /100
7	Execution time for the process	**19.34**	h/d	16.82 h/d + 3.78 h/d
	Person / operator			
8	Total basic time per day	**11.88**	h/d	(0.2 Min/part x 3564 parts/d) / 60 Min/h
9	Total setting up time per order	**1.80**	h/d	
10	Fixed setting uptime per production day	**0.50**	h/d	
11	Total basic time and setting up time	**14.18**	h/d	11.88 h/d + 1.80 h/d + 0.5 h/d
12	Additional time for the operator (distribution time)	**2.13**	h/d	14.18 h/d x 15 % /100
13	Execution time for the operator	**16.31**	h/d	14.18 h/d + 2.13 h/d
	Results of the Calculation			
	description	fig.	unit	Notes
1	Execution time for the process (machine) > operator (person) time	**19.34**	h/d	
2	Total execution - time (rounded)	**19.30**	h/d	
3	Panel saw utilization	**120.89**	%	(19.34 h/d / (8 Ph/d x 2 Sh/d) x 100 %
4	Number of operators	**4.84**	Pers./d	(19.34 h/d / 8 Mh/d) x 2 Sh/d
5	Decision: Quantity of Machines	**1.00**	machine	

Figure 4- Capacity Calculation for a Panel Saw in a Manufacturing Process

Figure 4 illustrates an example set of capacity calculations for one particular machine, a panel saw, in a manufacturing operation. The calculation takes into consideration the inputs, the operating time, and the labor hours to provide results which aid in a final decision of how many machines to have.

4.4 Log Breakout Optimization.

The very first step in any wood products manufacturing operation is the breakout stage, where the raw logs are turned into timber. The entire raw log coming into a plant has been paid for so the more effectively and efficiently that the log can be turned into timber; the more potential there is for value to be earned. There are a large variety of optimization procedures that can be done in order to maximize the final attainable volume and minimize the waste. One procedure that can be done is to pre-scan the raw logs entering the facility using a machine such a CT scanner. Pre-scanning can allow for detection of internal moisture content and wet pockets as well as knot locations. Figure 5 illustrates a computer representation of a CT-scanned log. Once the internal log has been analyzed, bucking can be done to maximize both the final volume and quality of the timber. Scanning techniques used in breakout applications have the potential to improve a factory`s yield by as much as 15%. (Pastorius, 2010)

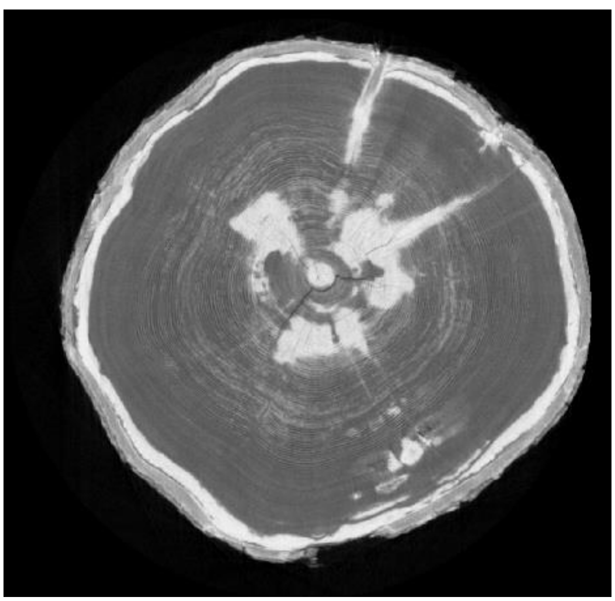

Figure 5- Internal Representation of a CT-Scanned Log Containing Wet Spots (Alkan, 2003)

4.5 Sawmill Cutting Patterns

Once the raw logs have been bucked to proper lengths, the timber must then be cut to workable pieces. Depending on the final use and the particular timber quality, the timber must to boards or planks. Cutting pattern optimization can be done in a large number of ways to maximize the volume and quality of the cut product as seen in figure 6. Grain direction, dimension, and wood type (heart wood versus sap wood) all contribute to the final quality and selling price of the cut lumber. A hardwood operation would be required to put large emphasis on having clear cut pieces with a visually appealing grain direction compared to a dimensional lumber operation which would have the largest emphasis on yield from the given log.

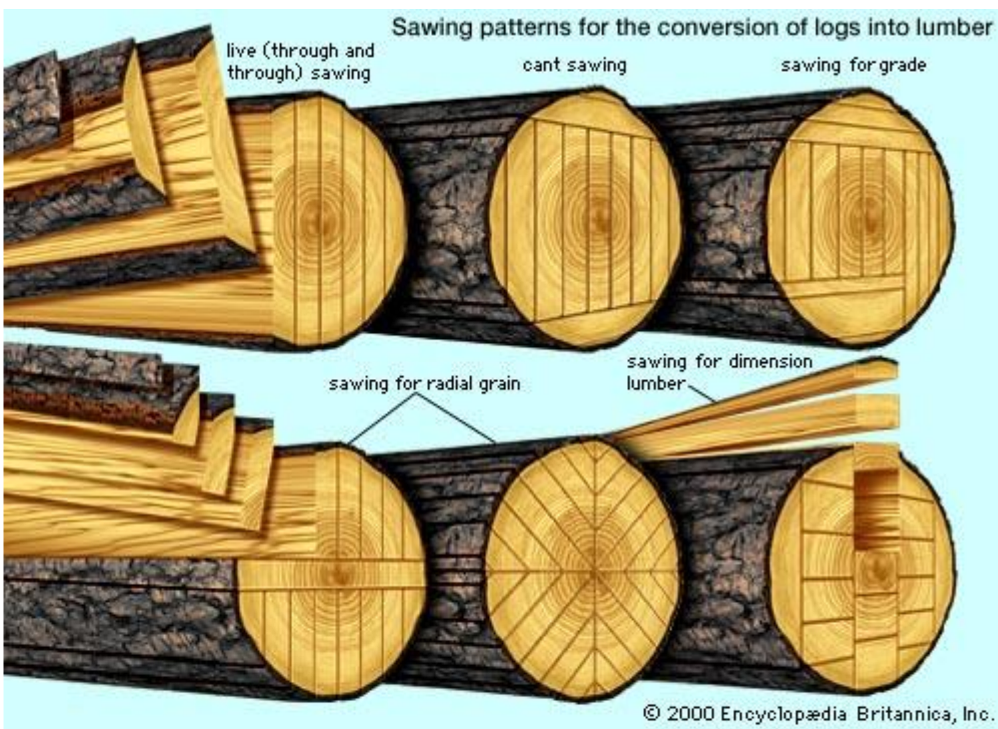

Figure 6- Three Different Cutting Patterns (Encyclopædia Britannica, Inc., 2013)

4.6 Activity and Path Scheduling

In every single manufacturing or operating process there exists and entire set of tasks, each of which need to be completed individually to reach the final goal. A large majority of these tasks are also dependant on preceding tasks in order to be completed. The Critical Path Method (CPM) is a technique which looks at the entire set of tasks, their costs and proceeding and succeeding tasks. The CPM can be used to either minimize the time requirements or the cost requirements of an operation. (Santiago & Magallon, 2009) The critical path method is often used alongside with the Program Evaluation and Review Technique (PERT) in order to provide a visual representation of the required tasks. (Concordia University, 2013) Figure 7 illustrates the first step in a generalized CPM example in which the time and costs are attempting to be minimized and figure 8 illustrates the PERT for the same operation.

Activity	immediate predecessors	Estimated Normal duration (months)	Normal Cost ($ '000)	Estimated Crash time (months)	Crash Cost ($ '000)
A	-	2	40	1	55
B	A	2	50	1	60
C	A	8	500	6	650
D	A	13	45	11	65
E	A	6	1000	5	1300
F	A	12	100	10	140
G	B	6	12	4	16
H	B	3	50	2	64
I	B	6	15	4	20
J	B, C	14	100	11	115
K	A	16	48	12	58
L	A	5	140	3	180
M	D	8	200	6	240
N	D	6	120	4	150
O	G,H,I,J,K	8	200	6	260
P	L,O	7	55	5	70
Q	P	3	50	2	60
R	Q	3	70	2	84
S	P,E,F	5	100	4	120
T	M,N,R,S	8	50	6	65
U	Q	18	100	14	125
V	T	13	200	12	230

Figure 7- A CPM Analysis

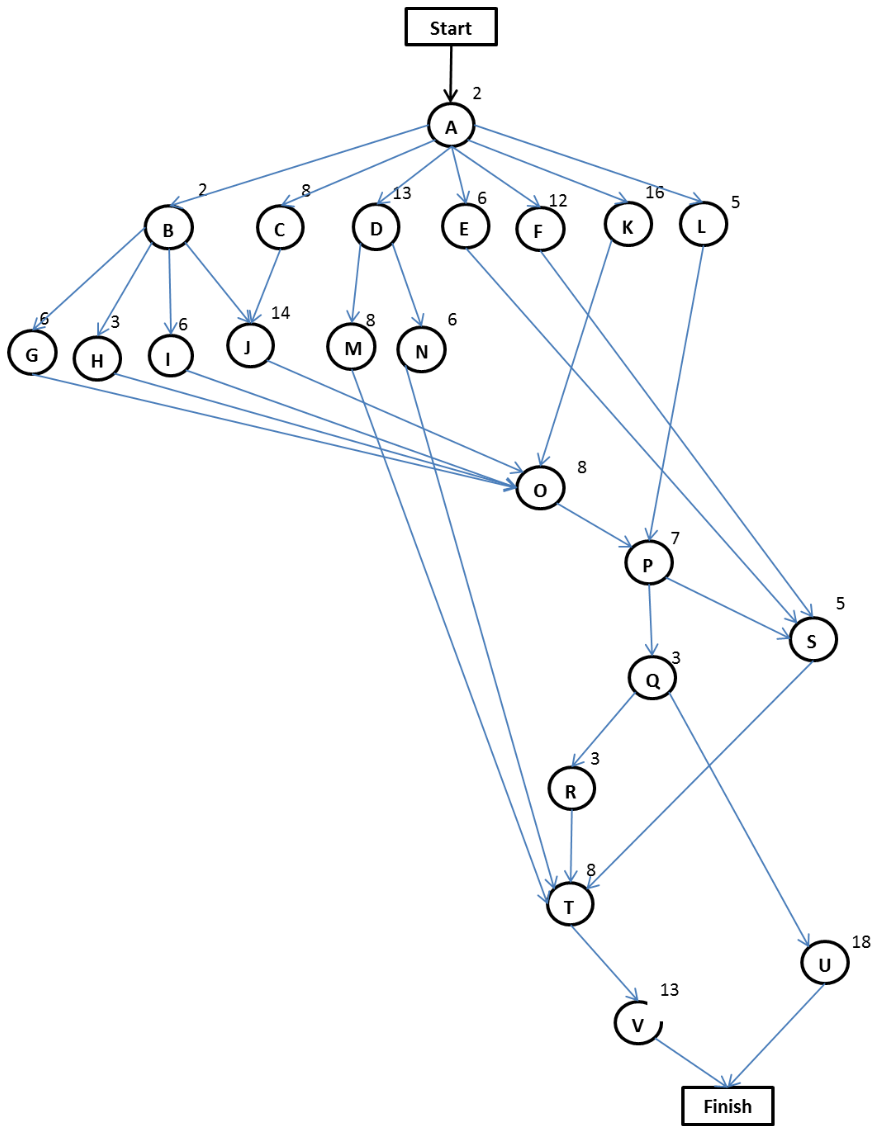

Figure 8- A PERT Analysis

5.0 Conclusion

Optimization programs were historically implemented in a variety of operations as a means to improve efficiency and increase output. As the wood products sector became more competitive and the industry became much more globalized, Canadian companies were required to continually find ways to minimize costs, improve their product quality, and become as lean in their manufacturing as possible in order to stay competitive internationally.

The benefits of optimizing operations in the wood products sector are numerous and are necessary if Canada hopes to continue to be competitive in the industry. It is the companies who continually evaluated their operations and attempted to optimize their entire set of processes that were able to stay competitive in the past, and it is these same companies that will be able to continue to thrive in the future. These companies were able to stay competitive by using optimization to improve every aspect of their planning: strategic, tactical, and operative. By implementing EOQ and scanning systems into their operations, Canadian wood products companies have been able to optimize their operative planning which led to improved yields and a constant inflow of inputs. The tactical planning in organizations has been improved through the use of activity and path scheduling which in turn provides an improved product flow from start to finish. The strategic planning of organizations has provided realistic long term goals which have been able to be reached through optimizing plant throughput and capacity.

By implementing optimization techniques into short- and long-term strategy, Canadians have found ways to reduce costs, improve efficiency, and increase savings. These optimizations are the competitive advantage that Canadian businesses use to allow themselves to compete internationally against nations with lower operating costs. Optimization programs have been used, and will need to continue to be used in the companies within Canada's wood products sector if they hope to remain competitive in the industry internationally.

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