Weyerhaeuser Decision Simulator Improves Timber Profits

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The VISION decision simulator was developed to implement dynamic-programming-based improvements in raw materials returns at Weyerhaeuser. Operational benefits to date exceed $100 million in increased profits. In addition, management philosophy has been changed, and, with the recent weakening in forest product markets, VISION benefits have increased in importance.

This paper expands on our recent *Interfaces* article [Lembersky and Chi 1984], which we will refer to as LC. It focused on a general approach, decision simulators, for implementing MS/OR algorithms and models. To illustrate the approach, LC also summarized the "VISION" decision simulator at Weyerhaeuser. The current paper describes the background, development, implementation, and benefits of VISION applications in more detail. Elements of LC are repeated here when necessary for completeness.

Weyerhaeuser is one of the largest forest products companies in the world. In 1984, company revenues were over $5 billion, predominantly through domestic and foreign sales of logs and timber, lumber, plywood, and paper products.

Forest products is primarily a commodity industry, which means there is little control over the prices realized from the sale of products. Facing such an environment, efficient utilization of Weyerhaeuser's raw materials base, its trees, is imperative; that, along with costs, is the principal profit factor under company control.

Also, the forest products industry is highly competitive, marked by relatively

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low profit margins. For example, in 1984 profits as a percentage of sales averaged about 2.5 percent for large, integrated firms. Consequently, even a small percentage increase in raw materials returns produces a disproportionately larger percentage increase in profits.

Weyerhaeuser operations handle a raw materials flow of just under one billion cubic feet each year — that's a volume of wood covering a football field and going four miles high! This large annual flow, divided about equally between the company's western and southern operations, means a very large absolute dollar impact from raw material decisions. Unlike other forest products firms, this flow comes mostly from trees Weyerhaeuser owns; so any increase in value results directly in additional company profits.

For all of these reasons, raw materials utilization decisions are very important to Weyerhaeuser's profitability.

In the mid-70s, a few senior company executives had a sense that better use could be made of the high-valued raw materials from western Douglas-fir operations. At that time, no such opportunities were thought to be available in the pine forests of the South.

Achieving improved use of raw materials meant seeking the best use of each individual tree. How a tree is crosscut into logs and what is done with the resulting logs largely determines the return that tree yields. For example, when and in what combinations should the 8½-foot logs be cut that are needed to make 4 × 8 plywood panels instead of cutting the metric length logs required by the export market? When should lumber length logs be cut, and so on? To increase raw material values, individual trees needed to be crosscut and the resulting logs allocated in a way that produced the maximum possible net profit.

This is made more challenging by the field environment where the individual decisions are made. In the western woods, the tree is felled, delimbed, and possibly topped. What remains is the tree stem. The "woods bucker," the worker responsible for making decisions on tree use, must then decide how to cut the trees into logs. He must bear in mind that length, curvature, diameter, and knots are all factors in the value of any particular log. He is not dealing with a raw materials base of interchangeable items: each log is different, each decision on its use is irreversible. Dealing with tree stems is not like dealing with lengths of pipe.

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In the South, crosscutting decisions are often carried out at large, fast-moving processing centers that handle the whole stem. The individual trees are smaller, but more crooked. The decisions are just as complex, and each operator is asked to complete several stems a minute, a much faster rate than in the West.

Depending on the decisions the worker makes, the stem can vary in value by 50 percent or more. Because making better decisions on tree cutting and log allocation entails no additional costs, any extra raw material value that can be consistently obtained by improved decisions goes directly into company profits. With Weyerhaeuser's large raw materials flow, the profit increase can be millions of dollars a year.

However, at first glance, making broadly effective improvements in our cutting and allocation decisions seemed difficult. Each year, Weyerhaeuser cuts and allocates approximately 15 million trees, one hundred trees a minute. No two trees are alike and each can be made into a variety of products. The decisions on cutting and allocation are made by hundreds of people in dispersed and often remote geographic areas. The initial proposal to use management science techniques to help improve stem-by-stem decision making was met with skepticism. With so many variables to account for, senior managers asked, how can we go beyond relying on the experience of our men in the field?

The response was what we call VISION. It consists of two elements: first, a dynamic programming optimization procedure that determines the best economic use for any tree; and second, a video-game-like computer system that allows woods and mill personnel, as well as company managers and top executives, to easily grasp what the best use is of any particular tree stem. Together, the result is better decisions in practice.

Funds were initially authorized for VISION in 1976. Weyerhaeuser did not publicize the VISION effort in order to retain its competitive advantage. This secrecy continued until we received a patent on the system in 1982.

Developing VISION

After the limbs and possibly the top are removed (Figure 1), the tree stem is then crosscut into logs. Each log is allocated to a market, such as export to Japan or sale domestically, or to a company manufacturing facility, such as a lumber mill, a plywood mill, or to one of several types of paper product mills.

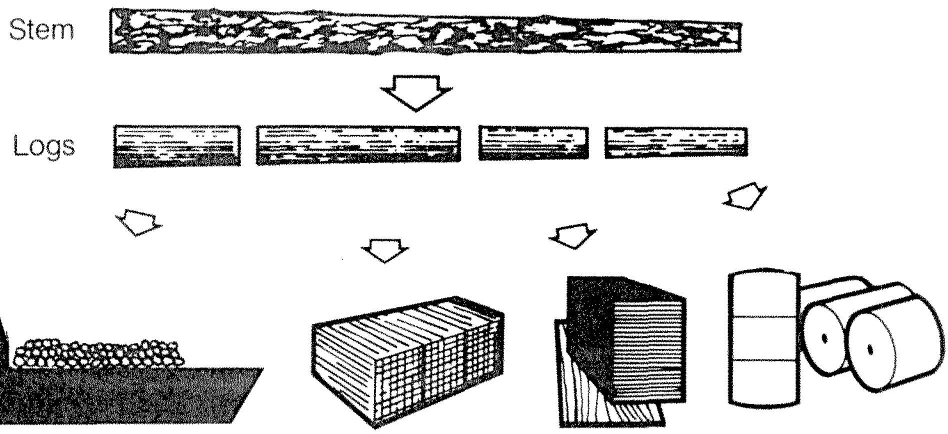

Figure 1: A tree stem is crosscut into logs and the logs are allocated to a market — such as export to Japan — or to a manufacturing facility — such as for production of lumber, plywood, or paper products.

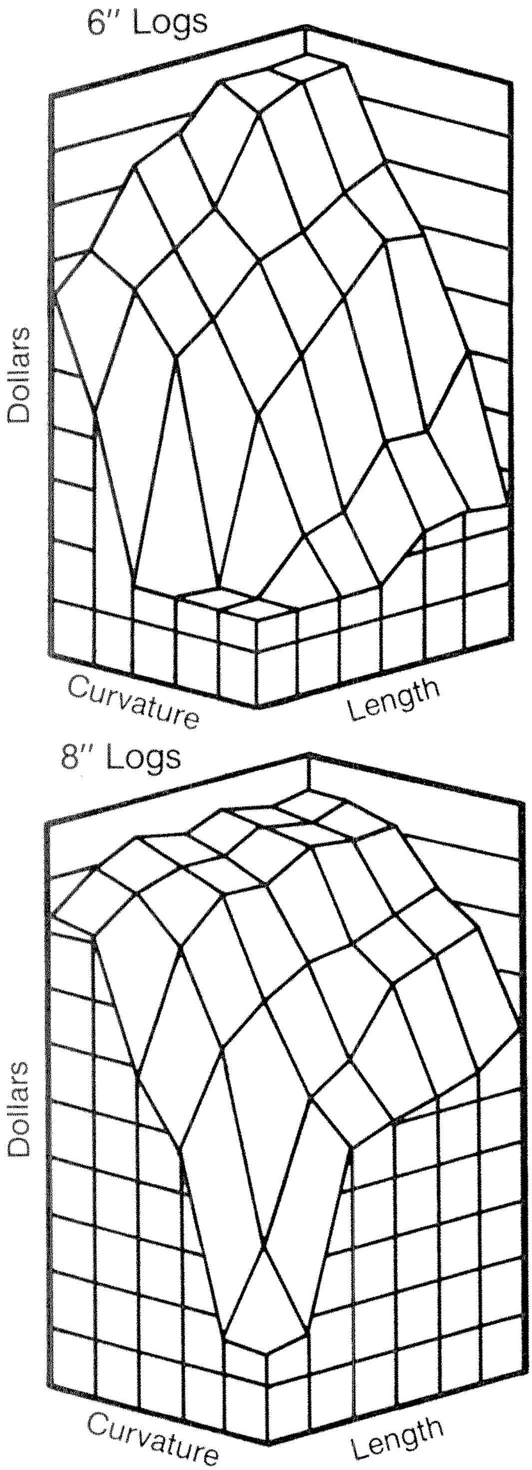

Figure 2: Log revenue varies dramatically as a function of log curvature, length, and diameter.

The value of a stem is the sum of the revenues produced from each of the individual logs it is made into, minus the costs associated with cutting the stem and processing the logs.

The revenue Weyerhaeuser derives from any particular log depends on many factors: the log length, curvature, diameter, and taper, its knot and quality characteristics, as well as the market or mill to which it is sent. Log values can vary dramatically with these parameters. Figure 2 shows actual data of revenue versus just two parameters, log curvature and length and also illustrates how the relationship can change significantly with a change in log diameter of only two inches.

Consequently, different decisions on crosscutting and allocating a stem can produce very different log revenues and, therefore, very different stem values (Figure 3).

Finding the optimal cut and allocation decisions for a particular stem can be formulated as a dynamic program. A highly simplified version was included in the appendix of LC. However, a number of analytic and practical difficulties need to be overcome in order to create and exploit a useful formulation. Three of the most significant are

— The algorithm must account for the complex geometry of stems;

— The logs that can be cut from a stem are not simple multiple lengths of each other, for example, eight-foot lumber is not produced from logs half the length of logs yielding 16-foot lumber; metric lengths for export must be considered, and so forth; and

— One must have extensive data bases

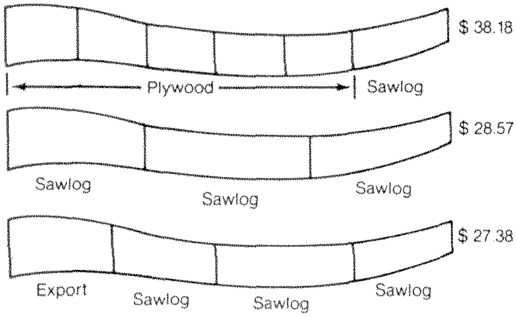

Figure 3: Different crosscut and allocation decisions for the same stem produce very different log revenues — and therefore very different stem values.

both of stems and of log values as a function of all the important log parameters and possible allocations.

Developing these information bases upon which to rest our dynamic programming algorithm required gathering information on thousands of stems and logs from each of our operating regions. Weyerhaeuser painstakingly collected stem geometry in two-foot increments and entered the physical attributes of each into a stem data base. Next, we had to gather all necessary log values. This required mill tests in many cases.

With this data assembled and with a proprietary dynamic programming algorithm the company developed to handle the complexities mentioned above, we could compute the optimal crosscut and allocation decisions for a stem. However, having this capability and having it actually change field decisions were two different things. Effective implementation was at least equally a challenge.

We faced several obstacles:

— First, we had to convince top management to provide us with the time and the budget to develop an effective implementation vehicle.

— Second, because no two trees are identical, the optimal dynamic programming solutions will also be different. It is not possible to compute a "right answer" that can be implemented for every stem.

— Third, and most important, we had to develop a means for transforming better decisions into field worker actions. It was not economically practical nor physically feasible to put computers loaded with the dynamic program in the field with each worker. Nor were these workers going to change their traditional way of cutting and allocating a stem just because some technical folks from corporate headquarters suggested there might be a better way.

Implementation required understanding and acceptance by these decision makers. This implied a great deal of management and worker involvement. Whatever our approach, it had to be easily understood and credible to experienced woodsmen.

VISION was our attempt to meet these challenges. Its name, decoded, suggests its purpose: *V*ideo *I*nteractive *S*tem *I*nspection and *O*ptimizatio*N*. VISION was our original "decision simulator" used as an implementation vehicle for an optimization algorithm. VISION was designed to provide its user with the opportunity to cut and allocate stems, receive immediate feedback on the economic consequences of those decisions, and see for comparison the dynamic programming decisions and their economic consequences. An illustrated description of the sequence of events in a VISION session is in LC.

VISION allows its user to make decisions, see what revenues they yield, and compare them with the optimal decisions. As a result, the user develops a better understanding of how to optimize the returns available from each tree. It's typical for the first-time user to distrust the optimal solutions and try to beat them. This creates a tremendous challenge. With time, users gradually discover that the dynamic programming cuts and allocations are better decisions than their early ones, and their decisions consistently improve. This improvement occurs at their own pace, with no one looking over their shoulders. When they return to the field, they take their improved decision-making abilities back with them.

We tried to design the system to be easy to learn and use. We didn't want to ask loggers to learn about computers. We wanted them to cut logs. Over 200 persons have interacted with VISION, most of them woods or mill workers. Almost everyone became comfortable with the system in the first five minutes. One logger from Dierks, Arkansas, told us that if we put VISION in his favorite tavern, our employees would pay to play it!

VISION Applications and Benefits

VISION has been used in Weyerhaeuser since 1977. The VISION system showed that senior management intuition was correct: raw materials values could be increased in western operations. Contrary to original perceptions, VISION also showed that there were opportunities for increasing raw material values in the South.

Seeing resources in this new way led to many changes in operations. Management used the system to formulate alternative stem-processing strategies and to evaluate their economics. Field workers also built decision skills by spending time with VISION. The most interesting uses involved both strategy changes and individual decisions. An important example of this type of use related to West Coast Douglas-fir operations.

The woods buckers in the West make their stem-by-stem decisions using their judgment aided by general strategies called "woods-bucking instructions" printed on a pocket-sized card. Early use of VISION showed that these instructions were producing suboptimal revenues. Weyerhaeuser used VISION both to improve the woods-bucking instructions and to enable buckers to improve their decision-making skills.

Alternative instructions were developed by first computing and displaying the profit-maximizing decisions for sample stems, then studying these decisions for patterns which reappeared for classes of stems, and finally, generalizing these patterns into new woods instructions (Figure 4). This generalization process was aided by a respected field veteran who applied his considerable operational experience

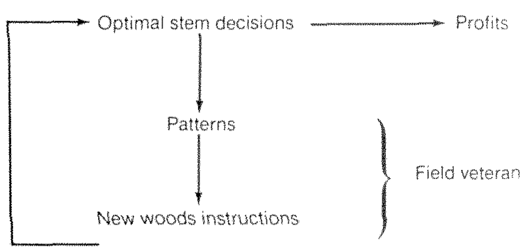

Figure 4: Optimal stem decisions are studied for reappearing patterns that are generalized into new woods bucking instructions; these are compared again with optimal stem decisions. This iterative process employs a respected field veteran.

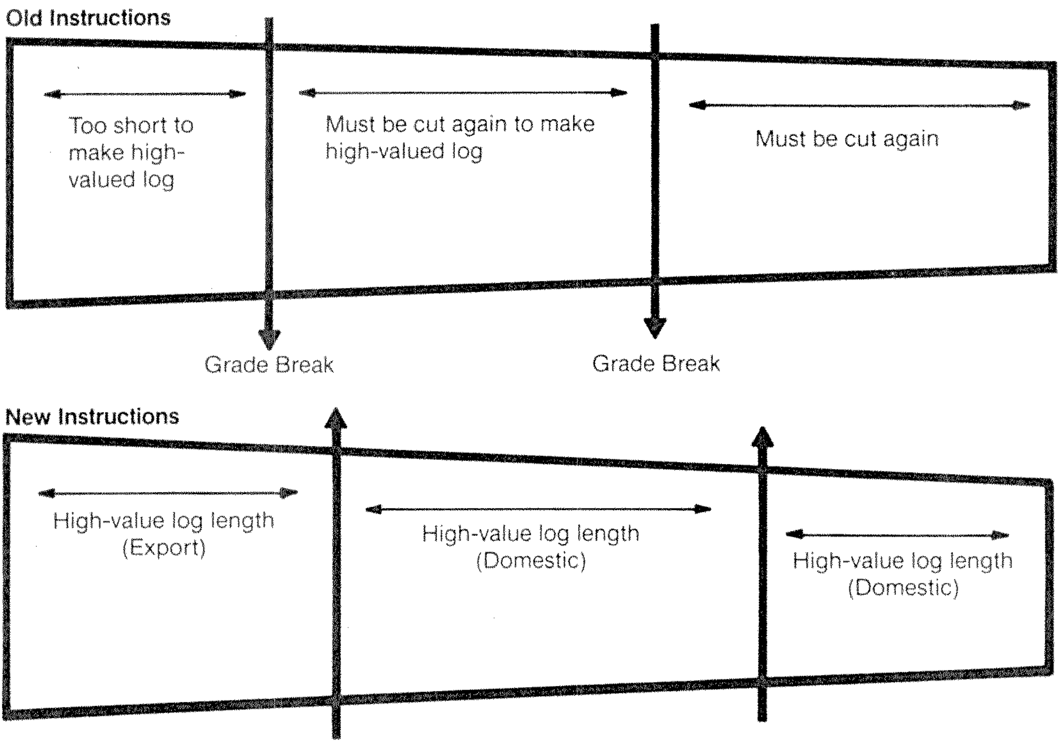

Figure 5: Old instructions emphasize cutting at changes in stem quality (grade breaks); new instructions emphasize cutting high-valued export and domestic log lengths.

and judgment. First, we had to establish the credibility of the dynamic programming algorithm in his mind. He put VISION through its paces and became convinced of the value of the dynamic programming solutions. He then used VISION to compare alternate cutting patterns and construct alternative bucking instructions. Once a number of promising candidate instructions were developed, each was applied to all the sample stems and the resulting aggregate profits compared. The best performing set of instructions was selected. It differed fundamentally from what was then common practice by emphasizing that selected high-value export log lengths be cut rather than instructing that logs be cut where stem quality changed (Figure 5).

We then had to gain the understanding and acceptance of the woods foremen. The foremen used VISION to see the results of cutting and allocating a sample of stems from their region using their old instructions. Then, they were given the new instructions and asked to recut the same set of stems. They were also encouraged to experiment with any other cutting patterns of their own invention. The experienced field expert sponsored and participated in these foremen activities. With their value demonstrated, the foremen readily embraced the new instructions and saw the implications of the dynamic programming algorithm. As a result, their operating regions implemented the new instructions quickly.

These new instructions were put into practice starting in 1977. A careful field audit of cutting practices was completed two years later during 1979. Woods bucker decisions and the values of logs produced were tracked both before and after introduction of the new instructions. The measured difference in value as a result of the new way logs were being cut and allocated was $7 million of additional annual profits, expressed in 1979 dollars.

During the same period, a group of other applications was directed at improving southern raw material values. Region raw material managers, operational superintendents, and operators took part in VISION sessions. By themselves, these activities improved stem-crosscutting and log-allocation decisions. This initial involvement with VISION also spawned many location-specific applications in the South, analogous to the woods-bucking changes in the West. For example, the manager responsible for raw materials in the Oklahoma-Arkansas region spent many sessions with VISION evaluating the consequences of alternative operating strategies and developing new strategies on the spot. He subsequently implemented new strategies for stem cutting and allocating across his operations. He also became a strong advocate of capital investments in his region that allowed increased control over stem cutting practices. At one location he installed a fully automated system to help achieve optimal cutting and allocation.

How a tree is crosscut into logs and what is done with the resulting logs largely determines the return.

In 1979 a careful quantification was also made of the impact across the South. The analysis was requested by the sponsoring group vice-president and reviewed by the chief operating officer. It showed just under $6 million of annual profit increase (again, in 1979 dollars).

Raw material values and therefore the annual benefits from this management science effort were relatively constant through the end of 1980, when adjusted for inflation. However, since 1981, the forest products industry has experienced a significant decline in end-product prices and general raw material values. So, to compute aggregate benefits to date, rather than just multiply by the number of years that have elapsed, the western and southern benefits for each year after 1980 are adjusted for both the decline in raw material values and inflation. For consistency, we put all aggregated dollars on a 1985 basis. We did not put a quantitative figure on the generally improved ability of our workers to adjust to changes, which is nonetheless a benefit of working with VISION. We only included the benefits from changes seen in field operations.

The result of these computations: a $59 million incremental profit contribution to date from the western woods bucking application and a profit increase for our southern operations of at least $42 million so far. Thus, total operational benefits to date are at least $100 million.

And, this is perhaps not VISION's most

important effect. As important is that VISION influenced management philosophy from the top on down.

Because a lot of time has passed since our first VISION efforts, we've had the opportunity to observe the staying power of its effects on the company. As timber values have fallen, industry profits have fallen even faster. Fortunately, the nature of the benefits from this management science effort do not decline proportionally to profits. In fact, the ratio of annual benefits to Weyerhaeuser operating profits has steadily increased since 1980 (Figure 6). By 1984, this contribution ratio had grown to over three times its pre-1981 level.

Decision Simulators

While developing VISION, it occured to us that there were some general features which could be profitably applied to a lot of our management science work. The literature revealed no prior use of an approach with VISION's features. Subsequently, we coined the term *decision simulator* to describe our approach. The term *decision simulator* is intended to suggest that VISION-like implementation tools provide experiences for a decision maker that are analogous to those a flight simulator provides for an airline pilot. A more complete discussion of decision simulators is in LC. Here we wish only to emphasize that decision simulators represent a generic approach to helping implement management science solutions. Systems like VISION can be built for many different applications. Indeed, we've built several other decision simulators ourselves since our first one in 1976. Others have been reported recently in MS/OR journals. We believe that management science practitioners have a wide-spread opportunity to exploit the decision simulator implementation approach. Because the ratio of computer cost to performance continues to improve, creating a decision simulator is becoming easier.

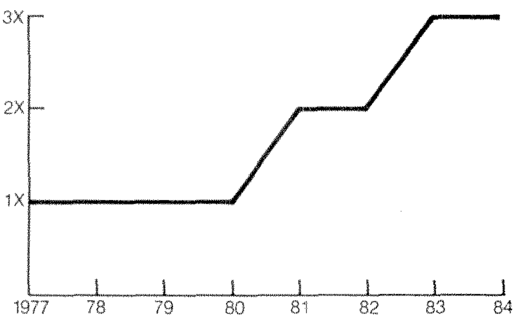

Figure 6: The ratio of annual benefits from VISION to Weyerhaeuser operating profits has increased with time.

Impact Summary

We conclude with comments from Donald E. Rush, Group Vice-President for Timberlands, on the impact on Weyerhaeuser of this implementation of management science:

> I'm convinced that improved bucking instructions in our western operations led to approximately $60 million more profit, as described in this paper. VISION has changed the West Coast mentality of doing business. We're doing a better job of matching our logs to the marketplace than ever before.
>
> VISION also showed us there was more variation in southern raw material values than we'd believed — and that, consequently, there was an opportunity to upgrade the average value of our southern trees. Implementation in the South led to enhanced profits of over $40 million.
>
> I reviewed these figures carefully and, in fact, reported them to our chief operating officer. They are, if anything, on the conservative side.
>
> I've seen the effect VISION has had on the thinking of even some of our most traditional woods workers. And I've seen the effect this effort has had on the thinking of our top man-

agers — even beyond what I've just described for the South and West.

Top managers were involved in the funding, testing, and implementation of VISION. Our chief executive officer, George Weyerhaeuser, used it. So did our chief operating officer, myself, and many others. We all realized from our interaction that there was more we could do with our timber resources — and we took action. For example, I've seen us commit many millions of scarce capital dollars to completely automate log processing facilities so that VISION-like procedures can be used on-line to process tree stems. Also, we've funded and developed other systems based on the same principles for such different areas as facility design and truck-routing.

VISION changed our corporate behavior in ways that have made us more money, and these changes have persisted. The contributions to our bottom line have not only held up over the years, but have actually increased in importance over time and under adverse industry economic conditions. This is an advantage unique and exclusive to Weyerhaeuser, an advantage enjoyed currently by none of our competitors.

Acknowledgment

Many persons played significant roles in the efforts described here. Bob Davis supplied his years of field experience and brought his credibility with foremen and workers. Bill Grunow and Lynne Stroh aided implementation of new woods bucking instructions. Doug Hay produced the original dynamic programming algorithm.

Reference

Lembersky, Mark R. and Chi, Uli H. 1984, "Decision simulators speed implementation and improve operations," *Interfaces*, Vol. 14, No. 4 (July-August), pp. 1-15.