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MEASUREMENT DIFFICULTIES IN THE LOG CONVERSION PROCESS

By

G. Robert Brian
Arthur Andersen & Co.

Donald O. Knodell
Boise Cascade Corporation

Dale D. McFarlane
Associate Professor
School of Business,
Oregon State University

Robert O. McMahon
Associate Professor
School of Forestry,
Oregon State University

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INTRODUCTION

A flow of operating data such as that related to labor, material, and machine usage is essential to the acounting process, if accounting is to provide management with the cost and value information it needs. The forest products industry, however, has found it difficult to produce such a flow of data in an accurate and timely manner.

In particular, methods used to measure material flows from tree to end-product evidence imprecisions that make material cost accounting objectives difficult, if not impossible, to realize. This paper will explore just one of these measurement processes—log scaling.

Within the Pacific Northwest, Scribner scaling rules, which were first introduced in 1846, remain the industry standard. In his "Ready Reckoner," published that year, Scribner described the basic inaccuracy that "gives the buyer the advantage of the swell of the log." Faced with this basic inaccuracy and with the drastically increased values for wood fiber, a few companies have converted to a cubic scale in an attempt to account for the whole log.

Further, scaling practices in general have long eluded the purview of the accountant. They have been treated as an operating management prerogative through which the manager gains buying, selling, and production advantages in proportion to his personal skill and experience. One of the "skills of the trade" the manager uses is to know precisely the inaccuracies of the measurement system and to use these inaccuracies in various ways according to his operational needs. The accountant, however, is rarely apprised of such information and is forced to take the measurement data at face value or, even worse, to ignore it and use alternative "bookkeeping" methods. In turn, the operating manager, seeing such data transformed into accounting statements, applies his "special knowledge" to them as well. The result is a credibility problem that will be overcome only when improved measurement systems, developed with accounting objectives in mind, are adopted.

In fact, accounting executives will need to become involved in the design and development of new or improved measurement systems, if measurements such as log scale are to fulfill their function as the bases for the production of accurate financial information.

In this paper, we will deal with the accounting requirements for log measurement, the ability of the Scribner and cubic scales to meet the requirements, an outline of the elements of an improved approach to log measurement that meets accounting and management control needs, and the role of the financial executive in shaping these practices.

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ACCOUNTING REQUIREMENTS

The measurement objective for accounting and management reporting purposes is to describe the log so that cost and value factors can be applied and transferred to succeeding steps in the conversion process. The measurements then form the basis for both economic valuation of resources and financial control decisions. The primary cost factors in this process are stumpage, harvesting, transportation, and manufacturing costs to bring the tree to its interim and end-products. The primary value factors are the market value of the tree in its present state and the value that the tree would have if it were further transported and/or processed.

In terms of evaluation and control in the forest products industry, there are two primary objectives for a measurement system:

1) The measurement system must be capable of reconciling quantity inputs to quantity outputs at each stage in the manufacturing cycle, from growing young stands to selling the final product. This ability to reconcile inputs to outputs is the most fundamental concept in the development of an accounting control system.

2) The measurement system must be related to both the cost of resources consumed and the value of the end-products produced.

The petroleum industry has attacked this problem by using a common unit of measurement to evaluate quality from well-head to end-product. The unit is BTU's, which can be easily determined at every point in the process. Similarly, the mining and metal refining industry can precisely evaluate the metallurgical content of ore by assay, in terms of percentages. Even in the banking industry, where the "products" are various returns on different uses of money, present value and other analytical techniques provide a common yardstick.

Using this line of reasoning, it would appear that the key to solving the accounting problems faced by the forest products industry would be the development of a common unit of measurement. A common unit of measure for the forest products industry has been an ideal that has been the topic of conversation among forest industry personnel for the last fifty years. But, to date, there has been little if any common agreement on this subject. At the present time, most end-products in the forest products field carry different units of measure, and these units are very difficult if not impossible to relate back to cost or economic value.

Two other important accounting requirements are frequency and accuracy of measurement. Ideally, each tree should be measured after it is felled and after it is bucked, as a basis for determining whether it has been cut into the best lengths, for reporting woods productivity, and for recording inventory. As soon as the logs are decked they should be fully scaled and graded, to provide a basis for allocation and transportation decisions as well as for more accurate accounting for inventory. The grading at this point should be particularly directed toward end-product *value* considerations, since some profit options are lost once the log is committed from the deck. Measurement information is also useful at this point for determining transportation and yarding performance.

All log sorts should be fully reflected in the accounting records since each represents a different end value determination. The measurement of the sorted inventory should follow the log as it moves to the mill. If additional bucking takes place or the log is otherwise altered, additional measurements should be made to reflect such physical change and any new insights gained as to its value. At a plywood mill, for example, it may be desirable to shift from log measurement to block measurement and to measure any by-products that may result in the process. A cull log carried at zero value may well contain a peeler grade block.

Yield analysis—relating mill production back to the raw materials used in the production process—is one of the most important economic and performance factors in the business. Yet the accuracy of yield calculations is entirely dependent upon the accuracy of the log measurement system being employed. In the past, the ability of financial and accounting executives to provide meaningful controls for the production process has been severely hampered by their inability to obtain accurate information concerning the input of raw materials at the mill site.

Therefore, in addition to the two primary objectives cited earlier, some additional positive attributes of a good measurement system would include:

3) Ease with which the measurement can be applied at the required points in the process.

4) Transferability of the measurement from one point in the process to the next.

5) Ability to identify and adjust the measurement for incidental by-products or material losses or gains that may occur.

Past attempts to meet more of these requirements have resulted in a myriad of measurement rules (there are some 20 different variations of Scribner scale in use), which, in many respects, have made accounting objectives even more difficult to achieve. Thus, we should add a final measurement attribute of:

6) Commonality and adaptability to the industry as a whole.

ADEQUACY OF SCRIBNER SCALE

The forest industries' concern with Scribner scale as a wood measurement system extends back nearly half a century. As early as 1929, a committee of lumbermen looked into the claims of problems caused by use of the Scribner scale (1),* and additional analyses have followed periodically (2, 3, 4, 5).

Yet despite all that has been written and said about Scribner scale, little change in industry standards and practices has resulted to date. Does this suggest that the problems are not serious enough to justify drastic remedial action, or that a satisfactory alternative system has not yet been devised? Probably both conditions exist, and they may account for the fact that a measurement system with acknowledged deficiencies continues to dominate industry practice after more than 130 years. While the system must have some benefits, a look at its claimed deficiencies suggests that what it does wrong under today's conditions outweighs whatever it does right.

One outspoken industry critic of the Scribner scale system commented as follows:

> "Present scaling and grading standards have weaknesses that result in distorted values; unrealistic volumes; unpredictable planning; loose inventory control; cost headaches for buyers, sellers, and contractors." (2)

This same critic went on to indict the Scribner standard of scaling and value determination in the following terms:

> "(It has) grossly inconsistent ratios of board foot per solid cubic content when taking a full range of diameters from 6 to 80 inches . . .
>
> In today's supposedly modern, up-to-date business, scaling contains standard provisions for deducting up to ⅔ of the volume of wood raw material. This deducted volume is lost forever in terms of control by management. It is not known how much of the deduction is usable—and for what; how much is not usable.
>
> (It) fail(s) to identify the highest potential—and the component potential, of the log.
>
> (It) gives(s) unrealistic recovery data in comparing log scale to production tally.
>
> (It) fail(s) to indicate raw material potential for secondary products.
>
> (It is) basically tied to an obsolete conversion base of production of 1-inch full sawn lumber only . . .
>
> (It) provide(s) misleading answers in modern production technology, for example, linear programming."

Much of the earlier concern with Scribner measurement centered on technical deficiencies, and many modifications made over the more than 130 years of its existence have been aimed at alleviating these concerns. It is a moot point, however, whether the proliferation of more than 20 different sets of Scribner scaling rules, each resulting in a different answer, exacerbated, rather than lessened, the system's technical shortcomings. It is the system's shortcomings in terms of fulfilling the needs of business management that have come under increasing fire in the past ten years. Critics specifically cite the system's inability to satisfy accounting objectives and practices, and this could be the issue that finally topples the Scribner system from its position of dominance.

The greatly increased cost of raw material in relation to the value of products produced has reached levels that would have defied rational expectation years ago, if not rational explanation today. A look at the accompanying table pinpoints the situation for Douglas-fir:

	Stumpage Cost[1]	Logging Cost[2]	Lumber Value[1]
	Dollars per 1,000 board feet		
1945	5	15	39
1971	49	30	98
1975	169	60	138

[1] 1945: (6)
1971 and 1975: (7)
[2] Informed estimate

Thirty years ago Douglas-fir stumpage on national forests in western Washington and Oregon sold for 12 percent of the realized value of lumber, the primary end-product produced at that time. Logging costs then were about three times the cost of stumpage. By 1971 the raw material/logging/end-product relation had changed so that the same stumpage was just half the value of lumber, and logging costs were only 61 percent of stumpage. By 1975, however, an even more drastic shift had occurred. Stumpage was 122 percent of lumber value and nearly three times the cost of logging.

* See sources listed at end of monograph.

Part of the explanation of how the cost of raw material could appear to exceed the value of a major end-product produced from it rests on certain peculiarities and deficiencies of the Scribner scale. For example, the system excludes from consideration the volumes of nonlumber component products, such as plywood and pulp chips, which were of minor importance in 1945, but had become major items in the product mix by 1975. Excluded volumes of sawdust and chippable wood residue, much of which had to be disposed of at a cost in 1945, had become major contributors to revenue by 1975, thus encouraging bid prices for stumpage well in excess of inherent average lumber values.

And there is another drawback to Scribner that is seldom recognized or discussed. Realized Scribner lumber volume for coast species habitually is overstated in terms of actual wood fiber content, because board foot measurements are based on nominal, rather than actual, dimensions. Thus actual (or net) board foot lumber tally is equivalent to only 55 to 90 percent of nominal (or gross) volume, depending on the thickness-width measurements and the green-dry condition of individual pieces of lumber. A surfaced, dry 2″ x 4″ which presumably should contain (2 x 4)/12 =.67 board feet per foot of its length actually has only (1-½ x 3-½) / 12 = .44 board feet per foot of length—resulting in a 52 percent overstatement of its volume. The seriousness of this drawback from an accounting-management control standpoint can scarcely be emphasized strongly enough.

These facts underscore the business management problem associated with the use of Scribner scale today: it ignores the volumes of all end-products—other than lumber—in a log, and it is independent of the economic value of any of these products, including lumber. The original objective of the Scribner system, stated by its designer, was to provide an estimate of the volume of one-inch boards that could be cut from logs of given sizes. The system did not profess to *measure* this amount but only to *estimate* it and to do so in such a way as to give a built-in advantage to the buyer using this system to purchase stumpage or logs. But even its estimates became less and less precise as, on the one hand, improved technology permitted narrower saw kerfs and, on the other hand, the trend toward increased production of dimension stock rather than boards reduced the volume of wood fiber going into sawdust.

Moreover, the system does not measure gross volume (including defect) of a tree or even gross volume of sound wood (excluding defect). Rather, it measures only net volume of sound wood within the small-end-diameter cylinder that can be converted into a single product—one-inch boards (excluding, in addition to defect, some sound wood within the cylinder that will not make boards of a given length). In short, the system has not kept pace with either technological or economic realities, because it is inherently incapable of such flexibility.

Nevertheless, in spite of these drawbacks, the Scribner system's primary virtue is its end-product orientation, which, although limited and imperfect, permits informed buyers and sellers to adjust prices to compensate for, and to reflect volume and value of, products produced. And here we get a glimpse of what Scribner does right or at least well enough to have enabled it to survive all these years. Because of its end-product-volume orientation, the rule is suited to arms length transactions where agreed-upon price adjustments permit experienced users to keep pace with an expanding product mix and shifting price relationships among components of that mix. Tradition and custom, together with the rule's built-in characteristics, suggest that its days probably are not yet completely numbered for scaling transactions where end-value considerations and superior economic strength of a buyer prevail, such as those between gyppo loggers and independent and unintegrated sawmills.

Given the implications of the raw-material-cost/end-product-value data cited above, and the rapid decline in the number of unintegrated sawmills in existence today, the objective of a modern measurement system must be reoriented to provide an accurate and precise measure of the volume and value of wood fiber contained in a log. A limited and imprecise estimate of a single component (1-inch boards) that constitutes a small proportion of today's product mix is a performance standard grossly inadequate for meeting the needs of an integrated log-processing enterprise. An accurate measure of the fiber content of high cost logs—the raw material input—is essential for the sensitive accounting necessary to achieve optimum allocation and conversion into a diversity of end-products.

It seems clear from the above discussion that the Scribner system fails to satisfy the primary objectives of a good accounting measurement system. The Scribner system does not measure the total quantity of inputs into the production process, and therefore reconciliation of inputs to outputs is not feasible. Few, if any, of the major costs of activities required to bring the raw material to a point of end-product determination are directly related to the Scribner measure. In addition, while the system was designed to measure the quantity of a single end-product (lumber), even here its imperfections make conversion from quantity to economic value of the end-product an exercise of dubious worth.

CUBIC VOLUME AS AN ALTERNATIVE MEASUREMENT SYSTEM

Advocates of the "cubic foot" as the primary log measurement system began to appear coincident with industry recognition of the inherent inaccuracies and deficiencies of the Scribner system. In 1929 Thornton Munger, Director of the Pacific Northwest Forest and Range Experiment Station, advocated adoption of the cubic foot as the "universal unit of measure." (1) Despite Munger's persuasive plea, movement toward the replacement of the board foot measure within the Pacific Northwest has been very slow. In 1948 the cubic system was declared the official log measurement system for British Columbia, and in the early 1960s several large wood products firms in the United States adopted the cubic foot for internal reporting purposes. Recent advances in both production and management technology have supplied additional reasons for advancement of the cubic foot measure, but to date acceptance of this system is far from universal. Munger initially listed 16 advantages of the cubic foot as a unit for measuring the contents of trees and logs. Since that time the list has grown. Unfortunately, in their enthusiasm, a number of spokesmen on both sides of the issue have misrepresented the opposing viewpoints. In addition, many of the arguments, while technically correct, are irrelevant to the interests and responsibilities of accounting and financial executives.

Within the forest products industry there is no universal definition of the cubic foot beyond the initial concept that the cubic foot measures the wood fiber content of a tree or log based on diameter and length, as contrasted with board feet, which measures product content of a log (lumber).

Firms within the industry have taken this concept of the cubic foot and modified the specifics of measurement and grading to match their individual management needs. Douglas Smith, a proponent of cubic measurement, proposed the following procedure: "The average diameter is recorded, the length is taped and cubic volume tables provide the gross volume in terms of cubic feet. To account for taper as the situation warrants, both ends of the log are measured to establish taper factors." (2) Quality considerations are characterized by breaking down cubic volume by percentage components of different quality (% sound clear wood, % sound knotty construction wood, etc.), with the sum of the components totaling 100%.

In terms of the primary objectives of a good measurement system, the cubic foot measure satisfies the first objective. The cubic foot measure is capable of reconciling the quantity of input to the quantity of outputs at each stage. From the standing tree throughout the production process, the sum of the individual outputs—lumber, chips, veneer, bark, waste, etc. (all measured in cubic feet)—must equal the initial input, that is, the cubic volume of wood and bark fiber of the tree.

A second advantage of the cubic measure lies with its cost behavior. Many of the costs associated with processing logs from standing timber to delivery at the mill site are linearly related to cubic volume. The costs of falling, sorting, and hauling are closely related to the volume of material being handled. In terms of costs, there is little, if any difference between hauling a cull log or hauling a number one peeler of the same size. Cost standards and many of the inputs to the more recently developed mathematical models, such as linear programming, explicitly assume a linear relationship exists between costs and the measure of quantity employed.

In that respect, using board feet to characterize young stands of timber can be very misleading. The relationship beween cubic feet and board feet shows the most distortion for small diameter logs. As a consequence, a number of companies that own their own land have switched from board feet to cubic feet in order to get an accurate description of the costs associated with managing young stands of timber.

While the cubic foot measure possesses some distinct advantages in terms of reconciliation of inputs to outputs and in cost evaluations, the measure fails to meet the economic value objective. The economic value of a log according to the principle of highest and best use depends on the various combinations of end-products that can be produced from the log and the prices associated with those end-products. But end-product yields cannot be derived from a *single* quantity measure, whether that measure be cubic feet or board feet. Board feet implicitly assumes the yield from the log will be lumber. This not only ignores potential by-products but also may be in direct conflict with the principle of highest and best use. In contrast, cubic feet makes no assumption about end-product yield, but requires accompanying information such as diameter and length, to derive estimates of lumber or plywood. Unfortunately, estimates of end-product yield will be subject to change whenever there is a change in either the prices of the products or the technology of production.

In summary, the cubic foot measurement system provides for reconcilation of inputs to outputs and exhibits a favorable cost behavior up to the point of end-product determination. However, the cubic foot meaurement is inadequate in terms of the complete determination of economic value, which requires some estimate of the various combinations of end-products that can be obtained from a log.

THE CASE FOR SEQUENTIAL MEASUREMENT

At this point one might conclude that inadequacies of both the Scribner and cubic measurement systems are such that an entirely new measurement approach is needed if the accounting requirements specified earlier are to be met. But one must recognize that no single quantity measurement system can provide the information necessary to achieve those accounting objectives for an industry as complex in product diversification as the forest products industry. Such a system would have to reflect total volume of wood fiber (including both sound and defective material), length, diameter, and quality characteristics, because each of these measurement elements is important for management evaluation and control of the resource. Recent advances in computer technology over the last decade may at some future date permit carrying all of these elements for every log entering the conversion process. At the present time, however, such a system may be cost-prohibitive.

Is there, then, a solution to this dilemma—a practical measurement system that meets accounting needs?

Some who have been concerned with this issue have suggested or even adopted a hybrid system incorporating both cubic and Scribner in an attempt to obtain advantages of each. A company could scale both ways if it were willing to incur the overhead cost involved. To keep cost to a minimum, some companies start with either scale and use simple conversion tables to get to the other at an appropriate point in the process. Because of inherent differenes in the scaling methods, however, the "converted" scale is less accurate using that approach.

From an accounting standpoint, dealing with dual scaling methods, each with its own set of inaccuracies, may well be more trouble than it is worth. More time will be spent reconciling measurement and bookkeeping differences than on the basic objective of tracking the handling and utilization of logs. Also, the results will be considerably more difficult to understand.

There is another alternative, however, and that is to use more than one scaling system but in a complementary, sequential manner so as to capitalize on the strengths of each, rather than to use them competitively, side-by-side. Earlier discussion of the particular characteristics of cubic and Scribner scales revealed that the former is input-oriented, while the latter is output-oriented. Cubic scale was seen to have substantial accounting advantages for tracking material flows and costs from standing tree inventories through the falling, bucking, yarding, loading, transportation, and sorting processes, since in these operations all fiber, regardles of its grade, quality, and content is treated essentially alike. Merchantable portions of the whole tree are accounted for and unit cost comparisons can be more consistent and meaningful when measured by cubic scale.

After the point at which logs are allocated to particular conversion options (lumber, plywood, poles, and piling, for example), measurement systems that reflect the product output of a log are needed to track yields. These measurements must then be reconciled to the beginning cubic scale to account for utilization of the whole log. The basis for accomplishing this reconciliation is contained in a recent publication (8) which shows how wood product volumes can be converted into a common unit ("solid wood equivalent") to facilitate comparisons among different products or to relate product yields back to initial input volumes. Some of the conversion factors are tentative or represent broad averages and may require further study and refinement before they can be applied with assurance in particular circumstances.

Looked at in this way, it is apparent that there are numerous decision options throughout the timber conversion process, and that there will be varying information requirements for effective evaluation and control at each decision point. Moreover, the cost and the availability of information also change at each successive decision point. The boxed table presented here gives a brief overview of decision options and the type and flow of information for accounting purposes required by an integrated forest products firm.

The terminology used to describe each decision option and the kind of information needed for evaluation purposes is arguable; the categories are perhaps even incomplete. But this is unimportant for the purpose at hand. What is crucial, and what the tabulation is designed to show clearly is that:

1. A series of decision options do exist.

2. For evaluation purposes, the accounting information flow needed in the early stages is of a general nature and not too detailed, but in the later stages it becomes progressively more specific and detailed.

3. For control purposes, cubic volume (input) information alone is sufficient up to where logs are actually allocated to various end-product options, at which point yield (output) data in appropriate product units then become necessary.

DECISION		INFORMATION REQUIREMENTS	
Form & Location	*Kind*	*Evaluation*	*Control*
Young stand	Stand management	Species, age, volume, management history	Volume (cubic feet)
Mature stand	Purchase, cut, sell	Volume, average diameter, species, quality class	Volume (cubic feet)
Log deck	Bucking, sorting, end-product determination, transportation	Volume, number, length, diameter by class, quality by class	Volume (cubic feet)
		Gross yield of products	Yield in product units (board feet, cubic feet, square feet, tons, etc.)
Mill site	Allocation and conversion	Net yield by product class (quality) and size	Yield in product units
In-process and fiinished goods inventory	Sale	End-products unit class (number and quality)	Yield in product units

Yield data means information that, ideally, would predict the output of given types of products prior to actual conversion of logs into such products. After yield data were combined with product price data, allocation decisions could then be made based on relative cost and value. Time and space limitations prevent a full exploration of all the ramifications of this idea as it relates to each potential product, but we will venture a few observations about lumber as an example.

For Pacific Northwest lumber production, Scribner scale is the widely used traditional "predictor" of output and might continue to serve in those instances where a strong case could be made in its favor. But as noted earlier, current defect grading rules and large overruns experienced by many companies indicate Scribner is a poor predictor at best and is unsuited to the increasingly precise accounting practices required today.

A better alternative is to develop localized yield tables to cover all products and by-products obtained from given log sizes and grades. For example, Plank and Johnson (9) have presented an empirical log rule for estimating lumber tally from Douglas-fir logs. Bruce (10) presented equations not only for estimating lumber output but also for estimating veneer, core, chippable waste, and shrinkage in veneer operations. These types of approaches need further exploration and development, especially for other species and products; they could well prove the answer for control information purposes.

The final step for accomplishing evaluation and control objectives is the reconciliation of yields back to the whole log. This assumes that all products and by-products from a log can be rather precisely measured, which, suffice it to say, introduces an entirely new set of measurement problems that we will not attempt to deal with here. The usefulness of yield predictors becomes apparent at this point: the actual realized volume and value of all outputs can be compared directly with anticipated volumes and values to determine the effectiveness and efficiency of conversion processes.

METRIC MEASUREMENT

The impending and inevitable change to metric standards throughout U.S. industries has special relevance to the subject of this monograph, in both good and bad respects. The bad news is that this change, when it comes, will not solve the basic measurement dilemma faced by the forest products industry today. The good news is that the change should not make the present situation any worse. Intra-industry committees for both lumber and plywood have already agreed on a "soft" conversion of present U.S. dimensions into their metric equivalents, but with slight modifications to round off odd numbers—and have recommended metric dimensions for all lumber and plywood items. In whatever units employed, whether standard or metric, the industry is still faced with the need to accurately measure gross input, predict output, and finally reconcile realized outputs with actual input volumes. The sequential measurement approach as described above will meet this need just as effectively with metric units of diameter, length, and volume for inputs and with those units eventually adopted to measure yields.

SUMMARY AND CONCLUSION

We selected measurement difficulties in the log conversion process as the subject of this monograph because of a recognized complexity and inaccuracy of current industry practices in measuring resources and products. This recognition has been accentuated by recent dramatic economic and social changes affecting the forest products industry. We are no longer producing a single product from an abundant resource, to say nothing of the fact that we are valuing trees for purposes other than converting them into wood products. As the cost of the resource continues to rise, firms within the wood products industry will be compelled to thoroughly examine and perhaps modify their accounting and control practices.

We have outlined management and accounting objectives of a measurement system, analyzed the capability of two standard log measurement systems (Scribner and cubic) to meet these objectives, and have found either system alone seriously deficient because of its inability to relate input volumes and cost to output yields in either volume or value terms. We then examined the characteristics of a sequential measurement system, which attempts to take advantage of the strong points of both systems and yet avoid unnecessary duplication of effort.

At the present time, several companies are involved in either the development or use of such a sequential system. As noted, however, most of the work with new systems of measurement is being performed by forestry and production personnel, with only limited participation by accounting and financial executives. We believe the expertise of these latter two groups is essential if companies are to achieve evaluation and control standards commensurate with the resource and product values involved. Financial executives must take an active role in the development of measurement systems that are a major factor in fulfilling their responsibilities. Our hope is that this paper will stimulate interest, on the part of these executives, in the measurement process and its managerial implications.

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"The Rush to LIFO: Is it Always Good for Wood Products Firms?" issued in December 1974 and published in condensed form in the April 1975 issue of *Forest Industries*.
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"Accounting and Financial Management in the Forest Products Industries: A Guide to the Published Literature," issued in June 1975.
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"A Decision Framework for Trading Lumber Futures," issued in October 1975.

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