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OPTIMISING PRODUCTION TO SATISFY A MARKET REQUIRMENT

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Introduction

The problem in question is how to optimise a sawmill operation to best satisfy a market requirement.

As we come from North America, it should be mentioned that this problem does not arise to the same degree in a typical North American sawmill. In the US and Canada, sawmills have the relative luxury of selling into a somewhat "big sink" of a market, for which the production of individual companies has much less effect on the market. Optimising a sawmill under these conditions is relatively easy. Generally speaking, the sawmill can optimise the use of each sawlog individually, to extract the maximum value out of the log with less consideration of the mix of products produced.

In most of the world, however, sawmills face a much more difficult task: to produce timber in predetermined quantities. Furthermore, these quantities may change often, many times from week to week, so it is not possible to devise a long-term solution.

Producing a solution to fill an order is not simple. Choosing the solution that benefits the system the most – the optimal solution – without the right tools is virtually impossible. As a result, sawmills tend to rely on experience to produce these "sawing recipes"; someone who has been in the sawmill "forever", and who knows the system well enough, is assigned to tackle the problem.

The basic question that needs answering is "What options can be manipulated to fill these orders?" Each sawmill is different, but here are some typical options that most sawmills will have:

1. A choice of sawlog source. Each source might have a different distribution of diameters and lengths. A different source can be a different supplier, or sawlogs extracted from a different harvest region.

2. Sawlog sort practices. Sawmills that pre-sort the sawlogs can change the sorting parameters and the sawing profile applied to each sort bin. Usually, sawmills that pre-sort will run the sawlogs in batches, each with the same profile.

3. On-line optimisation manipulation. Sawmills that do not pre-sort and run on-line optimisers can manipulate the price tables in the optimiser to yield the right timber mix.

4. A choice of manufacturing method. A sawmill may choose to produce wide timber in the sawmill and split in the planermill or produce the narrow timber directly in the sawmill.

In a perfect world a sawmill would optimise on a log-by-log basis and, at the end of the production, the timber produced would match exactly the timber required. In practice, however, the solution for individual sawlogs must be compromised to produce the required timber volumes. This wrinkle opens a whole new dimension: where should the sawmill compromise? The answer is that sawmills make adjustments based on the options described above. But the questions remain; what should be changed? and, to what?

Most sawmills currently solve the production problem by manipulating either option 2 (changes in sorting or profiles per sort) or option 3 (changes in optimiser parameters), depending on the case. The reason why options 1 (log source) and 4 (manufacturing method) are many times not considered is that the problem is complicated enough to solve with these fixed. Furthermore, note that an optimal solution might involve splitting the decision, for example to process x% of a certain bin with one profile and the rest with another, or to run x% of the time with one set of values in the optimiser and the rest of the time with another. This option is rarely considered in full when solving the problem.

The compromise must be such that the solution makes the best use of the resources: sawlogs and time. To produce such a solution, a system that has all the information available must be devised. The system must know:

- What is the production goal;
- What material is available and at what cost (sawlog distribution by diameter, length and perhaps quality, i.e. sawlog class);
- What are the different ways (methods) to process each sawlog class;
- The processing time for each sawlog class when processed with each method; and most importantly
- What is expected to be recovered when each sawlog class is processed with each method?

Incorporating all these variables will produce a superior solution, but it cannot be done without the right tools.

All items above, except the last one, are usually readily available in a sawmill, or systems can be put in place relatively easily to collect this information. The last item is a little more complicated; a system must be sought to predict the timber yields for each sawlog class when processed with each method.

A good solution must:

- Produce at least the required quantities.
- Produce as few non-order products as possible. Those non-order products will be inventoried so they should be products that are easily marketable in the future.
- Not “cream” the sawlog inventory; it should use sawlogs following the predetermined sawlog distribution. On the other hand, it should recognize the possibility of using different sawlog sources and/or deviating from the predetermined sawlog mix up to a fixed amount.
- Be easy to implement. The solution must be defined by variables that are easy to manipulate in real life.
- Account for time and materials.

Linear Programming – Overview

Orders are received daily and are aggregated into production targets. Combining orders is necessary since developing a production strategy for each market order would mean an unworkable scenario. Another option would be to incorporate market orders as they arrive into a dynamic system that continuously updates the state of the sawmill, constantly recalculating the production order and updating the necessary sawmill centers to produce it. The first type of system, where a solution for a static plan is sought, is an MRP (Material Requirement Plan) system. The main objective of MRP systems is to match materials to processes to achieve maximum productivity. The second type of system, where by continuously updating the system an optimum and dynamic schedule is produced, is an ERP (Enterprise Resource Plan).

Linear Programming (LP) solutions are examples of MRP systems.

Linear Programming is a problem solving technique that has been around since the Second World War. It is the best understood, most robust and perhaps the most widely used technique for solving relatively complicated industrial operations problems.

LP is based on simple algebra. The first step is to develop equations to represent the problem at hand. Basic algebra says that a system with more equations than variables is likely to be unsolvable. For example:

$X = 1$, and $X > 3$

Or,

$X + Y = 1$, $X > 3$ and $3X – Y = 0$

On the other hand, systems of equations with more variables than equations will have an infinite number of solutions. For example:

$X + Y = 1$

Or,

$X + Y + Z = 0$ and $2Y - Z \leq 10$

Most real-life problems, when reduced to equations, fall in the latter case. The implication is that there are many ways to solve a given problem. LPs add an extra dimension called the Objective Function, a way to measure the relative performance of each solution. One or more variables get an associated benefit measure and the goal of the LP is to find, within all the possible solutions, one that maximizes the benefits (or minimizes the loss). For example, in the previous equations:

$X + Y + Z = 0$, $2Y - Z \leq 10$ AND find the largest possible Y

The solution is: X = 5, Y = 5 and Z = 0 (assuming all variables are positive integers)

Linear Programming in Sawmills

To better understand how this technique would apply to sawmilling, let’s build a set of equations for a simplified problem. The equations will be developed one-by-one to ease the understanding.

Assume a mill has to process 10 sawlogs with either Profile A or Profile B. First the variables need to be defined:

SawlogsA represents the number of sawlogs processed with Profile A
SawlogsB represents the number of sawlogs processed with Profile B

The first equation would read:

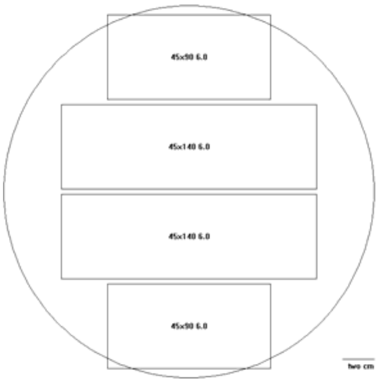
$$\mathit{SawlogsA} + \mathit{SawlogsB} = 10$$

Notice that the assumption is that exactly 10 (not fewer) sawlogs will be processed.

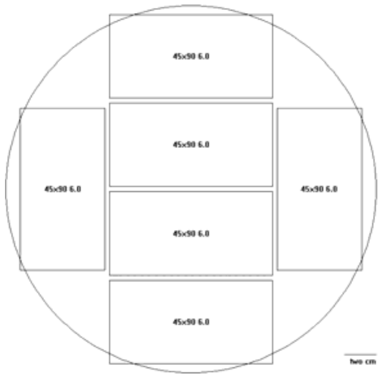
We also have the requirement that the solution yields an integer positive number for each variable. This can be overlooked when dealing with large numbers.

Now assume that there are 2 different products recovered in this sawmill: 90x45 and 140x45. Sawlogs will yield a different solution depending on which profile is used. Here is a table to represent the yields (in pieces):

Product	**Profile A**	**Profile B**
90x45	2	6
140x45	2	0



Profile A



Profile B

So, if a log is processed with Profile A it will yield 2 pieces of 90x45 and 2 pieces of 140x45, and if processed with Profile B it will yield 6 pieces of 90x45.

The equations for the production of 90x45 would look like:

$$2 * \mathit{SawlogsA} + 6 * \mathit{SawlogsB} = \mathit{90x45Prod}$$

The equations for the production of 140x45 would look like:

$$2 * \mathit{SawlogsA} = \mathit{140x45Prod}$$

Note that we have introduced "variables" to keep track of the number of pieces of 90x45 and 140x45 produced: *90x45Prod* & *140x45Prod*.

If we stop here and solve we notice there are many ways to process our sawlogs. We know what will be produced in each case, but we do not know which of these cases is the preferred one. Thus, let's add the value of the products as our objective function – the performance measure. Assume that 90x45s are worth 1.00 NZD per piece and 140x45 are worth 1.25 NZD each. Now if we solve these equations the optimum solution would be:

SawlogsA = 0
SawlogsB = 10
90x45Prod = 60
140x45Prod = 0
Value = 60

The optimum solution is to process all sawlogs with Profile B. 60 pieces of 90x45 are produced. The production value is 60 NZD.

However, let's say now that at least 10 pieces of 140x45 must be produced to fill an order. The following equation must now be added:

140x45Prod >= 10

Solving with this new equation would yield the following result:

SawlogsA = 5
SawlogsB = 5
90x45Prod = 40
140x45Prod = 10
Value = 52.5

The optimum solution is to process 5 sawlogs with each profile. 40 pieces of 90x45 and 10 pieces of 140x45 are produced. The production value is 52.5 NZD.

Of course, the previous example was a gross operational simplification. In reality, choosing the right variables and equations is an involved process.

If applicable, equations to represent:
- time available in each machine,
- cost of running each machine,
- opening and closing inventory levels,
- multiple sawlog sources,
- different finishing methods,

and many others can be easily included.

Variables need to represent reality as close as possible. For example, not all sizes of sawlogs will yield the same timber when processed in the same machine, so a variable representing each size of sawlogs should be created (e.g. instead of *SawlogsA* we could have *10cmSawlogsA*, *11cmSawlogsA*…). Once a variable is defined, the LP will treat it like a "decision", since it can be manipulated independently. Implementing the solution will require that each variable can indeed be manipulated in real life. Thus, care must be taken not to create variables that cannot be manipulated in real life. For example, the yield of sawlogs will also vary by taper, so a modeler might be tempted to create variables based on taper (e.g. *1cm/mSawlogsA*, *2cm/mSawlogsB,…*). If in reality the sorting system is unable to distinguish sawlogs based on taper, then it would not be possible to implement correctly the solution from the LP.

To account for these non-manageable issues, the modeler should include the effect of these in the yield data. For example, assume that there are low-taper sawlogs and high-taper sawlogs (not distinguishable by the sorting operator), and that it is determined that the low-taper sawlogs yield 2 pieces of 90x45, while the high-taper sawlogs yield 3 pieces of 90x45. Furthermore assume that 50% of sawlogs are determined to be low-taper and 50% high-taper. Instead of creating a variable for each (which can be treated independently by the LP), the modeler should set a yield of 2.5 pieces of 90x45 for each sawlog. This avoids solutions that cannot be implemented such as “send low-taper sawlogs to Machine A and high-taper sawlogs to Machine B”.

Setting up a Linear Programming model to represent the full operational scope of a sawmill, from log purchasing to selling timber, and perhaps even back to the harvest, takes time and a good understanding of the operations.

System Tools Required

In addition to a thorough understanding of the operations by the person setting up the model, there are a number of system requirements that are essential to a successful LP implementation:

1. A well-designed data management system. A “slick” system for data entry and report generation is essential. Without this, the user will quickly become bogged down with the mechanics of using the system, rather than spending the time analyzing alternative operating strategies.
2. A sophisticated sawing simulation program. Fundamental to a correct solution is accurate “yield” data – a measure of the timber and byproduct yields that would be produced from each sawlog class sawn with each possible method. A measure of the machine processing times required for each sawing method is also required. While this data can be determined through detailed sawing trials or mill tests, this approach is problematic for two reasons:
   - Mill test results tend to give unreliable data on the differences between alternatives;
   - Relying on historical results means limiting the options considered to sawing methods used in the past, and makes it very difficult to consider new sawing method alternatives.

   As a result, it is generally preferable for the yield data to be generated with a sawing simulation program, with the simulation model calibrated to match historical mill yields. To be effective, the sawing simulation program should consider “true” log form, rather than a simple “truncated cone” log model. This helps to ensure realistic yield data projections.

Additional Benefits of Linear Programming

LP systems have many additional benefits besides the optimal filling of orders, such as the ability to evaluate the introduction of new products. LPs can easily incorporate a new product by simply defining its dimensions, the sawing patterns that would be used to recover it and its demand.

LPs can provide information on the value of the resources and demands. For example, it can be determined that if the system had more demand for a given product then the solution would improve, or deteriorate, by a given amount. Or, it can be determined that if the system could find extra units of a given resource, like a given size of sawlogs or time from a bottleneck machine, the solution would improve by a certain amount. This gives the user an immense advantage in bargaining with customers and providers, as well as direction on which resources will most impact the performance of the sawmill.

The dependence that many sawmills have in certain key personnel leaves them in a vulnerable position. An LP system is easy to learn and use. Also, since the system can encompass the whole production cycle, from long-log to finished product, it provides the user with a unique, and extremely valuable, overview of the operations.

LPs can also be used as a long term planning tool, where the user can explore the introduction of products into new markets, or determine the benefit of potential improvements in the sawmill.

A fundamental difference between traditional production planning methods and an LP system is the time required to produce the solution. Traditional methods can take many hours, or a few days, to produce a solution, while LPs are capable of calculating the optimum solution in a few minutes. This enhancement brings more benefits than simply savings in computing time. Inevitably, after implementing the production solution of either the traditional method or an LP solution, a gap will exist between the timber produced and the production order. The difference is a consequence of variables not represented accurately, such as the assumed sawlog distribution, or the natural variability of the sawing process. Having a system that can produce an updated solution in minutes, not hours, means being able to fill the production gap efficiently by following a new optimised solution.

In conclusion, linear programming is an effective tool for optimising production to satisfy a market requirement. LP is not a “theoretical exercise”, but is instead a well-proven method used by many forest industry operations today to optimise their operations.