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Co-located mills that share a log resource through a single merchandising facility are challenged with the task of allocating the costs of joint-products in order to determine log cost for each mill during a given period. While allocating joint-costs is inherently arbitrary, some allocation must be made to include raw material in inventory cost and accurately apply the matching principle. This problem is aggravated by the technical challenges of measuring the large volume of logs often processed by mills in this situation. A co-located veneer mill and sawmill producing stud material were modeled to compare different methods for allocating log cost.

Allocation methods were compared individually to determine their sensitivity to influencing factors, and then compared as a group to determine how they relate to each other. The physical measure method was evaluated using both cubic and Scribner log scale. The estimated net realizable value method was evaluated using five different price scenarios representing different relationships of lumber and veneer value. Three examples of real world price relationships were also used. A third method, representing how at least one mill actually makes the allocation was also evaluated. This method attempts to apply a market price to log usage at the veneer mill, while

allocating the remainder to the sawmill. While most similar to the sales value at split-off method, it represents a completely different method for allocating log cost. The allocation methods were also evaluated under two different production ratios, one where the veneer mill only processed 25% of the total cubic volume, and one where the veneer mill processed 50% of the total volume.

Evaluating the allocation methods revealed that a minimum range of 2-3% of total log cost might be allocated differently based on choice of method and influencing factors such as a change in prices or log characteristics. Production ratio was found to have no effect on the relationship between different methods. The unique sales value method evaluated here dramatically allocated more cost to the veneer mill, making the sawmill look more profitable. The physical measure method using cubic measurement, however, allocated more cost to the sawmill, making the veneer mill look more profitable. The estimated net realizable value method allocated a similar portion to each mill under equal price situations where both lumber and veneer shared particular high, low, or average prices. The estimated net realizable value method, being based on relative end product values offered a more balanced allocation.

Log Cost Allocation for Multiple Mill Merchandising Systems

By

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APPROVED:

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Major Professor, representing Wood Science

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Louis M. Leatherman

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Log Cost Allocation for Multiple Mill Merchandising Systems

1. Introduction

Forest products companies, in particular those producing sawn wood products and panels, are often subject to intense pressure due to the nature of the commodity markets that govern product prices for both raw material and finished products. Raw material costs for softwood lumber are often 70% or more of the total cost (Fonseca 2005). This makes efficient utilization of raw material of paramount importance. In order to maximize the value of the available resource, companies sometimes operate two or more types of processing facilities that are co-located. One example of this is a sawmill and plywood plant combination.

When companies use this strategy, they are faced with allocating raw material cost among joint products. The forest products industry, as well as many other industries related to natural resources, face this problem. In these industries a company begins with a natural resource, in the case of the forest products industry, trees, and converts this resource into constituent components which are more useful, thus creating value. Joint products are a result of this manufacturing process. This is opposite of what most manufacturing does, where many pieces are put together to form a resulting product that is more valuable. Further complicating the accounting is the fact that the manufacturing company has little control over which products result from the joint process, and in what proportion (Lorig 1955). For example, when a tree is harvested there will be branches, a stump, and a stem which is usually divided into several parts of differing sizes. Companies can attempt to influence the natural resource, in the example by pruning or harvesting a tree at a particular age, but the fact remains that when that tree is harvested a fixed portion of each of its elements is inevitable. Taking the example one step further, when the sawmill receives a part of the stem and manufactures it, both residuals (chips, sawdust, bark, and shavings), and lumber of a variety of grades will result. Again, the sawmill can attempt to purchase logs of particular quality to influence this result, but it is inevitable that more than one product will result. Cost accountants are then faced with the daunting prospect of determining what portion of the original raw material cost should be attributed to each of the resulting constituent components.

Allocating raw material cost is necessary for Generally Accepted Accounting Principles. Managerial or executive compensation also may be based on profit, which in turn requires an allocation of joint-costs. In both of these cases the matching principle requires that revenues be matched with costs in the period they are recognized, and so an allocation is necessary. Allocation of joint-costs however is arbitrary. Because of this, many assumptions about business performance based on the allocation of joint-costs are made ambiguous. Many decisions, including pricing and production should not be made on the basis of allocated joint-costs, nor should this be a reason for allocating joint costs.

There are also other implications that cost allocation has, and it is important to keep them in mind. Measuring recovery as a factor of long log scale poses significant problems. Managers for each business unit are responsible for their unit's performance, and as such any allocation of raw material cost is a direct impact on them. This can cause conflict between business units.

Although the joint products situation has been studied for various agricultural products (Horngren et al. 2007, Chapter 16), little study has been done specific to the forest products industry. Even less has been done specific to log merchandising and none specific to merchandising for multiple co-located processing facilities.

This paper will examine log cost allocation using different methods at a co-located sawmill and veneer mill. Allocation methods include the estimated net realizable value method, the physical measure method, and a one sided transfer price. Joint log cost, log usage, recovery and other factors are modeled based on the core scenario described later in this chapter. Using this model, each log cost is allocated using the aforementioned methods. Each allocation method is looked at individually to understand its particular strengths and weaknesses. The allocation methods are also examined as a group to determine how they relate to each other, and which, if any are particularly appropriate for the co-located sawmill and veneer mill. The potential impact on operating income is also discussed.

1.1. Objectives

The objectives of this research are to:

1. Recommend a method for allocating log costs between two processing facilities utilizing a single log yard and merchandising system.

2. Determine the potential impact different log cost allocation models have on perceived profitability and performance of each mill.

1.2. Core Scenario

This paper will focus on the particular situation of a co-located sawmill and veneer mill. The sawmill in this exercise specializes in manufacturing stud length material. The veneer mill focuses on producing A-C grade veneer. These mills use only Douglas-fir logs, sawmill grades #2, #3, and #4. The two co-located mills share the log resource and a merchandising system. All incoming logs are fed through a single merchandising facility that bucks them to length and then routes them to either the veneer mill or the sawmill. The veneer mill tries to process only #2 grade material while the sawmill consumes the rest. Figure 1 illustrates the basic flow of material through the mill.

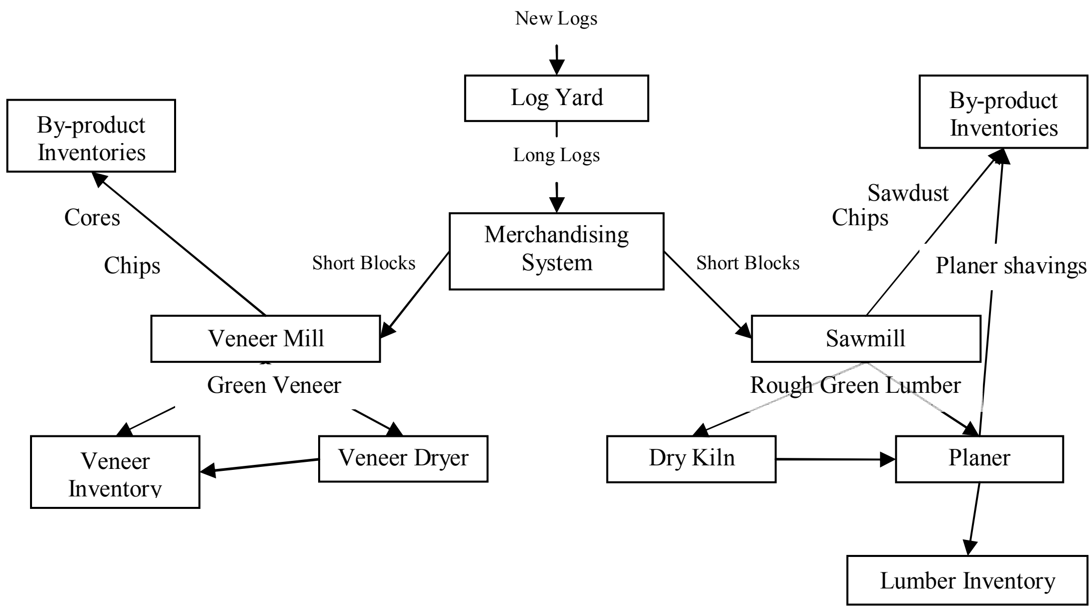


Figure 1: Flow of products from incoming raw logs to finish product inventories.

It can be seen that there are three points at which raw material is broken down from one product into a new product, the merchandiser, the veneer mill, and the sawmill. Each of these represents a split-off point in the joint products terminology. At each split-off point the joint-products problem arises. For the purposes of this paper, the split-off point at the merchandiser is the one of interest.

The common mill system for recording and measuring log inventory exacerbates the accounting problem. Joint-products present a basic, theoretical accounting problem, but the log inventory and measurement systems make this worse by introducing an information problem. Traditionally log inventory has involved two characteristics: volume and grade. Recording incoming logs is then a matter of taking length and diameter measurements to determine volume and making a visual judgment as to grade. This means someone must physically examine every log that enters the mill. In today's environment this is not economically feasible. Mills often utilize weight sample scaling to reduce the number of measurements that must be taken. In this process only certain log truck loads are graded. Data from these loads are correlated to the weight of other similar loads. The result is reduced cost, but restricted information. Inventory management software can use the sampled loads to estimate contents of the unscaled loads by diameter, grade and length, but the mill leaves these loads unsorted. This means the log input to the mill from this population of logs at any given time is unknown. It also means the accuracy of information regarding this population of logs is only as good as the error of its statistical estimates.

2. Literature Review

The literature review covers two different broad topics: log measurement, and joint products. Literature on cubic and board foot scaling is reviewed in the first section. Later sections discuss the problem of joint products, decision making, and methods for allocating joint costs.

2.1. Scaling

This section of the literature review will focus on log measurement; specifically it will address board-foot and cubic scaling. The board-foot type of scale is a method of measuring logs based on predicted lumber yield. Scales of this type have been published since at least the beginning of the nineteenth century. At the time lumber was the primary solid wood product that was manufactured from logs and so it was natural to measure logs based on the estimated lumber yield from that log (Snellgrove et al. 1984). Over the course of time, dozens of board-foot scales have been developed, presumably each one attempting to fix the perceived weaknesses of the one before it (Rapraeger 1940). Some of these scales were developed using logical mathematical techniques, but others were the result of local rules-of-thumb or diagrams. Today in the U.S. there are three major board-foot scales in use, Scribner, Doyle, and the International ¼ Rule (Briggs 1994; Fonseca 2005). The Scribner scale is based on diagramming 1-inch boards onto circles, and the other two use formulas based on log diameter.

Regardless of their differences, board-foot rules are subject to similar arguments for and against their use. The primary argument against board-foot rules is that they are simply not accurate in predicting lumber yield, particularly for smaller logs (Barnes 1945; Cope 1942; Herrick 1940; Rapraeger 1940). There are a number of reasons for this inaccuracy. When the rules were first developed, technology was crude and there was a lot of waste in the manufacture of logs into lumber. As technology improved, this waste was reduced, and as a result manufacturers were able to produce more lumber than the scale estimated (Rapraeger 1940). This extra lumber is referred to as overrun. Scribner also has many of its own peculiarities relating to overrun. The diagramming method used to create the table of Scribner board foot values resulted in a stepwise function to the rule rather than a smooth transition across diameters (Briggs 1994). The Scribner scale also did not take into account taper (Figure 2). This results in a disconnect between short log volumes and long log volumes (Staebler 1953) and logs with small or large degrees of taper. If, for instance, you scale a log at 20 feet and then buck it in two and scale each piece, the sum of those two pieces will usually be greater than the scale of the original log at 20 feet.

Those opposed to the board-foot rules argued that this was not fair and put those who did not understand the particular rule at a severe disadvantage (Rapraeger 1940; Snellgrove et al. 1984). It may even be true that the continued development of new board-foot rules was as much an attempt for one side to gain an advantage over the other as it was to provide a more accurate rule. It has been argued also that this problem in scaling affected not only those who owned the trees but those who harvested and transported those trees as well, as they are most often paid by the board foot (Rapraeger 1940). This is said to have further discouraged the harvest of small diameter trees, even when they might actually be profitably harvested (Barnes 1945). This effect he said is particularly evident in clear-cuts where many usable smaller trees may be left in the woods because they can not profitably be yarded and transported, or alternatively a loss would be taken on those trees. This is said to be a leading factor for the change to cubic measurement in British Columbia (Ker 1962).

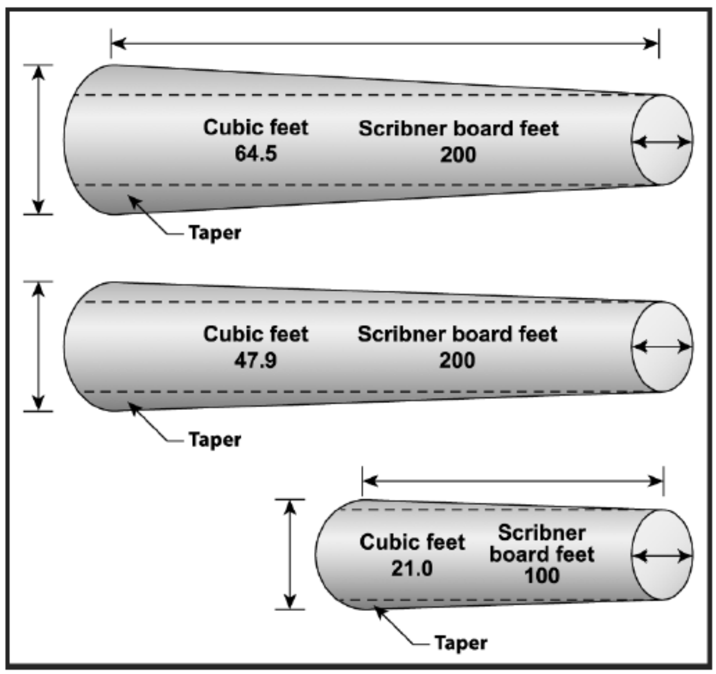


Figure 2: Scribner scale does not account for log taper (Spelter 2003)

Those in favor of board-foot rules argue that even if the rule was changed, prices would change too, effectively having no impact (Cope 1942). They also argue that smaller logs require just as much handling effort as larger logs and as a result cost more to handle on a board foot basis, thus justifying either a lower price or lower scale

(Herrick 1940). Herrick (1940) said that by undervaluing small trees, the growth of bigger trees was encouraged and that was not a bad thing.

The second major argument against board-foot rules points out the difficulty in applying the rule to non-lumber products (Rapraeger 1940). Producers of veneer, pulp and other products make up a significant portion of log buyers (Gebert et al. 2002). These products do not share the same board-foot measurement as lumber and so the usefulness of measuring the log in board-feet is eliminated. Using the board-foot rule makes measuring efficiency for these manufacturers more difficult (Rapraeger 1940). It also makes pricing more difficult for these manufacturers, which results in possible confusion for loggers and land managers trying to get the highest value for their trees (Rapraeger 1940). This argument has not been readily disputed.

The answer to the arguments against the board-foot rule has been the institution of a cubic foot rule for measuring logs. A major push for this in the U.S. came in the 1940's. This followed closely after British Columbia began using a cubic rule, although the U.S. did not officially sanction a cubic scaling method until the 1980's. Ker (1962) noted that Europe, and countries historically under European influence, have used cubic measurement for logs for much longer. Rapraeger (1940) and others argue that the cubic rule readily solves the problem of pricing logs for different products. The cubic foot is a universal measurement and makes no assumption about the end product. They also argue that cubic measurement is better for log accounting because all constituent pieces should theoretically sum to the scale of the original piece. They also argue that maintaining consistency and accuracy among scalers should be easier as well. This is due in part to much of the pressure to predict product yield being relieved from the scaler (Rapraeger 1940).

Unfortunately, not all methods for cubic scaling are created equal. As easy as it sounds, non-computer-aided cubic measurement still rarely provides the exact cubic volume of wood fiber in a log (Barnes 1945). The shape of a log is not strictly conical throughout its length. At the top it is mostly conical, in the middle parabloid and the butt neilloid (Fonseca 2005). It is difficult for one formula to account for each of these three shapes. The most common methods for measuring the cubic volume of a log are the Huber formula and the Smalian formula. The Huber method takes a measurement at the middle of the log to calculate cubic volume; the Smalian formula requires measurements at both the small and large ends.

Huber's Formula: $V = L * D^2 * .00545$

Where:

- V - Volume in cubic feet
- D - Diameter in inches at the logs midpoint

Smalian's Formula $V = (A_1+A_2)/2 * L$

Where:

- V - Volume in cubic feet
- A_1 - Area of small end in square feet
- A_2 - Area of large end in square feet
- L - Length in feet

Although some researchers have found the Huber formula to be more accurate overall, the Smalian formula is the most widely adopted for commercial scaling (Ker 1962). The reason given is that a measurement at the middle of the log is just too difficult and time consuming for commercial use. These formulas have the most trouble dealing with logs with flared butts (Barnes 1945; Ker 1962). The Canadian method simply instructs the scaler to ignore the flare and judge the diameter of the butt as if the log tapered uniformly.

Given the presence of accepted methodology and the excellent reasons to use cubic measurement, why is it still not widely used in the U.S.? Although written in 1940, Herrick presents a number of reasons why which still hold today. Summarized, these are:

- Board-foot rules are a part of our heritage, and as such easily understood and applied by everyone
- Many users do not know about the short-comings of the board-foot rule
- Board-foot rules generally favor the buyer

As the world market for timber grows, the conflict between scaling methods also grows. The U.S. is one of perhaps three countries left in the world that does not account for log volume in cubic measurement (Fonseca 2005). One important example of this is trade between the U.S. and Canada. The accepted log prices in Canada are listed in cubic meters and those in the U.S. are listed in board-foot volume. In order to properly apply tariffs, some sort of conversion between the two scales must be attempted (Spelter 2002). It is apparent that recent research has moved towards better understanding of the conversion between scales due to the lack of cubic adoption in the U.S. Although the example of Canada is important, any international log trade is subject to some scaling difficulty. A universal conversion factor has been difficult to establish, and many have said that no such factor should exist but rather depend on the particular characteristics of the resource (Snellgrove et al. 1984). A commonly used conversion factor is 4.53 m^3/MBF (Spelter 2003), or about 160 ft^3/MBF. This factor has been in wide use, but more recent studies have shown that it is no longer accurate (Spelter 2003). The timber resource has changed quite dramatically in the last 50 years, and due to the many inconsistencies in board-foot rules, the conversion factor necessarily has changed as well. Regional differences in diameter and log length and taper all can have significant impacts on a conversion factor. Spelter (2002) found that over a range of species and diameter classes as average log diameter decreased (due to the reduction in old growth harvest) the conversion factor increased to 7.18 m^3/MBF (250 ft^3/MBF)in 1998 for the coastal region of Washington state. A 1998 study (Gebert et al. 2002) of the economic benefits of the timber industry to Oregon used a conversion factor of 5.66 m^3/MBF (200 ft^3/MBF)for sawlogs and 5.15 m^3/ MBF (180 ft^3/MBF)for veneer quality logs. Although not as extreme as Spelter's finding, they still represent an acknowledgement of an increase. Fonseca (2005) recently published conversion factors for the major scales across the world, including the major board-foot rules in the U.S. Although he used spruce specifically for his study, he found similar results to Spelter, who used a variety of species from Washington State. Over all diameter classes and lengths when converting from long log Scribner to U.S. Forest Service cubic, Fonseca found a conversion factor of 5.05 m^3/MBF (178 ft^3/MBF), but his results ranged as high as 8.3 m^3/MBF (290 ft^3/MBF) for diameters less than 7.5 inches and as low as 4.6 m^3/MBF (160 ft^3/MBF)for diameters greater than 15.5 inches. Briggs (1994) also showed some examples of scale conversion, but with small samples, which highlighted the variability. He showed Scribner to cubic ratios of 5.5 m^3/MBF to 11.3 m^3/MBF (190-395 ft^3/MBF). Briggs also stated firmly that statistical sampling should be used to convert any given batch of logs from board-foot to cubic or the reverse.

One group has suggested that both methods of measuring logs need to be used to create the best business system for accounting and control purposes (Brian et al. 1975). They note that both methods have strengths and weaknesses and that the best system might incorporate the particular measurement system when its strengths were needed, but the other when they were not. In particular, they note that although cubic is universal, it does not say much more about output value than Scribner.

2.2. Joint Products

A proper review of the literature concerning joint products begins with a clear understanding of what joint products are and why they are of interest. Joint products are products that result simultaneously from a manufacturing process, known as joint production. When one is produced, the other is inevitably produced. Joint products are most commonly found in agricultural industries (Horngren et al. 2007, Chapter 16). One example of joint production is butchering. A whole cow is purchased and butchered resulting in high value steaks as well as low value hamburger. Another common but more relevant example is that of lumber production (Avery 1951). A log is purchased and lumber of a variety of qualities as well as chips and bark are produced. To put it another way joint production is like backwards manufacturing. Instead of buying many components and assembling them into something new, one component is bought and broken down into new parts. In part joint production is driven by necessity. In order to get and sell clear lumber you inevitably end up with some stud lumber and chips. Basically, someone must accept the joint production situation for clear lumber or by analogy, filet mignon, to be sold at all. Joint production is also driven by efficiency, it is assumed to be more efficient to break down the raw material into constituent components than to buy the components individually (Cole 1923; Moriarity 1975). This is more readily seen when the constituent components undergo significant additional treatment to reach their final state, such as veneer to plywood.

For accountants these situations result in a problem for allocating costs. How much of the purchase price should be allocated to each of the new parts? Filet Mignon is worth more than hamburger, but does that mean it should carry a higher burden of the total cost? Clear lumber is worth more than stud lumber, does that mean it should also carry more of the material cost? This problem has been apparent and written about since the 1920's (Cole 1923).

2.3. Decision Making and Joint Cost Analysis

Why would anyone want to allocate costs in the first place? There are several reasons (Horngren et al. 2007, Chapter 16):

- It is required by some outside agency for external financial reporting or inventory valuation for tax purposes
- It is instinctual to want to understand the complete "cost" of a particular product so you can make a decision about it
- It completes financial statements in the traditional manner (joint-cost included), making them simpler and easier to understand for a broader group of people
- Economic calculations for profit maximization may need a full cost including allocated joint-costs)
- Compensation or some other reward may depend on an allocation

No one in the literature disputes the necessity of allocating costs when it is required by an outside agency. Even Thomas (1982), an advocate of leaving costs unallocated says it is useful to allocate costs in the most ambiguous situation if it is required by an outside agency. Horngren (2007, chapter 16) as well cites this as a primary reason for allocating costs. An outside agency in turn requires joint-costs to be allocated to comply with the matching principle, so that revenues are appropriately matched to expenses within the period they are recognized. This is notable for this paper because the products produced from a co-located sawmill and veneer mill will not likely be sold in the same period they are produced. Since raw material is still a direct cost, some allocation must be made to value inventory. Debate arises around whether allocated costs can be useful to management in making decisions.

All literature on allocating joint costs begins by acknowledging that allocating joint costs is an arbitrary decision and the choice of method should be based on whatever is reasonable, logical, and cost efficient (Anonymous 1927; Avery 1951; Cole 1923). The classic economic view is the mostly widely held among scholars. This view is that since in joint production multiple products are inevitable then the decision to process them further should be based on the incremental income they provide. As long as the incremental revenue exceeds incremental costs then the product should be processed further (Lawson 1956). Essentially all costs up to the split-off point are classified as sunk, so any allocation is irrelevant. It is widely thought then that allocated joint costs should not be used for decision making purposes.

There have been some dissenters over the years. Lorig (1955) argued that joint cost allocation could be used as an aid to managerial decision making. He asserted that given a particular allocation with equal gross margins, if a result were negative that would signal to managers that a particular product might better be treated as waste rather than processed further. Lawson (1957) and Hill (1956) quickly responded to this assertion with strong arguments against his conclusions. Hill points out that basic economic theory says that if a product can be sold for more than its marginal cost plus the cost of capital then it is advantageous to do so as it contributes, however small an amount, to fixed costs. Lawson adds to Hill stating that if your allocation starts as arbitrary your result will also be arbitrary. In addition he shows that interpreting the allocation in the way Lorig recommends would result in a radical reduction in potential profit with no other benefit. The resulting decision would reduce overall company profit rather than maximize it.

Another approach taken to this problem was to apply game theory to cost allocation. Shubik (1962) started this movement and based his allocations on the Shapley value, which attempts to allocate costs based on an average contribution. He argued that through applying the mathematics of game theory an allocation could be derived that would prompt the correct decisions from management, and therefore be the correct allocation of otherwise arbitrary costs. Others followed, expanding the research started by Shubik by applying new principles to further guide the allocation (Hamlen et al. 1977; Roth and Verrechia 1979). Not everyone was convinced however. Thomas (1982) argued that the allocations obtained from these methods were no less arbitrary than other methods. Finally the results gained by game theory analysis provided no information different than could have been calculated based on original economic theory much more easily. In other words Thomas still did not buy the reason that cost needed to be allocated for management decision making.

Despite general consensus about the failure of cost allocation to be valuable fore decision making, it is also noted that companies still use allocations in their cost data used for decision making. Given this fact, as well as the necessity to report to outside agencies scholars continue to evaluate old and invent new methods for allocating joint costs.

2.3.1. Choosing a method

Allocating costs is an arbitrary matter, which makes choosing a best method for doing so subjective and open to debate. The literature offers two very simple pieces of advice for choosing a particular method: it should be low cost and easy to implement. This advice is good common sense and provides an obvious foundation for determining a method. If the nature of the situation is pondered some other considerations might also be apparent. Considering that the allocation, although not actually affecting profitability, implies something about performance, the method should be easily understood by everyone involved with evaluating performance (Thomas 1982). Given that this implication will also cause friction and debate over the allocation, the method should have some way to be validated. In other words, the method should be transparent (Anonymous 1927; Avery 1951). Everyone involved should easily be able to understand not only the calculation but also the assumptions involved and how the constituent data is taken. They should also be able to check to make sure that the assumptions are being met. Finally all the assumptions should make sense. For instance, a veneer mill should not always be charged for #2 mill logs and never get the chance at a discount because a block was taken from a #3 mill log.

2.4. Methods for Allocating Joint-costs

Over the years many methods for allocating cost have been used in the literature. Sometimes, the same method even varies from author to author. For the purposes of this review similar methods will be grouped together as they generally share the same strengths and weaknesses. Horngren et al. (2007, chapter 16) does a good job generalizing the methods. They categorize methods most generally as either based on physical measure or on market selling price data. Within the market selling price category they further break it into the relative sales value method, the estimated net realizable value method and the constant gross margin methods. Horngren (2007) do not discuss game theory, but a section here will be devoted to it as it represents a significant component to the literature of joint costs.

2.4.1. Physical Measure Method

The physical measure method allocates costs based on the ratio of physical measures at the split-off point (Horngren et al. 2007, Chapter 16). If one product has more weight or volume at the split off point it is allocated a greater portion of the total cost accordingly. Table 1 below shows how this method might work in the core scenario. For the example, total log cost is $700,000. The top line contains log volumes measured in Scribner scale at the split-off point. A ratio of each mill's processed log volume to the total determines the portion of the total log cost that will be allocated to each mill.

Table 1: An example of the physical measure method.

	Plywood Plant	Sawmill	Total
Volume @ split-off	500 MBF	1,000 MBF	1,500 MBF
Ratio of Volumes	500/1,500 = 0.33	1,000/1,500 = 0.66	1
X Material Cost	$ 700,000 * 0.33	$ 700,000 * 0.66	$ 700,000
Allocated Cost	$ 280,000	$ 420,000	$ 700,000

This method is not useable when the resulting products share no similar form of measurement. Even when they do share the same measurement, often this is deceptive. Cole (1923) uses the example of extracting silver and lead from ore, although they are both measured in weight, allocating cost based on weight might not be very equitable. Others suggest this method when the actual physical measure of a product can be tracked and the resulting end products have similar values.

2.4.2. Sales Value Method

A less used but similar method is the relative sales value method. Horngren et al. (2007, chapter 16) define this method as the ratio of sales values at the split-off point. The product with the higher value at the split-off point is allocated a larger portion of the cost. This method is less used than the other methods perhaps because sales values of joint products at the split off point are perhaps not as readily available as end product values. The lack of an outside value for the product at its split-off point is one of the main drawbacks of this method.

Moriarity (1975) presents an alternative way to look at this method. He suggests comparing the cost of obtaining the constituent products individually to the joint production and allocating the savings. Table 2 provides an example of how this method might work in the core scenario. In this example total log cost was again chosen to be $700,000. The top line is the volume of short logs in Scribner board feet. The next line is a hypothetical price on the open market. The product of these two is a total market value for the short logs going to each mill for the month. A ratio of each mill's value to the total determines the portion of total log cost (far right column, bottom line) to be allocated to each mill.

Table 2: An example of the textbook sales value method.

	Veneer Mill	Sawmill	Total
Volume @ split-off	500 MBF	1,000 MBF	1,500 MBF
Estimated Value	$ 600/MBF	$ 500/MBF	
Total value	$ 300,000	$ 500,000	$ 800,000
Value ratio	300/800 = 0.375	500/800 = 0.625	800 MBF
Weighted value	$ 700,000 * 0.375	$ 700,000 * 0.625	$ 700,000
Allocated cost	$ 263,000	$ 437,000	$ 700,000

2.4.3. Net Realizable Value Method

The net realizable value method allocates joint costs based on final product value less estimated separable costs (Horngren et al. 2007, chapter 16). The theory is that joint costs should be weighted based on end product value. If a more valuable product is produced then that product should bear a greater portion of the log cost. Table 3 provides a simple example of the NRV method. Total log cost is again set at $700,000. The top most line of the table offers the gross end product values for each mill, below that are the separable costs associated with each mill. The result is the net realizable value. A ratio of the net realizable value for each mill to the net realizable value of all products for the site provides the portion of the total log cost that will be allocated to each mill.

Table 3: An example of the net realizable value method.

	Plywood Plant	Sawmill	Total
Product Value	$ 400,000	$ 600,000	$ 1,000,000
Less separable costs	$ 100,000	$ 150,000	$ 250,000
Net Realizable Value	$ 300,000	$ 450,000	$ 750,000
Weighting	300/750 = 0.4	450/750 = 0.6	1
X Material Cost	$ 700,00 * 0.4	$ 700,00 * 0.6	$ 700,000
Allocated Cost	$ 280,000	$ 420,000	$ 700,000

A basic strength of this method over the physical measure method is that there needs to be no common measurement among products. The main argument for this method is that higher end product values are directly linked to higher costs in most products, thus it is no stretch to allocate more cost to the product with a higher end value for joint-products. Opponents often note that this method is highly subject to demand fluctuation and that unfairly changes the allocation. If demand drops for one end product, then its value also drops, thus shifting cost to the other joint product.

Given that nothing has changed with the other product, why should it bear a heavier burden than before? Often however, the other methods are not viable. The NRV method is particularly useful when physical measure is not appropriate and a sales value at split-off is simply not available.

Closely related to the net realizable value method is the constant gross margin method. Horngren et al. (2007, chapter 16) classify this method as a variant of the net realizable value method, but the exact application has varied. Lorig (1955) applied the overall constant gross margin to his NRV method, but argued against applying separable costs. He argued that "every dollar invested is equally profitable" and as such all products should share the same gross margin percentage. He also believed that applying separable costs after the allocation allowed management to make decisions about whether or not to process the product further. Lawson (1956) denies Lorig's claim that each dollar invested should be equally profitable, but this claim is still the argument for applying a constant gross margin.

2.4.4. Game Theory Allocations

An alternative to all of these methods is the use of game theory. Shapley allocations are the focus of much of the research. The Shapley allocation is an average of different allocations that order the importance of a set of products (Roth and Verrechia 1979; Tijs and Driessen 1986). A key concept in these allocations is that of the core. The concept of the core is an attempt to provide boundaries to allocations such that it would not be more beneficial to a team to work separately than together (Hamlen et al. 1977). In other words if it cost you $10 to do something on your own, but $20 for a group of three, you would not expect to pay any more than $10 yourself, otherwise there would be no benefit to going in the group. Those advocating this methodology argue this makes logical sense as it maintains the necessity of teamwork, and perhaps provides some sense of actual product profitability. Thomas (1982) argues that this methodology does not provide any better information than any other cost allocation method.

There is debate about whether these allocations provide any better representation of cost than the other methodologies (Thomas 1982) Further, these allocations are complicated and require a relatively high level of economic and mathematical understanding to properly employ. One important part of choosing a method is that it be transparent and easy for everyone to understand. As the benefit of using game theory is unclear and it also moves against one of the objectives of this study it will also be excluded.

3. Methods

This chapter details the preparation of a theoretical exercise designed to evaluate the methods described in the literature review. This exercise uses the core scenario described in the introduction as a model to employ the cost allocation methods found in the literature review.

3.1. Scenarios

Two different factors were used to develop scenarios for this exercise: price and production ratio. Price scenarios are used primarily to test the volatility of the NRV method while production ratio scenarios are used to test all the methods. Five different price scenarios were evaluated:

- High lumber and high veneer prices (HLHV)
- High lumber and low veneer prices (HLLV)
- Average lumber and average veneer prices (AVAL)
- Low lumber and high veneer prices (LLHV)
- Low lumber and low veneer prices (LLLV)

These categories were further segregated into theoretical scenarios and real world scenarios. In the theoretical scenarios statistical highs, lows, and averages were paired. Price data from 1999-2006 were evaluated. In the real world scenarios certain months that represented similar relationships were chosen. Similar relationships meant choosing times when lumber prices were significantly higher than veneer prices in their respective ranges or vice versa. Not surprisingly some of the theoretical relationships have not actually occurred in the past. More often in the real world scenarios high or low prices in one product were paired with average prices of the other. The one exception was low lumber and low veneer prices. In 2003 both lumber and veneer happen to have been close to the very bottom of their respective ranges. In the end, only three real world scenarios were used.

Two different production ratios were evaluated: equal production (50/50) and weighted sawmill production (25/75). These two represent the most likely real world scenarios. These ratios fluctuate all the time in real life in response to demand and price pressures. The important facet of doing these different production ratios is to discover if and how the allocation methods relate to each other under changing conditions.

3.2. Equations

This section details the equations used to determine log cost and calculate each of the methods used to allocate log cost in this paper.

3.2.1. Log Volume and Cost

The number at the core of this exercise is log cost. Log cost is a product of volume and price. As described in the core scenario, the two mills share the log resource through a single merchandising facility. The merchandiser represents the split-off point. Everything before it is a shared or joint cost, and everything after it applies to each mill individually. Log cost for this exercise is determined by choosing a total log volume in Scribner board feet and distributing between the three log grades (the core scenario stated that the log yard consists of #2, #3, and #4 sawmill grade logs). Equation 1 expresses this distribution. Log volumes for each grade are paired with prices for that grade to determine a total cost for each grade, this is equation 2. The sum of these is the total log cost and equation 3. The physical measure and sales value method also require cubic volume, equation 4 was used to convert the log volume of each grade from board feet Scribner to cubic feet.

Equation 1: Scribner volume by grade.

$$SV_g = TSV * D_g$$

Equation 2: Log cost by grade.

$$C_g = SV_g * P_g$$

Equation 3: Total log cost.

$$TLC = \sum C_g$$

Equation 4: Cubic volume by grade.

$$CV_g = SV_g * F_g$$

Where:

g	- Log grade
TSV	- Total Scribner Volume in board feet
D	- Distributed portion as percentage of the total
C	- Cost in dollars
P	- Price in dollars per MBF
TLC	- Total log cost in dollars
SV	- Scribner Volume in board feet
CV	- Cubic volume in cubic feet
F	- Scribner to cubic conversion factor in ft^3/MBF

3.2.2. Physical Measure

Calculating the physical measure method is straightforward. As described in section 2.4.1 of the literature review the physical measure method allocates cost based on a ratio of some physical measurement. Two measurements of volume are used, cubic feet and board feet Scribner scale. Also, as described in section 3.1 of this chapter two different production ratios, 25/75 and 50/50, are used for comparing these methods. These production ratios form the basis of the physical measure method and modeling log input to each mill. The starting point for determining log cost is Scribner volume for long logs as this is the standard basis for price and measurement.

Scribner volumes for each grade must then be converted to cubic volume with help from a conversion factor. The total cubic volume is used as the basis for the production ratio division. In the 25/75 scenario, 25% of the total cubic volume is assigned to the veneer mill and 75% to the sawmill. In the 50/50 scenario, each mill gets 50% of the cubic volume. Allocating log cost based on the ratio of cubic volumes is simply a matter of applying these ratios to the total log cost, as shown in Equation 5.

Equation 5: Physical measure cubic allocation.

$$LC_m = TLC * CR_m$$

Where:

m	- either sawmill or veneer mill
LC	- Log cost in dollars
TLC	- Total log cost in dollars
CR	- Cubic ratio as a percentage of the total

The alternative unit of measurement is board feet Scribner. To determine short log Scribner volumes, the portion of cubic volume is then converted back with help from a second set of conversion factors, this is equation 6. The resulting Scribner volumes creates a new ratio that is used to reallocate log cost and is compared to the cubic volume allocation, this is equation 7.

Equation 6: Converting cubic volume to short log Scribner.

$$SR_m = \frac{TCV * CR_m * SF_m}{\sum (TCV * CR_m * SF_m)}$$

Equation 7: Physical measure Scribner allocation.

$$LC_m = TLC * SR_m$$

Where:

m	- either sawmill or veneer mill
LC	- Log cost in dollars
TLC	- Total log cost in dollars
CR	- Cubic ratio as a percentage of total cubic volume
SR	- Scribner ratio as percentage of total Scribner volume
TCV	- Total cubic volume in cubic feet
SF	- Conversion factor, short log Scribner in ft^3/MBF

3.2.3. Sales Value

The sales value method used in this paper is not the true sales value method. As described in section 2.4.2 of the literature review the sales value method allocates cost based on the ratio of product values at the split off point. There exists no true market value for the type of short logs present in the case scenario described in the introduction. Discussions with one mill revealed that a method similar to the sales value method is actually used. This method, involves applying a transfer price to the log volume used by the veneer mill to determine log cost for the veneer mill. This cost is subtracted from the total cost to determine log cost for the sawmill. As this method is actually used by at least one sawmill it is included here for comparison purposes.

The concept of this method is to determine how much the veneer mill would have paid for logs, had it bought them independently on the open market and merchandised them separately. To accomplish this, a set of conversion factors is once again necessary. In this paper, the equations convert the long log Scribner price to a cubic price (equation 8), and then apply that to the cubic volume used at the veneer mill as found in the physical measure method (equation 9). The remainder belongs to the sawmill (equation 10). In case of the real mill doing this, they attempted to convert short log volumes to long log volumes and then apply the long log price. The net effect is the same.

Equation 8: Cubic price.

$$CP_g = \frac{LSP_g}{CF_g}$$

Equation 9: Sales value veneer mill log cost.

$$LC_v = CP_{\#2} * CV_v$$

Equation 10: Sales value sawmill log cost.

$$LC_s = TLC - LC_v$$

Where:

g	- Log grade
v	- Veneer mill
s	- Sawmill
CP	- Cubic price in dollars per MBF
LSP	- Long log Scribner price in dollars per MBF
CF	- Cubic conversion factor in ft^3/MBF
LC	- Log cost in dollars per MBF long log Scribner
CV	- Cubic volume in cubic feet
TLC	- Total log cost in dollars

3.2.4. NRV

The NRV method is the most complicated of the three used in this paper. As described in the literature review the NRV method uses a ratio of end product values to determine how joint-costs should be allocated. In order to calculate the allocation of log cost using this method, the log input and subsequent product output of each mill must be modeled. Log input is based on the cubic ratio set forth in the physical measure method. Using this cubic volume, product recovery is modeled using the recovery factors. For each product, recovery was measured in the unit appropriate to its final sale. Equations 11 and 12, describe product recovery for the sawmill.

Equation 11: Lumber recovery.

$$V_l = CV_s * LRF$$

Equation 12: Sawmill residual recovery.

$$V_r = CV_s * CRF_r$$

Where:

r	- Residuals (chips, sawdust, and shavings)
l	- Lumber
s	- Sawmill
V	- Product Volume in board feet, or ft^3
CV	- Volume of logs processed in ft^3
CRF	- Cubic feet of residual per cubic foot of log
LRF	- Board feet of lumber per cubic foot of log

Equations 13 and 14 describe product recovery for the veneer mill.

Equation 13: Veneer recovery.

$$V_v = CV_{vm} * VRF$$

Equation 14: Veneer mill residual recovery.

$$V_r = CV_{vm} * CRF_r$$

Where:

v	- Veneer
r	- Residual (chips and cores)
vm	- Veneer mill

V - Product volume in square feet 3/8" or ft^3
CV - Cubic volume of logs processed
VRF - Square feet of veneer (3/8") per cubic foot of log
CRF - Cubic feet of residual per cubic foot of log

Residuals are generally sold by the bone dry ton, so conversion from cubic feet to bone dry tons is necessary. This requires assumptions about moisture content and related density. Equation 15 describes this.

Equation 15: Volume to weight conversion

$$T_r = \frac{V_r * D * CF}{2000}$$

Where:
r - Residual
T - Tons
V - Volume in ft^3
D - Density assumption lbs/ft^3
CF - Conversion factor to bone dry weight

With an estimate of quantities for all the end products, prices can be applied and the total end product value found (equation 16). The sum of all end product values produces a gross realizable value for each mill (equation 17). From there, manufacturing cost can be deducted to determine net realizable value (equation 18).

Equation 16: End product values.

$$EPV_p = Q_p * P_p$$

Equation 17: Gross realizable value.

$$GRV_m = \sum_p EPV$$

Equation 18: Net realizable value.

$$NRV_m = GRV_m - (MfC_p * V_p)$$

Where:

p	- Product (lumber, veneer, chips, sawdust)
m	- Mill (sawmill, veneer mill)
EPV	- End product value in dollars
V	- Product volume in board feet, square feet, or tons
Q	- Quantity in relevant unit
P	- Price per relevant unit
MfC	- Manufacturing cost per unit (lumber and veneer only)
GRV	- Gross Realizable Value in dollars
NRV	- Net Realizable Value in dollars

3.3. Assumptions

The highly sensitive nature of cost and recovery information to mills makes acquiring that data very difficult. In the absence of hard data from a mill, a number of assumptions need to be made in order to simulate the core scenario and execute each method. The previous section identified three methods to be used for allocating log costs in this study: physical measure, sales value, and estimated net realizable value (NRV). The following is a list of necessary inputs.

- Total log cost
    - Log volume, by grade
    - Log price, by grade
- Conversion Factors
    - Cubic to long log Scribner, by diameter class
    - Cubic to short log Scribner, by diameter class
    - Green volume to bone dry weight
- Recovery Factors
    - Cubic recovery for a sawmill
    - Cubic recovery for a veneer mill
    - Lumber recovery factor
    - Veneer recovery factor
    - Long and short log overrun
- Manufacturing Costs
    - Per unit cost to manufacture lumber

  - Per unit cost to manufacture veneer
- End Product Prices
  - Lumber
  - Veneer
  - Chips
  - Sawdust
  - Shavings

3.3.1. Total Log Cost

Log prices are readily available from the Oregon Department of Forestry. Quarterly prices all the way back to 1977 are available (Oregon Department of Forestry 2007). Log prices are seasonal, peaking in Spring and Summer and bottoming in Fall and Winter. Prices are also subject to larger cyclical changes in the demand for logs. Finally prices are influenced by changes in log availability. For the purposes of this paper, Douglas-fir prices for the northwest region from the 2nd Quarter of 2006 were used. These prices are recent and similar to prices during the times chosen for the real world scenarios. Also important to price selection was the relationship of the price of each grade. Most of the time #2 sawmill grade logs have a higher price than #3 and so on, but occasionally, this is not true. It is important then that the price period chosen maintain a normal price relationship, rather than an anomalous one.

Log volume usage for one month was chosen to represent a mill scenario potentially similar to one in the real world. The final volume chosen was 6000 MBF. Log usage for the co-located mills is limited to the three primary sawmill grades. The first step to determine log usage is to decide in what proportion each of these grades is present. Two production scenarios will be used in the following examples, one in which the sawmill uses 75% of the raw material, and one in which the sawmill uses

50% of the raw material. With this in mind, the portion of #2 sawmill grade logs should be enough that in the 25/75 scenario, the veneer mill could theoretically use all #2 mill grade material and still leave some for the sawmill, but the portion should be small enough that in the 50/50 scenario, the veneer mill must pull some portion from other log grades. While still mostly subjective, portioning log grades in this way may provide some additional insight. The remaining portions of #3 and #4 grade logs were weighted in favor of #3 grade logs. Table 4 shows the final assumptions for log cost.

Table 4: Log cost and volume assumptions.

Log Grade	Cubic Volume (ft^3)	Conversion Factor (ft^3/MBF)	Scribner Volume (MBF)	Portion	Price (MBF)	Cost
#2 Sawmill	496,617	220.72	2250	37.50%	$650	$1,462,500
#3 Sawmill	573,869	294.29	1950	32.50%	$615	$1,199,250
#4 Sawmill	605,400	336.33	1800	30%	$595	$1,071,000
Total	1,675,886		6,000	MBF		$3,732,750

3.3.2. Conversion Factors

In the literature review of this paper it was found that converting between Scribner and cubic scaling is often difficult due to the high level of variation in factors influencing the conversion such as taper and diameter class. In order to apply the sales value and physical measure methods without hard data from a mill, using conversion factors is necessary. The core scenario as laid out in the introduction is conducive to overcoming the difficulty of conversion. As stated in the core scenario, the veneer mill processes #2 sawmill grade logs, with an average diameter class of 15-16 inches. In this particular situation, a more solid case for the reliability of conversion can be made. Much of the variation may be overlooked given the particular diameter class and the size of the population in this exercise.

Conversion factors were obtained from Fonseca (2005). Important for this exercise is converting Scribner values for logs 32-40 feet in length to cubic feet across the diameter range of 6-24”. Another important conversion is cubic feet to Scribner scale in logs 8-12 feet in length with an average diameter of 16 inches. Also of interest is the ratio of long log Scribner values to short log Scribner values. Table 5 lists the conversion factors used.

Table 5: Conversion Factors

Long log Scribner (1 MBF)		Cubic Feet
5-7 inch diameter	=	336.33
7-11 inch diameter		294.29
11-15 inch diameter		220.72
Short log Scribner (1 MBF)		
15 inch diameter		177
Long to Short (1 MBF)		1.25

3.3.3. Recovery Factors

The volume of lumber was determined by applying generally agreed upon recovery factors (Fonseca 2005; Steele 1984; Willits and Fahey 1988) to the theoretical volume of logs processed at the sawmill. Similarly, generally agreed upon cubic recovery factors (Fonseca 2005; Willits and Fahey 1988) for by-products were used to convert the initial cubic log volume into cubic volumes of chips, shavings, and sawdust. These green volumes were then converted to bone dry tons as that is the standard unit of measure for these products.

The volume of veneer produced was also determined by applying generally agreed upon recovery factors to the theoretical volume of logs produced at the veneer mill (Clark 1957; Fahey 1991). Chip and peeler core volumes were determined by applying cubic recovery ratios to the volume of logs processed (Fahey 1991). Table 6 shows the recovery factors that were used. Percentages represent the portion of cubic volume to end in these products, while VRF and LRF convert cubic volume to either square feet or board feet.

Table 6: Mill recovery assumptions.

Recovery Matrix			
Sawmill		Veneer Mill	
LRF	9.8	VRF	18.50
Chip Volume	30.40%	Grades a/b	30%
Sawdust Volume	7.30%	Grades c/d	65%
Shavings Volume	8.70%	Utility grade	5%
		Chip Volume	32.90%
		Core Volume	3.80%

3.3.4. Manufacturing Costs

Manufacturing costs can vary widely for producing lumber. When considering manufacturing costs, there is also some question about whether or not to include both fixed and variable costs, or just variable costs. Most publications dealing with sawmill manufacturing costs include only variable costs. This is inline with economic theory as fixed capital costs are sunk and should play no role in making production decisions. In either case, coming up with a manufacturing cost is quite difficult as different mills have radically different fixed to variable cost ratios. In the end a range of $50-$75 per MBF was settled on. This is based on personal communications with managers in the industry (Dickey 2007; Kundert 2006) and represents a modern low cost producer.

Determining veneer manufacturing costs has the same difficulties as determining the manufacturing costs for the sawmill, but there is even less published on the subject. From census data (Industry Canada 2007), confirmed by personal communication (Freres 2007), veneer manufacturing costs were determined to be between 20% and 25% of the price of veneer. The composite veneer price determined using the distribution of veneer grades listed in Table 6 shows a range of between \$200 and \$300/MBF, with an average value of about \$240/MBF. This offers us a range of between \$40 and \$70 per thousand square feet (3/8" basis) with an average of about \$55.

3.3.5. End Product Prices

Prices for lumber and veneer were found using Random Lengths 2006 Yearbook (Random Lengths Publications Inc 2007b). The Yearbook offers monthly prices back to 1999. Chip prices were obtained from Random Lengths monthly Yardstick publication (Random Lengths Publications Inc 2007a). Some sawdust and shaving prices were obtained from Stewart et al. (2004) although they represented prices in the mountain west. Slightly higher, but similar prices were later confirmed by personal communication (Mitchell 2007). Core prices were determined by comparing them to similar sized fence posts and converting to a per ton price. Table 7 below details the prices used.

Table 7: Product price assumptions.

	Lumber	Veneer	Chips	Sawdust & Shavings
Statistical				
High	$496	$298	$140	$13
Average	$350	$250	$70	$6
Low	$253	$191	$40	$0
Real World				
HLLV - Aug, 2004	$469	$259		N/A
LLHV - Apr, 2006	$365	$298		N/A
LLLV - Apr, 2004	$278	$191		N/A

4. Results and Discussion

In this chapter the methods presented in chapter 3 are applied to the core scenario and evaluated. Each method is analyzed individually to discover any sensitivity it may have to the assumptions used, as well as to its basic inputs. All of the methods are compared to each other under a variety of different scenarios that might result in different relationships. The methods are further compared with respect to operating income. Finally, the results of this analysis are discussed with respect to utilizing one of these methods in an actual mill setting. This component is itself divisible into two sub-components: allocating log costs according to several methods and comparing these allocations.

4.1. Internal Evaluation

This section will look at how the chosen inputs and assumptions impact each of the methods used in the exercise.

4.1.1. NRV

Figure 3 below shows the NRV allocation of each price scenario. It can be seen that the NRV method is predictably sensitive to changes in product values. Figure 3 below also shows that whenever product values are in similar positions within their respective ranges, the allocation also remains similar. If both lumber and veneer prices happen to be at their respective highs, lows, or averages the allocation is similar. The range of allocation between these scenarios is about 3% of the total log cost. This small percentage, however, represents approximately $112,000 per month in this model.

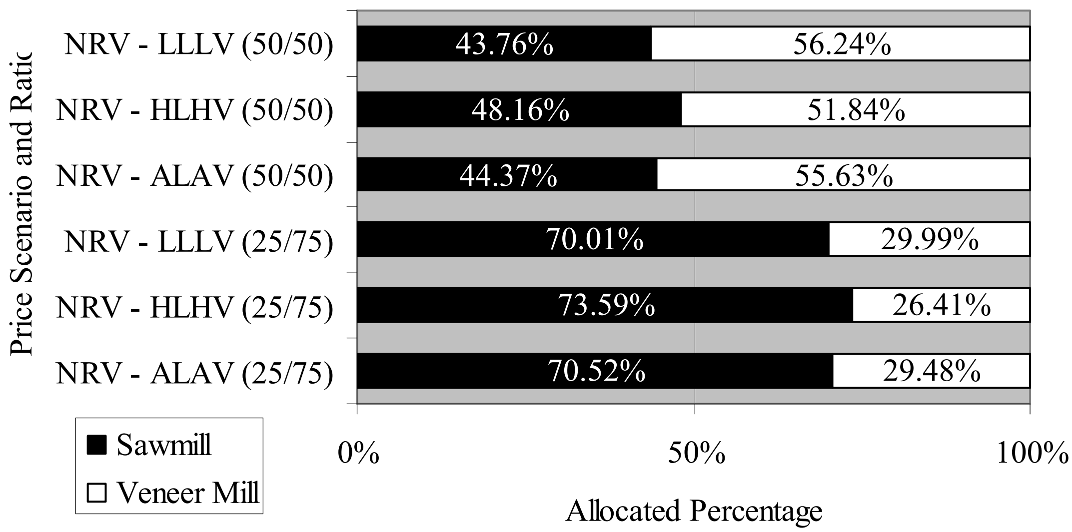


Figure 3: Comparing the NRV allocation in the ALAV, HLHV and LLLV scenarios.

As discussed earlier, manufacturing cost can be highly variable among sawmills and veneer mills in operation. A sensitivity analysis, evaluating a range of potential manufacturing costs offers some insight into how the NRV allocation might look for mills with different operating costs. As a portion of total cost, manufacturing cost is more significant to the sawmill, so analysis is limited to evaluating lumber manufacturing costs.

Figure 4 shows the percentage of log cost allocated to the sawmill under the HLLV and LLHV price scenarios with a production ratio of 25/75. Changing the lumber manufacturing cost resulted in a range of between 3% and 10% of the total log cost being reallocated. When lumber values were high the range was closer to 3% and when lumber values were low the range was closer to 10%. Looking at a range of manufacturing values in each scenario shows that the higher product values reduce the impact of manufacturing cost. As product values increase manufacturing costs become a smaller portion of the total and thus differences in this number have a smaller impact.

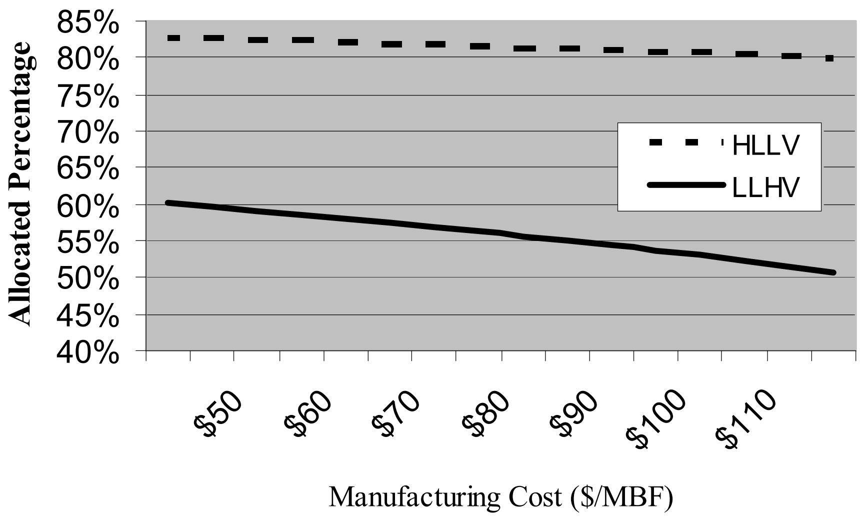


Figure 4: Sensitivity of the NRV method to manufacturing cost.

This means that changes in lumber manufacturing cost can have a significant impact, but unless lumber values are really low it takes a change in the tens of dollars per MBF to effect a large change on the allocation. Even when lumber prices are low it takes a change in manufacturing cost of $5/MBF to reallocate 0.5% of the total cost. The NRV method, while sensitive to relative differences in manufacturing cost between mills, probably is not severely sensitive to changes in manufacturing cost within a particular mill.

4.1.2. Physical Measure

As described in the literature review portion of this paper, Scribner measurements more dramatically underestimate volumes as diameter decreases. Smaller diameter logs are also more likely to have more taper than larger diameter logs. For this reason it is expected that allocating costs based on Scribner volumes will favor the sawmill.

This prediction is shown to be true in both of the production ratio scenarios. Figure 5 illustrates the difference between the two physical measure methods in the ALAV price and across both production scenarios. In the 25/75 scenario comparing the ratio of short log Scribner volumes to the ratio of short log cubic volumes allocates about $166,000 more to the veneer mill than to the sawmill. In the 50/50 scenario about $200,000 is moved from the sawmill to the veneer mill.

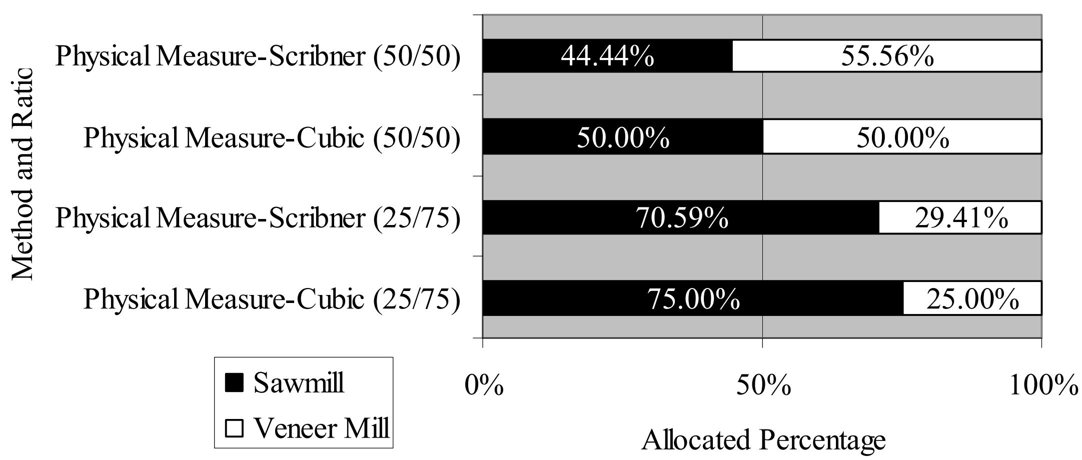


Figure 5: Comparing cubic and Scribner measurement.

Many mills continue to use Scribner scale as the primary form of measuring short logs. This is done even though cubic volume is used to measure recovery. While only a theoretical scenario, the results here clearly illustrate how different measurement scales present very different pictures of the same situation. Table 8 shows the details of the physical measure calculation. The second column shows the distribution of cubic volume between the two mills based on the production scenario. The third and fourth columns show the conversion of the cubic volume to short log Scribner scale. The last two columns show the portion of cost to be allocated, and the actual allocated cost.

Table 8: Physical measure method allocation results.

	Cubic Feet			Portion	Allocated Cost
		25/75			
Cubic Measurement					
Sawmill	1,256,914			75.00%	$2,799,563
Veneer Mill	418,971			25.00%	$933,188
Total	1,675,886				
Scribner Measurement		Conversion Factor	Scribner MBF		
Sawmill	1,256,914	221	5695	70.59%	$2,634,882
Veneer Mill	418,971	177	2373	29.41%	$1,097,868
Total	1,675,886		8067		
		50/50			
Cubic Measurement					
Sawmill	837,943			50.00%	$1,866,375
Veneer Mill	837,943			50.00%	$1,866,375
Total	1,675,886				
Scribner Measurement		Conversion Factor	Scribner MBF		
Sawmill	837,943	221	3796	44.44%	$1,659,000
Veneer Mill	837,943	177	4746	55.56%	$2,073,750
Total	1,675,886		8542		

In the 50/50 scenario, if only Scribner values are used to determine how much log volume each mill is using, the veneer mill looks like it uses 25% more log volume than the sawmill when they are using the same cubic volume. In the 25/75 scenario the veneer mill is allocated 29.4% of the cost, 4.4% more than the base 25% (see Table 8).

Analysis of the underlying assumptions for conversion factors shows that the equation is very sensitive to both conversion factors, but of the two conversion of veneer usage is more critical. Figures 6 and 7 show three different conversion factors for sawmill material over a range of values for conversion of veneer mill material. Each figure represents one of the production ratios. The three lines share similar slopes and indicate a potential range of +/- $150,000 from the chosen conversion factor for veneer mill usage. Similarly the three lines are consistently separated by around $100,000. The resulting total range is close to $500,000.

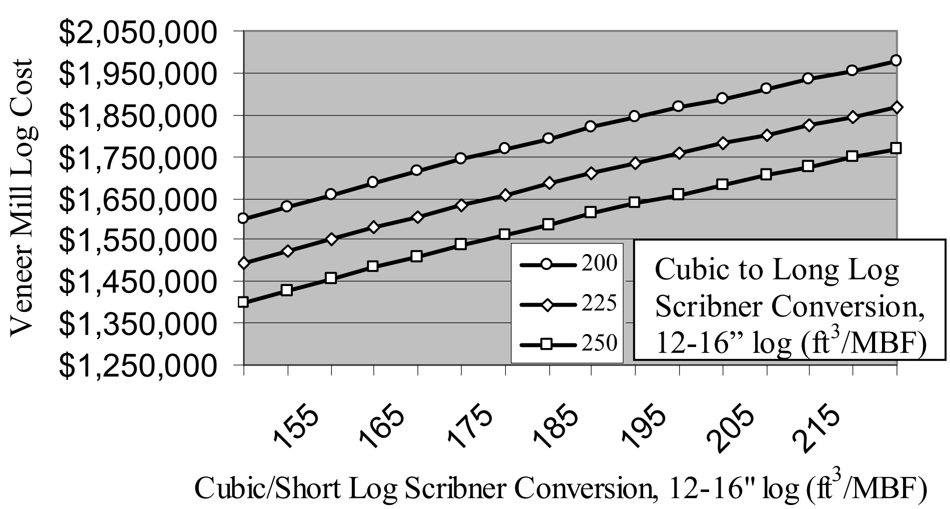


Figure 6: Physical measure conversion factor sensitivity for the 50/50 ratio.

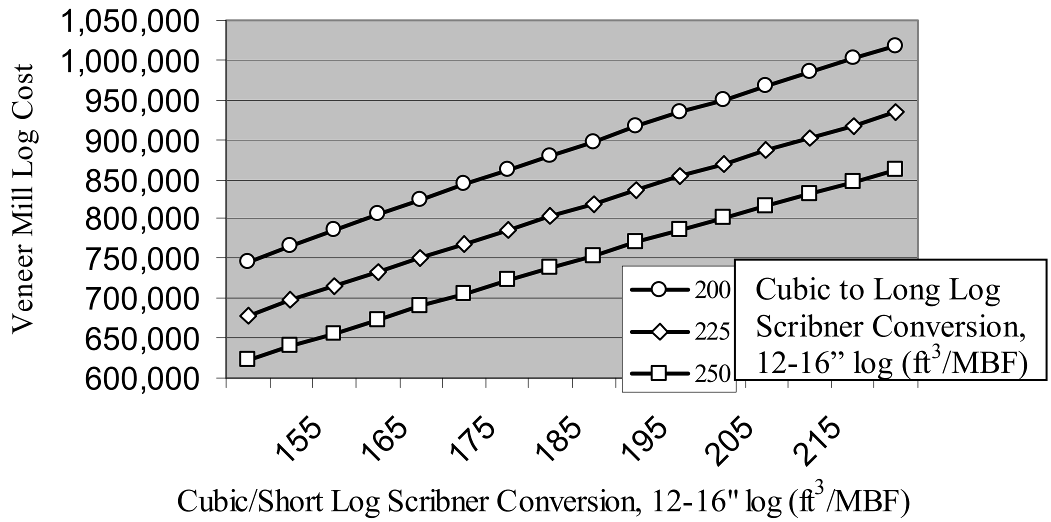


Figure 7: Physical measure conversion factor sensitivity for the 25/75 ratio.

4.1.3. Sales Value

The sales value method as presented here attempts to either develop a transfer price or determine the price the veneer mill would have paid had it obtained its log supply separately and on the open market. To do this, conversion factors were used to create an absolute price.

The sales value method is sensitive to the various conversion factors used to develop the aforementioned absolute price. Figures 8 and 9 illustrate this sensitivity for both methods of finding an absolute price (cubic and Scribner conversion). The two graphs are similar in their ranges over the entire spectrum of plausible conversion factors, from around \$1 million to \$1.5 million. In the most likely range of conversion factors the allocation has a range of about \$150,000. This method appears to benefit the sawmill in all respects. Even if all logs were purchased at the same price, the smaller taper and larger diameter processed at the veneer mill would mean a higher cost per cubic foot. The additional cost of the higher grade log further increases the cost to the veneer mill.

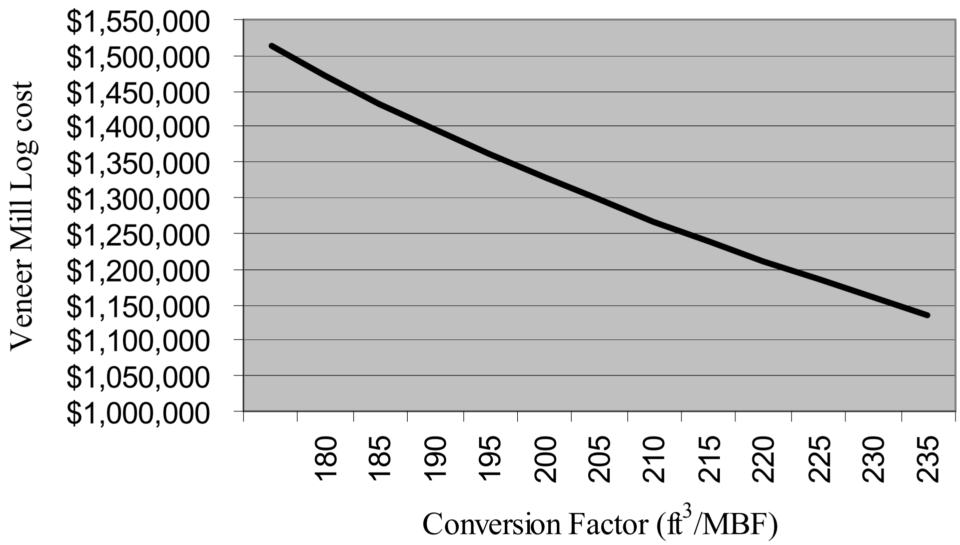


Figure 8: Sales Value sensitivity to Cubic Conversion

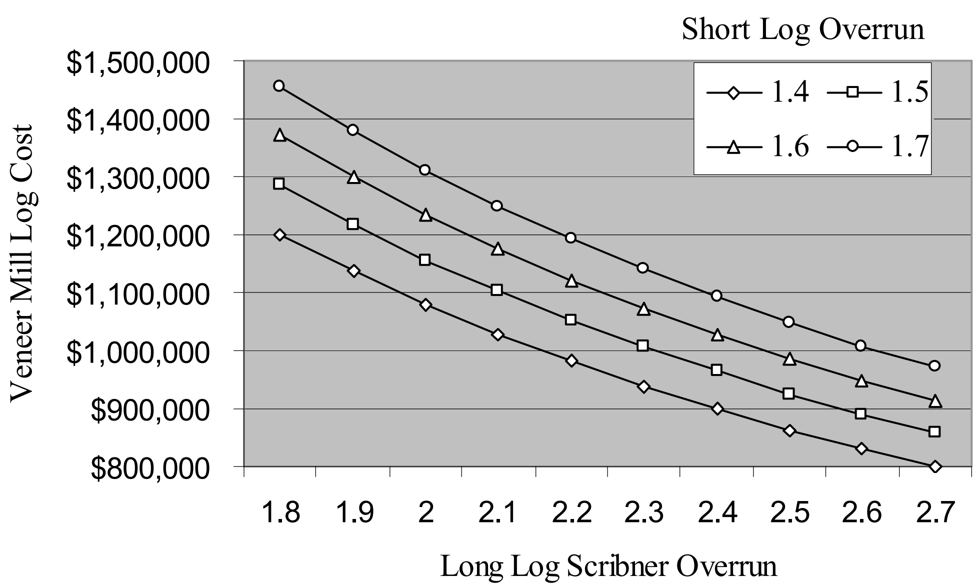


Figure 9: Sales Value Sensitivity to Overrun Conversion

4.2. External Evaluation

This section begins by comparing the sales value and physical measure methods which do not change among the different price scenarios and finishes with additional comparisons to the NRV method in its various price scenarios.

Looking at the physical measure method and the sales value method, which stay static in the price scenarios, it can be seen that the sales value/transfer price method always allocates more cost to the veneer mill than either of the two physical measure methods. As discussed earlier, using the Scribner scale to compare volumes in the physical measure method always allocates more cost to the veneer mill. Figure 10 shows a comparison of both physical measure methods and the sales value method in the ALAV price scenario across both production scenarios.

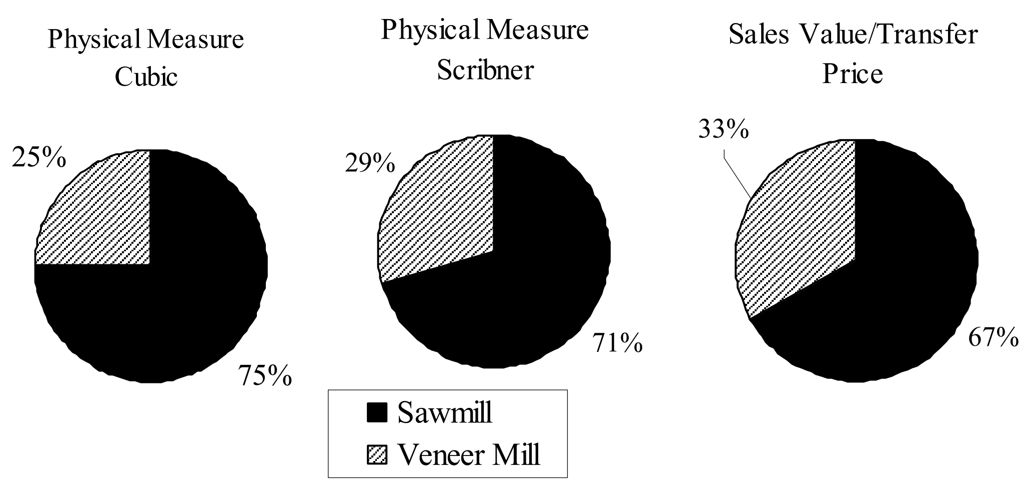


Figure 10: Physical measure and sales value/transfer price comparison.

In the 25/75 production scenario, using the Scribner scale for physical measurement moves the ratio closer to 30/70, and the sales value method moves the ratio even further to 33/66. . In absolute dollars this means the veneer mill pays $300,000 more for its raw material each month using the sales value method than it would under the strict physical measure cubic method, and $130,000 more than the physical measure Scribner method. In the 50/50 scenario, using the physical measure Scribner method moves the ratio to 56/44, and the sales value method moves it even further to 66/33. In the 50/50 scenario the difference in dollars is even more pronounced with the veneer mill paying $600,000 more using the sales value method than the physical measure cubic and $400,000 more than physical measure Scribner.

Comparing these to the NRV method is more complicated due to the fluctuation of the NRV allocation in various price scenarios. In the NRV section it was found that when product prices were in similar positions in their price ranges (that is when both lumber and veneer were at their statistical average, or high/low) that the allocation was comparable. Given this, rather than look at each scenario individually, all three of the equal price scenarios are examined together.

Figures 11 and 12 compare all four methods in the ALAV, LLLV and HLHV, price scenarios across both production scenarios. Comparing the NRV allocation to the other methods in those scenarios reveals that the NRV method is comparable to the physical measure Scribner method in both the ALAV and LLLV models. In these figures the similarity in allocation between the NRV and physical measure Scribner method can be easily seen. This relationship is also seen to hold despite production ratio.

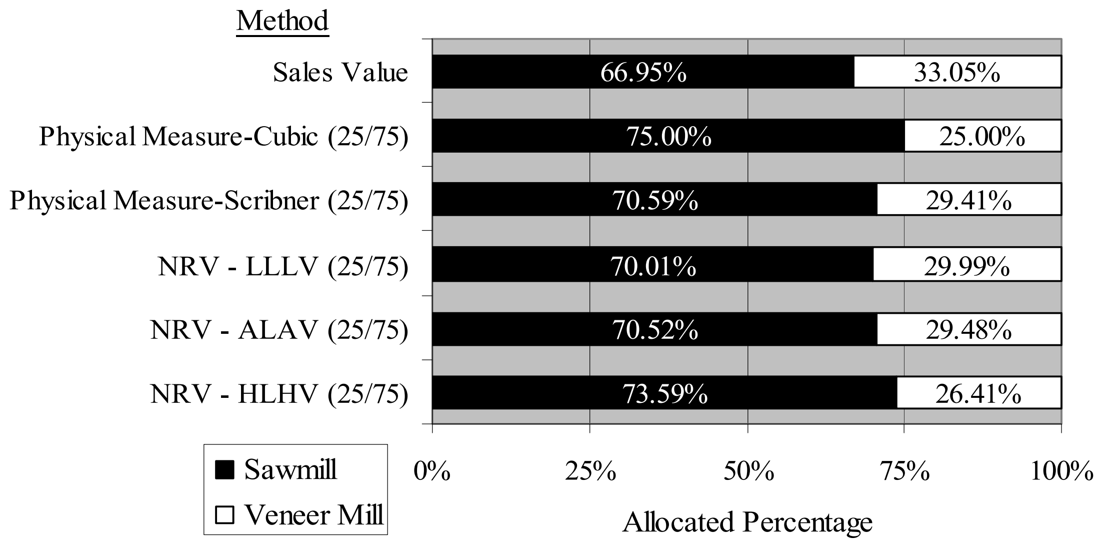


Figure 11: Equal price comparison for the 25/75 production ratio.

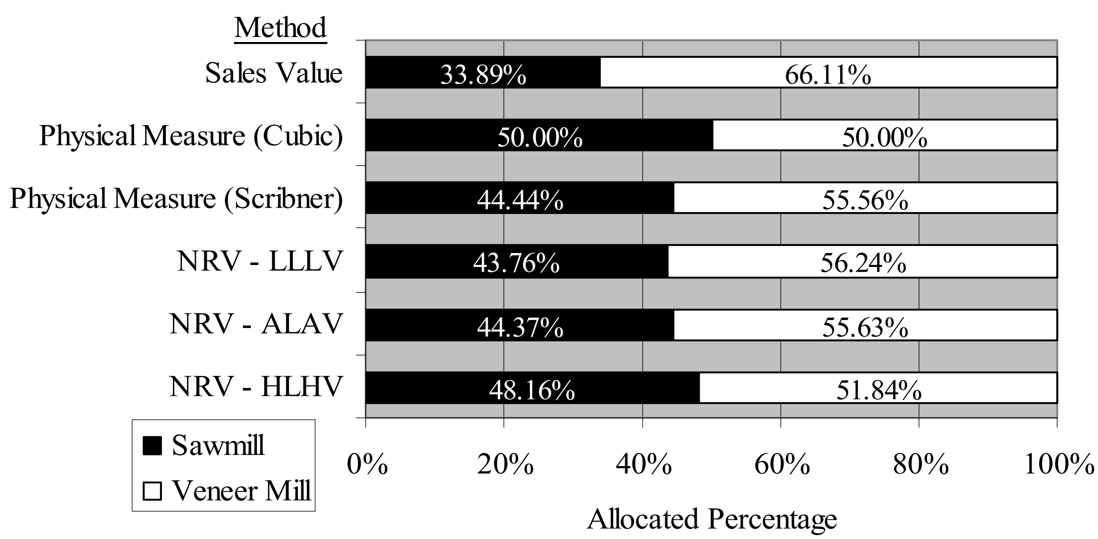


Figure 12: Equal price comparison for the 50/50 production ratio.

While the ALAV and LLLV scenarios compare well to the physical measure Scribner method the NRV method in the HLHV scenario allocates more cost to the sawmill than the other two equal price models, but is still similar. This means that the physical measure cubic method allocates more cost to the sawmill than any of the other methods in these three price scenarios. Similarly, it means that the sales value method allocates the least amount of cost to the sawmill.

The other two price scenarios, HLLV and LLHV feature situations where one price is at its ultimate peak, and another at its ultimate valley. Figure 13 shows the HLLV and LLHV price scenarios side by side in the 25/75 production scenario. The NRV method reacts expectedly in these situations. When taken to extreme price differences (lumber at its peak with veneer at its bottom) the NRV method will similarly allocate more or less than any of the other methods.

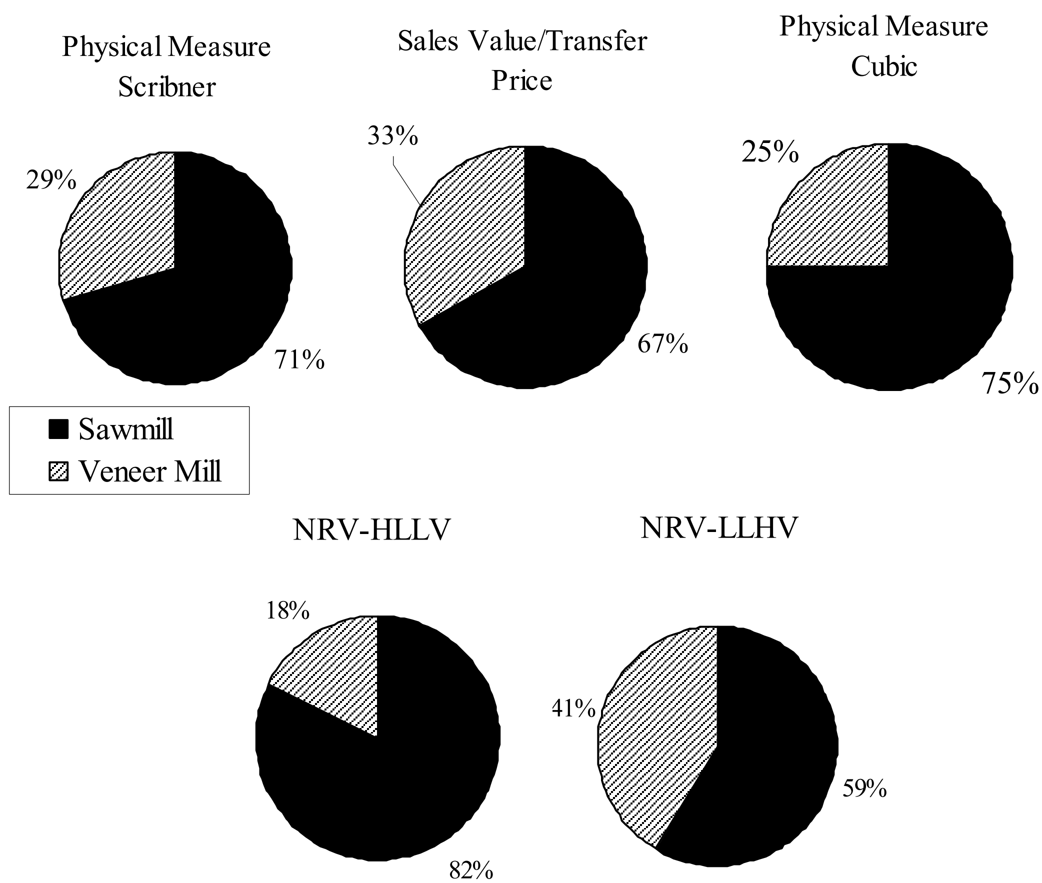


Figure 13: HLLV and LLHV comparison in 25/75 production ratio.

It is unknown if extreme price differences like this have ever happened historically, but it displays the complete nature of the NRV method. Looking at the real world examples of high and low prices shows that the NRV method is likely to produce more moderate results. Figure 14 shows the allocations of each method in the real world HLLV and LLHV price scenarios.

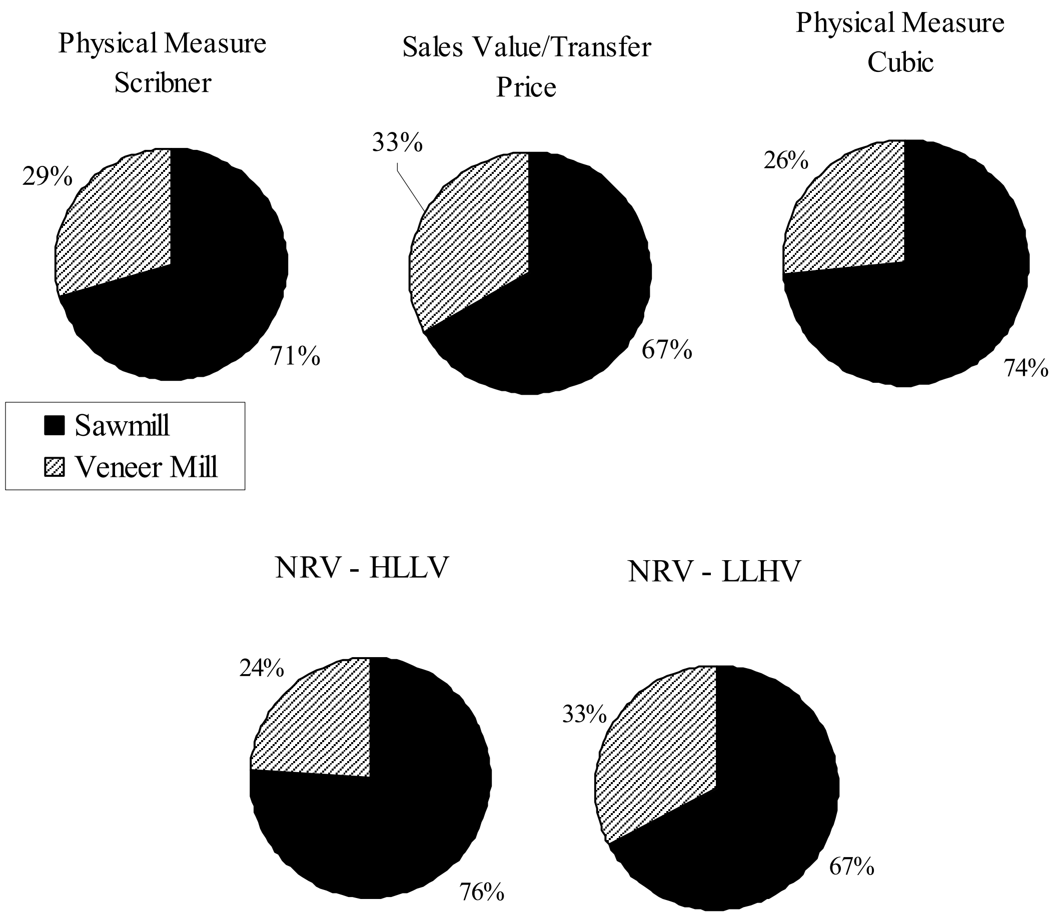


Figure 14: Comparison of the HLLV and LLHV real world scenarios.

When lumber prices are higher comparable to veneer prices the NRV method allocates similarly to the physical measure cubic method, which in the equal price scenarios allocated the most cost to the sawmill. But when the reverse is true and veneer prices are higher in their relative scale than lumber prices the NRV method allocates a similar portion to the sales value method, which in the equal price scenarios allocated more cost to the veneer mill.

4.3. Effect on Profit

In the previous section price scenarios were grouped into two categories, those with similar price relationships (ALAV, HLHV, and LLLV), and those with opposite price relationships (HLLV, LLHV). This section will follow the same path by first looking at the scenarios with similar price relationships followed by those with opposite price relationships, but from the viewpoint of effect on profit.

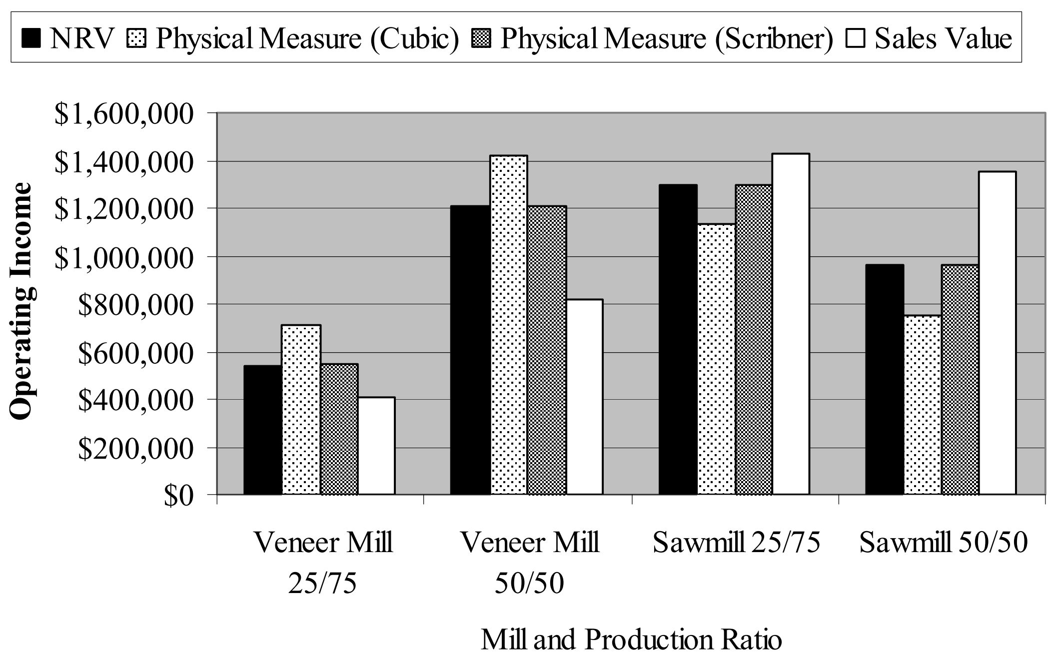
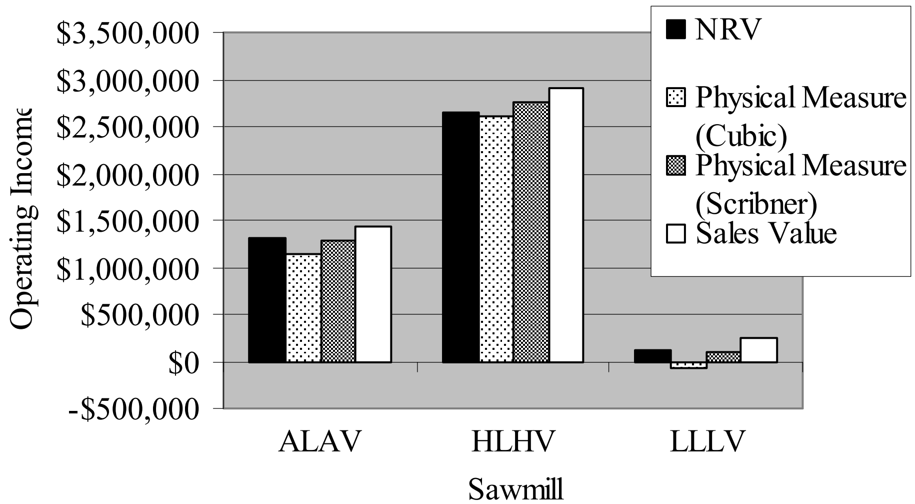


Figure 15: ALAV Income Comparison between methods and production ratios.

As found in the previous section, the relationship between methods is similar among the equal price scenarios and between production ratios. In Figure 15 the similarity between production ratios can clearly be seen. Because of this, discussion and figures for the rest of this section will be limited to the 25/75 and real world scenarios

Figure 16 shows each mill's operating income for each of the equal price scenarios. Noticeable is the effect some methods, such as physical measure cubic or sales value that allocated particularly in favor of one mill, have on operating income. The physical measure cubic method allocated more log cost to the sawmill than the other methods in equal price scenarios. The increased cost to the sawmill results in lower operating income than the other methods, and in the LLLV scenario, this results in a loss for the sawmill. Conversely, the sales value allocated more cost to the veneer mill than any other method, and the result is a loss in the low veneer price scenario. Figure 16 shows also how the relationships between methods remain similar in the equal price scenarios.

In the opposite pricing scenarios the NRV method balances the gross profit between the two mills more effectively than the other methods. This means that using the NRV method never resulted in a loss for either mill. Figure 17 illustrates this difference by showing where losses occurred in given scenarios. When veneer prices are low, the sales value method shows a loss for the veneer mill (Figure 17, Veneer Mill LLLV and HLLV). When lumber prices are low, the physical measure cubic method shows a loss for the sawmill (Figure 17, Sawmill LLLV and LLHV). The physical measure Scribner method barely avoids losses in these scenarios, but is often closer to the other physical measure allocation than the NRV method. Both the physical measure cubic and the sales value method resulted in either the veneer mill or the sawmill showing a loss for the month in particular scenarios, but the NRV method always avoided a loss.



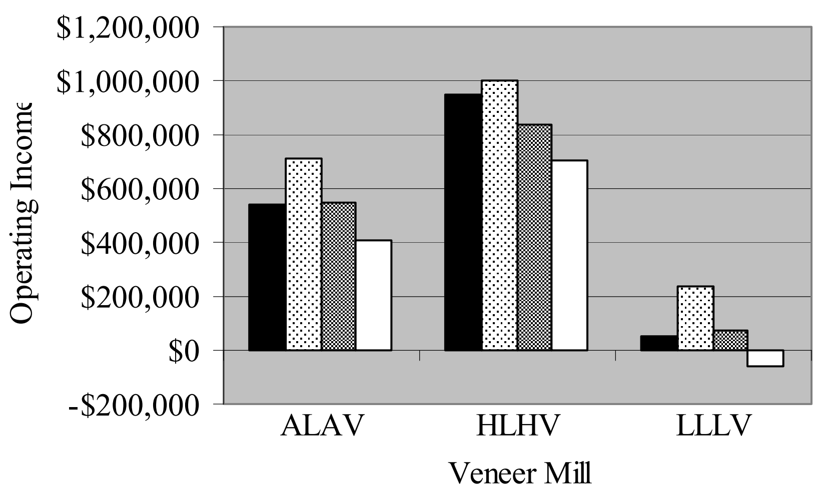


Figure 16: Income comparison across equal price scenarios.

This was not the case in the real world Scenarios where low values were substituted with average values to achieve the desired relationship between lumber and veneer prices. Figure 18, shows the same price scenarios as Figure 17, but uses the real world data. Figure 18 shows, in the real world price scenarios, only the veneer mill shows a loss, in the LLLV scenario using the sales value/transfer price method. Surprisingly the sawmill still did not show a loss even in the real world low lumber low veneer price scenario, which is very similar to the statistical low lumber low price scenario. The real world composite stud price was $25/MBF more than the statistical low, which was enough to result in a positive operating income for the sawmill.

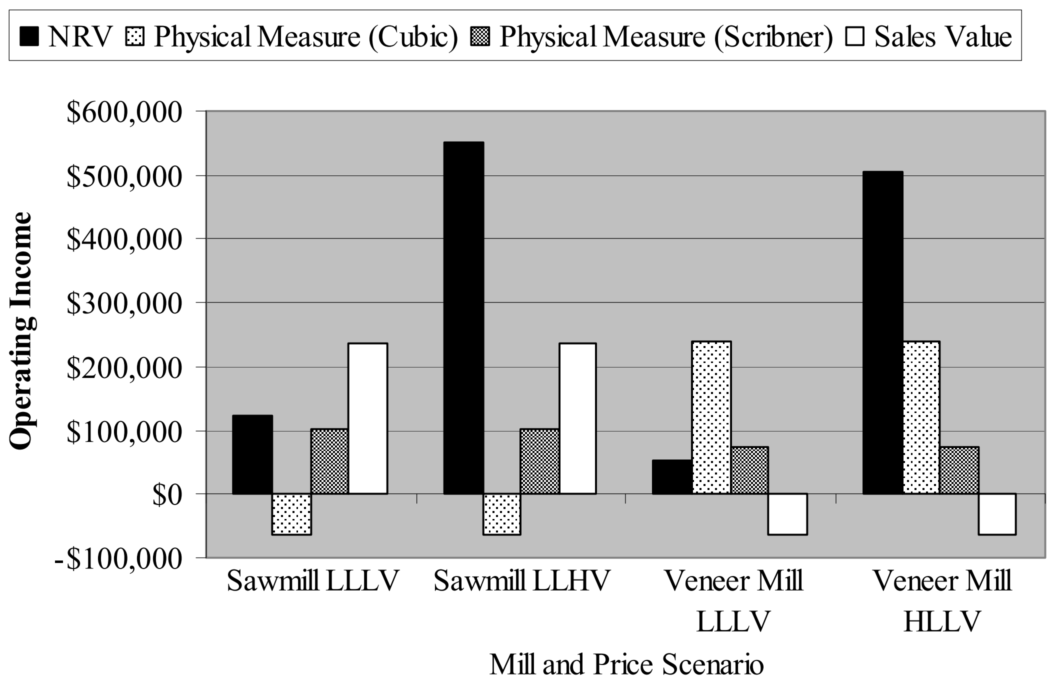


Figure 17: Sawmill and veneer mill loss comparison.

If Figure 18 is compared to Figure 17, some similarity in the relationships between methods can be seen. Figure 17 shows the same basic relationship between methods as Figure 18, but exaggerated. Comparing these two figures provides some context between the extreme theoretical scenarios and the milder real world scenarios.

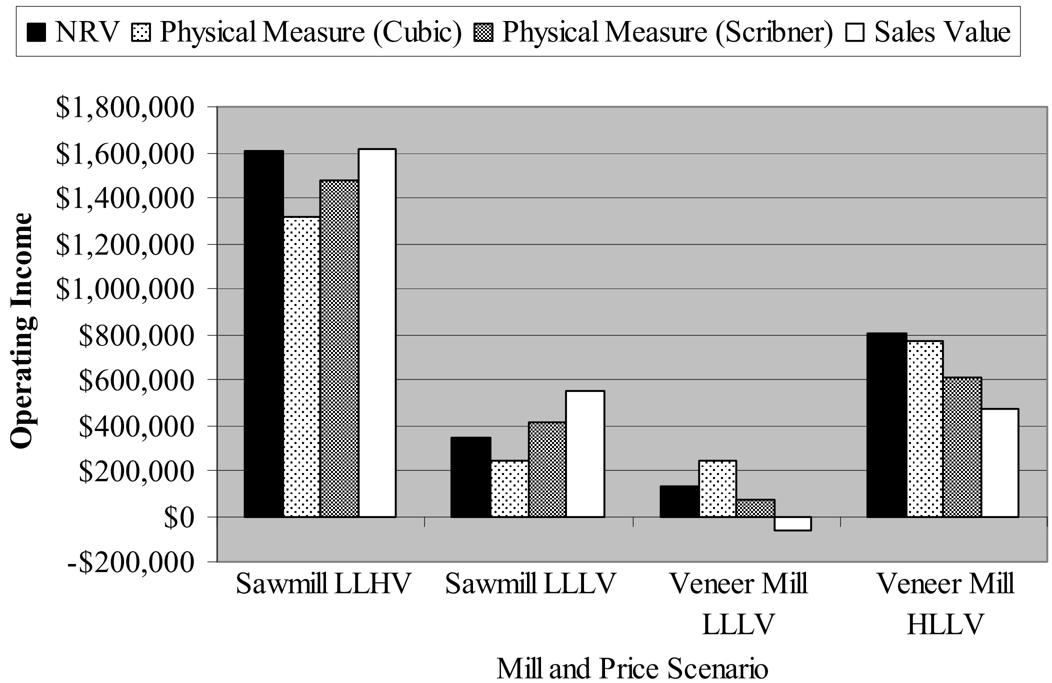


Figure 18: Low product value comparison in real world price scenarios.

The effect of chip prices, while having only a very small impact on the cost allocation, has a significant impact on operating income. Figure 19 shows the portion of total end product value chips are responsible for in the LLLV scenario. Consider the $70/ton price used in this exercise chips generated $343,000 in revenue for the sawmill and $124,000 in revenue for the veneer mill. When prices spike by 50% or even 100%, this means a significant bonus in revenue to each side. This is especially important as a spike in chip prices is usually precipitated by a drop in lumber or veneer production due to low lumber or veneer prices. Shavings and sawdust were not included because they represented less than 1% of the total end product value The losses seen when using either the physical measure cubic or the sales value method were all less than $65,000. As a result, in times where prices are low and potential losses might be seen to either the sawmill or the veneer mill, the effect of an increase in chip prices could easily be significant enough to counteract the loss. This coincides with what happens when this occurs in real world situations.

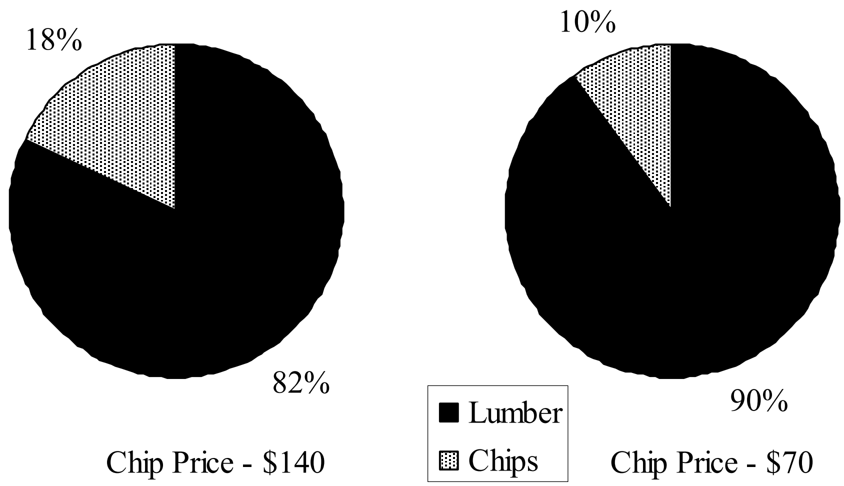


Figure 19: By-product contribution in the LLLV scenario.

4.4. Choosing a method

One of the objectives of this exercise was to determine if one allocation method stood out from the others as a more logical choice. The sales value method/transfer price stood out from the others, because of the way it drastically allocated more cost to the veneer mill. Fundamentally, it is different from the other methods. Rather than being a true allocation, it forces a transfer price on one of the mills. This transfer price is an attempt to evaluate what the mill would have paid for its raw material, were it not a part of the joint system. There may be some value in this approach, as it forces the veneer mill to stand on its own without any of the possible cost benefit implied by the shared merchandising system. On the other hand, the sawmill receives all of the benefit to be received from the joint-production of short logs. If the basic assumption, that cost savings occurs through the joint-production of short logs, is believed, then the sales value/transfer price method must heavily favor the sawmill.

On the other side of the spectrum is the net realizable value method, which is very fluid in its distribution of cost. This method in previous work and this exercise demonstrates the ability to distribute cost such that all products appear profitable. While perhaps not important for making a production or price decision, this fact may be important for perceptions. Given that joint-products inherently must be produced together, it makes sense that if the entire operation is profitable, then each part should share in that profit. The downside of the net realizable value method is that it is fairly complicated to calculate in this particular situation. That means more time and money spent on accounting, and checking for accuracy.

The alternative to either of these methods is the physical measure method. In this exercise the physical measure was really treated as two methods as the two types of log scales (Cubic/Scribner) yielded significantly different results. When product prices were widely distributed as in the HLLV and LLHV theoretical scenarios, Scribner in particular, offered similar results to the NRV method. This is particularly notable in the real world scenarios where the difference between lumber prices and veneer prices was significant, but not as extreme as the theoretical scenarios. The physical measure methods offer a similar distribution of costs as the NRV method, but with a much simpler calculation.

As a result, the NRV method probably offers the fairest distribution of costs, but may be too complicated to implement, depending on the mill, its resources and ability to adapt to change. The physical measure methods in this situation offer a simpler alternative to achieve a similar cost distribution. Physical measure methods are also less abstract, and therefore more easily communicated and understood by all parties involved.

5. Conclusions

A variety of things were learned in this exercise that offer a better understanding of allocating joint-costs to co-located mills. The first and most important thing that was learned is that the likely variation in allocated log costs among methods is at least +/- $100,000, or 2.5% per month for co-located mills. That could easily be more than $1,000,000 by the end of the year, simply due to the choice of method. Annually, the sawmill represented in this paper might recognize $50 million in sales, and the veneer mill $25 million. That $1 million represents around 2% and 4% of annual revenue respectively. As shown in section 4.3, this can easily mean the difference between a profit and loss when used in the income statement. In some ways this makes the problem of allocating joint-costs seem all the more serious. In other ways, it can serve as a reminder that allocating costs is in large part arbitrary and good decision makers will take that into account.

Another important lesson is that changing the ratio of production between the sawmill and veneer mill, while changing absolute values, has little effect on the relative relationships between methods. Regardless of whether the sawmill was processing the same, or twice as much volume as the veneer mill, the methods shared the same relationship (i.e., physical measure cubic allocating more cost to the sawmill than the sales value method). This relationship carried directly through to operating income. While absolute values changed due to the price scenario, the relationship between the methods stayed the same.

Finally, this particular exercise did not reveal one method as an obvious choice for use among co-located mills. It did reveal that both the physical measure cubic and sales value (i.e. veneer mill transfer price) consistently favor the veneer mill or sawmill, in that order. The NRV method appears to be the best way to convey the realities of joint-products in terms of perception based on allocated cost. The NRV method is also complicated, and the simpler physical measure method based on Scribner measurements may serve this same purpose.

The results shown in this paper best represent a preliminary look at the use of joint log cost allocations. Recovery, conversion factors, manufacturing cost and log population all had to be modeled based on assumptions. These assumptions are present in a large range and number of combinations in actual mills. This paper shows that if a given company decides that sharing a resource among mills will maximize profit, then some attention should be paid to understanding the resulting accounting ambiguity. Further work could include simulations that better model recovery and cost, as well as surveys to learn about the conceptual understanding of joint-costs for mill staff.

Current issues in the forest products industry may warrant further work in joint-costs. These issues include small diameter timber utilization and bio-refining. As of the writing of this paper the forests of the western U.S. contain a significant volume of very small diameter timber that increases the risk of catastrophic wildfire. One proposed solution has been the creation of utilization centers, where several business, such as a sawmill, post and pole peeler, and firewood processor, co-locate to reduce transportation costs and increase merchandising options. These utilization centers will definitely have to deal with the joint-products issue. The other issue of bio-refining presents a similar solution. Newly proposed bio-refining centers also will merchandise the timber resource for sawmill quality logs, pulp, and other products, again raising the issue of joint-products.

The concept of joint-products is an integral part of understanding forest products, and as such the problem of allocating joint-costs is also a part of the forest products industry. Understanding the nature of joint-products and the problems they can create, then, is an important part of making sound business decisions in the forest products industry.

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