FOREST HARVESTING MANAGEMENT DECISION METHODS

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PLANNING HARVESTING SYSTEM CONFIGURATION

Harvesting System Objectives

Maximize Profits

The most difficult and complicated task in evaluating a harvesting system is cost analysis which in turn is a function of production. Cost analysis is often the primary focus when planning a harvesting system. However, a cost minimizing harvesting system is useless if it produces revenues less than its cost.

The primary objective of any business should be to maximize profits or net income. This should also be the over all objective in planning a forest harvesting system. The ultimate outcome criteria for judging between mutually exclusive alternative systems should be net income or profit per unit of output.

To clarify the importance of this overall objective, consider the following example. A harvesting manager is considering supplying raw material to a large pulp mill which has made a firm, long-term commitment to purchase the material at certain prices. The material can be delivered as roundwood or as whole-tree chips. The mill will purchase roundwood for $18 per ton delivered however, because pulp quality is adversely affected by the bark and foliage contained in whole-tree chips, it offers only $16 per ton for whole-tree chips. The harvesting manager after exhaustive analysis identifies a tree length roundwood system and a whole-tree chip system that satisfy all market and physical constraints. The roundwood system can produce the raw material for a total cost of $15 per ton, the whole-tree chip system for $14 per ton. If the harvesting manager makes his decision based solely on cost minimization, and chooses the whole-tree chip system, he will be making a serious mistake. The whole-tree chip system yields a profit of only $2 per ton while the roundwood system yields a profit of $3 per ton.

There are many more examples of this important principle. In many cases the more costly, less technically advanced system, possesses flexibility necessary to exploit more profitable markets. In fact, the trend in the South at present seems to be toward merchandising at the landing not at the mill. More and more the forest harvesting manager is assuming the key role of allocating or merchandising the trees to the various primary forest product producers so as to maximize the value added by the harvesting process which he measures as his system's profitablity. The merchandising harvesting manager demands flexibility as well as cost minimization.

Market and Physical Constraints

With the system objectives clearly defined the next step in designing a forest harvesting system is determining the requirements of the potential forest product markets. Are the potential markets: sawmills, veneer mills, or pulp mills? What species are required? What stem size is optimal? Is log grade a consideration? What size tracts will be harvested? Do the trees have to be bucked to length? Answers to these questions are critical constraints on the harvesting system configuration, and they must be kept in mind throughout the planning process.

Probably, the most important market constraint to consider is the possibility or probability of unanticipated downtime. If the potential markets are volatile in nature, the more capital-intensive systems should be considered only if long-term contracts can be secured. The high fixed costs associated with the more efficient capital-intensive systems demand stable markets and uninterrupted production.

After the marketing constraints are identified, any physical constraints on harvesting should become more readily apparent. These physical constraints should be considered next. The following is a partial list of possible physical constraints to be considered: volume per acre, average stem size, species(e.g. limbiness, brashnness), terrain, weather, underbrush, silviculture requirements(e.g. residual stand damage), environmental (e.g. easily erodable soils, noise restrictions), safety, labor market, equipment dealers. The imposition of constraints, such as special equipment to satisfy silvicultural requirements, will likely increase costs. The importance of these constraints cannot be over-empahsized.

Every possible marketing and physical constraint should be considered before any detailed systems analysis is attempted. At this point many of the possible machines and configurations will be eliminated due to infeasibility concerning the market and physical constraints.

Identifying these constraints may be difficult and time consuming. The intended purchaser of the product should be helpful. It would also be wise to observe the operations of competitors, but it should not be automatically assumed that present configurations cannot be improved upon. Introduction of innovative technology could produce a competitive advantage. Current forest journals, such as: the Southern Journal of Applied Forestry, Forest Products Journal, and Journal of Forestry, and forest harvesting textbooks, such as: those written by Conway(1982), Stenzel, Walbridge, and Pierce(1985), and Staff and Wiksten(1984), are good sources of information on current forest harvesting techniques and practices.

Analysis of Control Centers

Identify Possible Configurations

To better analyze the harvesting system configuration it is helpful to break the system into manageable units. These units can be called control centers. Control centers are groups of related men and machines which, for the purpose of analysis and control, can be logically treated together. A break down of control centers of a typical harvesting system would be: cutting, primary transportation, loading, and secondary transportation.

Each control center should be considered separately first. Identification of possible configurations for each control center should be made, while keeping in mind the previously identified market and physical constraints.

Production Information

Once the potential configurations for each control center are identified, data must be collected that will enable comparisons to be made between the configurations. Production information is necessary. What volume per unit of time, such as logs per day, can be transported, loaded, skidded, or cut? Precise production information is often difficult to obtain. Invariably production rates are based on past data and are influenced by many variables, such as:

weather, terrain, species, underbrush, volume per acre, and stem size. Because of the many influencing variables, production information should be used as broad guidelines in the planning stage. The primary goal at this point is to insure that the configuration will at least satisfy the minimum production requirements. Once a configuration is chosen and put into production, methods are available to determine production rates more precisely. These methods will be discussed in greater detail in the operations analysis section of this paper.

Equipment manufacturers can often provide production information. For example the Caterpillar Performance Handbook (1984), contains a detailed section describing methods of precisely estimating skidder production. Specifications sheets for equipment give information on horsepower, drawbar pull, load capacity, etc., which is helpful for inferring production rates. The Green Guide (1986), and the Specifications for Construction Equipment (1986), provide detailed specifications and costs for most currently available forestry equipment. Observing the production of existing systems is another good source of information. Many managers have past experience to draw upon.

Cost Information

Often the production requirements and the market and physical constraints of the control centers can be met by several different configuratins. At this point the primary determinant of the configuration chosen is cost.

Considereable research concerning forest harvesting costs has been conducted in recent years (Miyata,1980), (Werblow and Cubbage,1986), (Plummer,1982). These researchers all use machine rate formulas to calculate fixed and operating costs of forest harvesting equipment.

Miyata (1980), details this method of determining fixed and operating costs. Fixed costs consist of depreciation, interest, insurance and taxes. There are several methods of calculating depreciation or equipment cost recovery. The ACRS (Accelerated Cost Recovery System) required by the IRS for tax purposes allows recovery of more of the purchase price early in the life of the machine. However, for purposes of cost comparison the straight line method is often used because it is more realistic. The mathematical formula for calculating straight line depreciation is:

$$\text{Depreciation} = I-R/\text{total hours or miles}$$

I = Initial cost

R = Residual or salvage value

The initial cost informatin is available from equipment dealers or the Green Guide (1986). Salvage value is also available from the Green Guide (1986), or as a rule-of-thumb 20% of the purchase price can be used. The total hours are productive hours and can be calculated as a percentage of scheduled hours. Appendix A gives a list of utilization percentages(Miyata,1980). Estimates of total equipment life are available from Plummer (1982) and Werblow and Cubbage (1986), (Appendix B).

Interest, insurance, and tax expenses can be calculated by contacting financial institutions, insurance companies, and the Internal Revenue Service. These expenses can also be calculated quickly by multiplying the estimated percentage expense of these items on an average annual investment basis by the average annual investment and dividing by the estimated annual operating hours or miles. Average annual investment is calculated according to the following formula:

$$AAI = [(I-R)(N+1)/2N] + R$$

I = Initial cost
R = Residual or salvage value
N = Number of years of equipment ownership

The rates for off-road equipment are currently 5% to 7% for insurance. Taxes are currently 2% to 3%. Interest rates are currently 10% to 12%.

Operating costs consist of maintenance and repair, fuel, lubricants, and tires or tracks. If experienced owners or cost records are not available, the houly maintenance and repair cost can be estimated as a percentage of houly depreciation cost (Miyata,1980). The hourly maintenance and repair costs are calculated as follows:

Hourly Maintenance and Repair = (YD)(PR)/Productive Hours per yr.

YD = Yearly depreciation
PR = Percentage Rate

Percentage rates are listed in Appendix C.

Hourly fuel costs can be estimated for off-road equipment as follows (Miyata,1980):

Diesel equipment = (.037 x hp.) x cost per gallon
Gasoline equipment = (.050 x hp.) x cost per gallon
(hp = net horsepower)

Fuel costs for on-highway vehicles can be estimated by multiplying local cost per gallon by miles per gallon figures compiled by sources such as Plummer and Stokes (1985). Hourly engine oil cost can be calculated by:

$(.0005 \times hp + c/t) \times$ cost per gallon (Miyata, 1980)

hp = Net horsepower

c = Crankcase capacity in gallons

t = number of hours between oil changes

Fifty percent of engine oil cost may be used for other lubricants (Miyata, 1980).

Tire and track cost information can be obtained from dealers, or hourly tire cost can be calculated as follows:

Hourly tire cost = (1.15 × tire cost) / tire life(hrs)

Labor costs for operators can be computed on an hourly basis and added to the fixed and operating costs of the machines to determine the total hourly cost of owning and operating the machines. Prevailing wage rates can be obtained from other owners. Labor cost should also include employers expense for social security, federal and state unemployment insurance, and workmen's compensation insurance.

Rough estimates of hourly costs for representative forest harvesting equipment have been compiled by Werblow and Cubbage (1986) (Appendix B), and Plummer (1982). These figures can be used for rough comparison purposes, if there isn't time to calculate costs for individual machines. Appendix D gives an example of individual machine cost calculations (Miyata,1980).

Cost Analysis for Each Control Center

With production and cost informatin aggregated for all possible configurations, machines can be compared directly by placing them on a common basis. For example, if productivity is measured in logs per hour and costs as cost per hour; costs per log for each machine could be calculated by the following equation:

$$\text{Machine Performance} = \text{Average Hourly Costs} / \text{Average Hourly Productivity}$$

If the machines are considered equal in all other areas then the machine or configuration with the lowest cost per log should be chosen. So cost minimization should be the decision criteria.

At this point it would be wise to conduct sensitivity analysis on the configurations. That is, observe the changes in machine or configuration performance resulting from changes in key productivity and cost assumptions. This procedure gives an indication of how critical a component is to the performance of a configuration.

Harvest System Analysis

The various control centers should be combined into a harvesting system to ascertain that the control centers are compatible as a system. Certain control center configurations may limit the configurations of the next associated control center. For instance, a cutting control center composed of feller-bunchers usually require that grapple skidders compose the primary transportation control center to achieve maximum over all productivity.

Finally, the average cost per unit of volume of the entire harversting system shoud be calculated. This figure subtracted from the projected average revenue from the same unit of volume gives the average profit of the system.

Again, it would be wise to conduct sensitivity analysis. This time on the entire system. Key variables should be altered to ascertain the resulting changes in over all productivity. For example, would the system still be profitable if the average number of days worked per year was reduced by 10%? Another important item to observe is the sensitivity of the control centers to each other. If the configuration of one control center is altered, how will it affect the others? Changes should be made to see exactly what the resulting impact will be on the other control centers. All variables that are expected to have a high degree of variance should especially be examined closely. If historic data is available for key variables, probability distributions can be constructed. If these distributions appear to be approxiamately normal, the variables should be examined at least to two standard deviations.

One popular method of checking sensitivity is break-even analysis. With this procedure the amount of production that equates revenue and cost can be determined so that the manager knows the minimum required production to cover costs(Conway, 1982). The solution can be found by trial and error by altering production amounts and calculating the resulting revenue and costs, or it can be found algebraically using the following equation by plugging in the parameters and solving for X:

$$a + bX = cX$$

X = Production amount units

a = Fixed costs

b = Variable costs

c = price received per production unit

The availability of fast efficient computers has made more powerful, complex management techniques available for analyzing large, complex harvesting systems. Linear programming has been widely used to help solve complex allocation problems. It is especially useful for allocating fixed resources under numerous operating constraints. The secondary transportation control center would be especially suited to linear programming solutions, especially when multiple destinations or job sites are anticipated. Linear programming software packages, such as LINDO, are available for inexpensive microcomputers.

Linear programming is a deterministic method which means that input values and solutions are assumed to be known with certainty. It also assumes that relationships between variables are straightforward and mathematically describable. These assumptions are often abstractions from reality.

There are also some special linear programming algorithms that utilize matrices to simplify the linear programming solution process. The transportation algorithm, the assignment algorithm, and the network models (shortest route, maximal flow, and minimal spanning tree) are especially suited to transportation problems(Anderson, Sweeney, and Williams, 1985).

The most powerful tools currently available for analyzing harvesting systems are forest harvesting simulation models. During the past 15 years many computer simulation models have been developed, some of which are undergoing continued development and evolution (Goulet, Iff, and Sirois,1979), (Stuart,1981), (Cubbage and Granskog,1982). Unlike linear programming, system simulation is probalistic, that is , it does not optimize or find the best solution, but it predicts what will happen when certain conditions are changed.

Some of these models, such as the Harvest System Simulator (Stuart,1981), are very detailed and attempt to account for all of the complex variables involved in a harvesting system. Forest industry has begun to utilize these powerful simulation models even though they are still in the evolutionary stage.

Unfortunately, at this point there appears to be no concensus between individual modelers on what constitutes a harvesting model's essential elements (Goulet, Iff, and Sirois,1979). Each model reflects the individual modeler's point-of-view, so care should be exercised in selecting a model to use. Presently, there are no "user-oriented" models available and fairly large computer systems are required. At this time the services of a computer specialist are required to interpret the user's questions into a form permissible by the models. The development of "user-friendly" models will probably be the next major break-through in forest harvesting operations analysis.

Regardless of the harvesting system analysis technique chosen, it is essential that the marketing and physical constraints be accurately identified and that production and cost information be precise as possible. The most sophisticated computer model will output garbage if the input is garbage.

DECISIONS TO ACCEPT OR REJECT FOREST HARVESTING CHANCES

Objective

One of the most important decisions facing forest harvesting managers is the decision to accept or reject harvesting chances. For most managers this is a recurring decision. Many managers, through valuable experience accumulated over a period of time, can quickly assess potential chances and make sound decisions based on their experience. However, even experienced managers can be overwhelmed by the many variables affecting the decision. A systematic decision process is a valuable managerial tool even for the experienced manager.

The rational forest harvesting manager's over all objective should be to maximize conversion surplus. Conversion surplus is a comparative value useful for comparing alternatives. It is the total delivered revenue less all variable costs of conversion. Why use conversion surplus rather than profit or net income? Because decisions to accept or reject harvesting chances are usually short-term in nature. Costs which are fixed in the short-term, such as depreciatin and interest expense on equipment, will be incurred regardless of the harvesting chance chosen, and are therefore irrelevant to the decision. In fact inclusion of irrelevant costs could actually lead to an erroneus decsion (Duerr, 1984). Only those costs that would vary between chances, such as: equipment operating expenses, road costs, moving costs, and stumpage, should be included in the analysis.

The estimation of conversion surplus is often an elusive goal, primarily due to the uncertainty characteristic of most forest harvesting industries. This uncertainty can only be reduced by securing long-term supply contracts which are often not available. Without long-term contracts managers should keep abreast of all potential markets and try to forecast future raw material demands and prices. The manager's ability to forecast raw material demand and prices is crucial to the process of estimating projected revenues for a potential harvesting chance. How can a manager acquire the information necessary to make these forecasts? There are publications such as Timber Mart South (1986) which track timber prices. Information can be obtained when attending timber bid opennings. Often primary producers will give non-binding estimates of the future prices they expect to offer.

Weather is one of the most critical factors affecting successful operation of a forest harvesting firm. Modern capital-intensive harvesting operations incur high fixed costs that must be met even when the firm is shut-down. Obviously, steady uninterrupted production is vital to the success of these operations. Harvesting chances that will allow operation during adverse weather conditions should receive premiums for the purpose of comparison to recognize this important attribute. One method that could be used to incorporate the weather value into the comparison is to multiply the conversion surplus of the individual chances by the estimated percentages of the year that the chance can be harvested. For example, the conversion surplus of a chance located in a swamp might be multiplied by .25 if it could only be harvested during the three summer months. Conversly, a chance availabe for harvesting any time of the year would be multiplied by 1.0. Any method used will be inexact and not always accurate, but the point is, weather operability is too important not to incorporate into the analysis.

To summarize, the decision criteria should be conversion surplus. However, conversion surplus should be weighted in some manner to reflect the weather operability of the chance.

Projected Revenues

To estimate the projected conversion surplus of a potential harvesting chance projected revenues and expenses must be calculated. Projected revenues are dependent on many factors: volume, species, delivered price, purchase price, market conditions, and utilization are a few of the more important ones. All of these factors must be estimated and aggregated to project expected revenues.

The first factors to be considered in projecting revenue are volume and species identification. These two factors combined with projected prices are the primary determinants of revenue. Although some landowners offering timber sales for bid include detailed accurate perspectuses, most managers consider personal surveys of logging chances essential. If the manager is uncertain that the chance has any potential, he should make a preliminary visit before incurring the surveying expense. These surveys or cruises usually take the form of sample surveys and are usually performed by persons trained in forest mensuration procedures (Avery, 1975). A good cruise should give a manager an estimate of the various products and volumes that can be produced from the chance. The manager can then apply the prevailing product prices to the volume figures to determine projected revenues for the chance. The cruiser should also compile a map of the chance including all information pertinent to planning the harvesting operation for use if the chance is accepted.

During this process of estimating projected revenues the harvesting manager must exercise insight and good judgement. For instance, what will market conditions likely be when the harvesting actually occurs? Can a long enough cutting period be secured or should provision for an extension be negotiated? Will delivered prices change substantially? Will the harvesting operation utilize the raw material as efficiently as planned? Answers to these questions and possibly others will have pronounced effects on revenue projections.

Because of the many variables that can affect revenues, the harvesting manager should conduct sensitivity analysis on the projected revenues. He should estimate what production would be if unfavorable conditions occur. For example, what will be the estimated conversion surplus if the delivered price is cut by two dollars per ton. If there is a significant possibility of the unfavorable circumstance occuring then revenue estimates should be adjusted accordingly.

Through experience, insight, or circumstances the manager might be able to estimate the probabilities of receiving certain prices. He could quantify these estimates by multiplying the probabilities by their respective prices and summing the resulting figures to obtain a weighted average price that now to some degree incorporates uncertainty into the analysis. The following example illustrates the procedure:

Estimated Price	Probability	Wt. Average
$26/ton	.25	$6.50
$28/ton	.50	$14.00
$29/ton	.25	$7.25
		$27.75/ton

The manager would use the price of $27.75 to project revenues in the analysis.

The harvesting manager should also not neglect marketing strategy. For example, he may recognize a substantial volume of pole quality trees which if marketed properly could increase revenues substantially.

Projected Variable Costs

Cruising and Stumpage Costs

The harvesting manager must accurately project his variable costs involved with harvesting a given chance. Each potential chance will have unique costs, it is therefore necessary to calculate costs for each individual chance.

The first costs encountered include surveying or cruising costs and stumpage or purchase costs. In fact, cruising costs will usually be incurred for missed chances as well as those that are actually purchased. Cruising and stumpage costs are usually the easiest costs to measure since the cruising costs are often already incurred and stumpage prices are set by the manager.

In actual practice the stumpage cost, which is often the biggest expense, is set by the manager after all other projected variable expenses are subtracted from projected revenues. The actual stumpage price chosen will depend on the desired profit margin, the availability of alternate chances, what the manager expects competitors to offer, and any other desirable or undesirable characteristics of the chance. Setting the stumpage price is often the most improtant decision a manager faces. If his bid or offer is too low he may miss the chance which he might have needed to continue operations. If his bid or offer is too high he gives away a protion of his profit unnecessarily.

All expenses associated with acquiring the stumpage should be included. These include such items as: interest if the money for the stumpage is borrowed, title search, mortgage certificate, and payments to other landowners for access if necessary.

Road Construction Costs

Another major cost that needs to be estimated is road construction costs. This is an expense that is unique to each individual chance. The cruise map should supply most of the necessary data to make the estimation, however a good working knowledge of the soils present and the expected weather conditions during harvesting are helpful. On big road jobs the construction may be subcontracted. In this case bids should be taken from more than one road contractor. It should be remembered that the extent to which roads are constructed will affect other logging costs such as skidding. Sometimes a "bare minimum" road is not the most economical decision. In fact bad road decisions could drastically curtail production or greatly increase other expenses. Capital-intensive harvesting systems demand high continuous production. The expense of "lost" production can quickly offset road costs.

Deciding what type and quantity of roads to build is a decision that must be made before the road costs can be estimated. This decision is affected by many factors, such as: desired skid distance, individual site characteristics, planned season of harvest, and volume to be moved. The road decision must be evaluated by considering its affects on the weighted conversion surplus. Some decisions may be simple. If the chance is small and will only be harvested during dry weather then obviously a bare minimum road is indicated. However, if the chance is to sustain the firm during the entire wet season then a gravel surface all-weather road may be necessary. The key question to ask is how will weighted conversion surplus be affected?

Moving Costs

As larger more capital-intensive harvesting systems are adopted, moving costs become more and more important. To properly assess the cost of harvesting a particular harvesting chance these costs must be included. The time involved in moving is the most critical component in the move cost. To account properly for all machine, labor and overhead costs, the following should be included: cost of transporting harvest equipment, wages paid to employees who are not productive during a move, charges for fixed costs of non-productive equipement, if the move is made during scheduled working hours, and value of profit foregone during the move. Cubbage (1983) found that small systems such as bobtail systems and prehauler systems have costs of $0 to $400 to move, while large harvest systems such as feller-buncher and grapple skidder combinations and whole-tree chip systems cost $1000 to $2000 to move. With the larger systems Cubbage found that equipment transportation costs are only about 10% of the total move costs. Payroll costs account for 35% to 45% of the total. Fixed costs for non-productive equipment constituted the largest share of costs, ranging from about 35% to 57%.

There are various ways to reduce move costs. Moving after regular working hours or on weekends is likely to reduce costs the most. Reducing the length of the move time by more efficient planning and equipment loading could also reduce moving costs. Organizing logging chances to minimize move distances could reduce costs if the need for a lowboy is eliminated. Selecting larger average tract sizes would result in fewer moves per year and lower average yearly or long-run move costs. Also, paying labor on a piece-rate basis tends to reduce move costs.

Standard Harvesting Variable Costs

Standard harvesting costs are those costs directly associated with conversion of the standing trees to the delivered product. These costs should be estimated for each control center. Typical control centers are: cutting, primary transportation, loading, and secondary transportation. The section dealing with analysis of control centers in the preceeding chapter on planning harvesting system confiurations details methods of estimating production and cost information for control centers.

Cost information for the control centers can be estimated rather precisely using the methods outlined (Miyata, 1980), however labor cost must be added to equipment operating cost to obtain total operational costs. Labor costs should also include employer's workmen's compensation, unemployment, and social security expense as well as any other fringe benefits paid (Appendix D). However, fixed equipment costs should not be included in this analysis because they are not relevant to the decision. Costs can be expressed on a per hour basis, then, depending on the control centers' estimated productivity, a standard cost for the chance can be estimated.

Precise production information is often difficult to obtain. Invariably production rates are based on past data and are influenced by many variables, such as: skid distance, haul distance, weather, terrain, species, underbrush, volume per acre, and stem size. Methods for estimating production rates will be discussed in greater detail in the operations analysis section of this paper.

Harvesting Chance Analysis

To determine the conversion surplus simply subtract the projected variable costs from the projected revenues, and then weight the conversion surplus in some manner to account for weather operability. The chances with the highest conversion surplus should be chosen. The harvesting manager should also look for stand characteristics, such as: volume per acre, tree size, or species, that are especially well suited to his operation.

At this point sensitivity analysis should be conducted to ascertain the profitablility of the chance if certain key variables are altered. For example, what will costs be if productivity falls 10% short of projections? What will revenues be if the delivered price is cut by 5%? Variables that are expected to be volatile should be examined closely.

Break-even analysis is a good method of checking sensitivity (Conway, 1982). This procedure equates revenue and costs to determine the minimum required volume. The solution can be found by trial and error or algebraically using the following equation and solving for X:

$$aX = bX$$

X = volume

a = variable costs

b = price per unit of production

Linear programming is another managemnt tool useful for helping solve harvesting chance decisions. Linear programming software packages, such as LINDO, are available for inexpensive microcomputers. This methods's ability to allocate fixed resources under numerous operating constraints makes it especially suited to analysis of secondary transportation control centers (Anderson et.al., 1985). There are also some special linear programming algorithms, the transportation algorithm, the assignment algorithm, and the network models(shortest route, maximal flow, and minimal spanning tree), that are especially suited to transportation problems (Anderson et. al., 1985).

Especially large problems may be suited to forest harvesting simulation models (Goulet et. al., 1979), (Stuart, 1981), (Cubbage and Granskog, 1982). Some of these models, such as the Harvest System Simulator (Stuart, 1981), are very detailed and attempt to account for all of the complex variables involved in a harvesting system. Unfortunately, there are no "user oriented" models available and fairly large computer systems are required. At this time the services of a computer specialist are required to interpret the user's questions into a form permissable by the models.

OPERATIONS ANALYSIS

Methods Improvement

Purpose

Modern, capital-intensive forest harvesting systems demand efficient continuous production. The high level of fixed costs characteristic of these systems make unproductive time very costly, because these costs continue to be incurred even when the system is shut-down. Lost time is not only costly, but it can also never be recaptured. Obviously, minimizing lost time increases the system's productivity or efficient use of inputs. Methods improvement is a term that refers to tools and procedures useful to a manager for the purpose of minimizing lost time as a method of increasing productivity. For the small operator these inefficiencies and delays are often obvious. Methods improvement however, becomes more important as the size of the operation increases and the causes of lost time are harder to recognize.

Record Operation

The first step in methods improvement is to record the operation. Usually the harvesting operation is broken into control centers, such as: cutting, primary transportation, loading, and secondary transportation, so that each can be observed and analyzed separately.

Daily production reports are one means of recording operations. Each day someone from each control center could be responsible for recording the date, hours worked, crew size, production(number of logs, loads, etc.), downtime in hours, and any comments concerning production or downtime. Over time managers can begin to set production standards based on these production reports, and fairly accurate predictions of expected production for given situations can be made. If the subsequent production does not meet expectations the manager should seek to determine if his predictions were unrealistic or if there is an efficiency problem or other unforseen problem.

Production reports and standards are helpful to a manager, but they have limited use in recording operations for methods improvement because the standards are based on the assumption that past methods of operation are optimal. This assumption is contradictory to the idea of methods improvement. To truly evaluate an operation with an in-depth operations study a more precise method of recording the operation is needed.

Before beginning the recording phase of the operations study, a preliminary investigation of the operation should be made. Actual observation should be made of the operation to be studied. The foremen or men performing the operation should also be consulted to get their ideas on possible problems and improvements.

A continuous time study is one means of recording the operation to be studied(Conway, 1968a). First, the total operation should be broken into elements. Then the observer records with a decimal stopwatch the time necessary to perform each element. The following table illustrates what a typical continuous time study sheet for a loading operation for one cycle might look like:

Continuous Time Study Sheet (Log Loading)

Element Description	Element	Time Reading	Time Elapsed	R	Normal Time
	Start	0.00			
	Unload Tr.	1.15	1.15	__	1.15
jump-start!	Mount Lo.	5.95	4.80	1	.48
	Swing out	6.10	.15	__	.15
	Pick up	6.20	.10	__	.10
	Swing in	6.30	.10	__	.10
	Load Log	6.35	.05	__	.05

(in actual practice elements would be numbered)

(__= 100% efficiency, 1= 10% efficiency)

(delay in "mount loader"-jump start required)

The "R" column represents the estimated percent efficiency rate at which the operator performed the element. The 1 in the "mount loader" row indicates 10% efficiency. This is the hardest part for the observer because it is a judgemental decision, that can only be learned through time and experience.

The information from the continuous time study is useful in itself for spotting inefficiencies, but it can also be used to develop a time standard for the operation which can in turn be used to calculate standard costs. In the log loading example a manager can use the standard loading time per log along with estimated hourly operating cost for the loader and the tract's volume per acre and average log size to accuratly forecast loading cost. The following table illustrates a time standard for the previous log loading illustration:

Time Standard(Log Loading)

Element	Normal Time	Freq. Occ.	Normal Min./Log
Unload Trailer	1.15	50/1200*	.05
Mount Loader	.48	50/1200	.02

Swing Out	.15	1/1	.15
Pick Up Log	.10	1/1	.10
Swing In	.10	1/1	.10
Load Log	.05	1/1	.05
Sort Logs	1.20	200/1200	.20
Dismount Loader	.35	50/1200	.01
Trim and Bind Load	4.25	50/1200	.18

Standard Normal Minutes per Log.............. .86

(*50/1200 indicates element occurred 50 times in 1200 logs)

Of course the level of accuracy obtained depends on the number of cycles observed. There are statistical formulas that indicate the acceptable sample size for any given confidence level(Freese,1962), but in practice common sense and available time will often be the guidelines. When enough cycles have been observed the observer will notice that individual element times have stabilized within a narrow range.

Another method of recording an operation is work sampling(Conway,1968b). It is probably the least expensive method available. Work sampling is accomplished by taking instant observations of an operation or process at random intervals and determining what element of work is being done. As with the continuous time study what, operations that are to be studied and the elements of the operations must be determined beforehand. Two other major considerations must also be addressed. The number of observations to be made and when the observations will be taken must be determined. To get accurate results the timing of the observatons should be at random. A simple method would be to divide the day into periods on pieces of paper and draw them from a hat. A random number table could also be used. Determining the proper sample size for work sampling is more important than determining the number of cycles to observe in continuous time studies. The sample size depends on the confidence level desired and the variability of the times encountered. Statistical formulas or tables can be used to make this decision(Freese,1962).

The following example summary of a work sample for the secondary transportation control center clearly shows where time was spent:

Work Sample Summary (Secondary Transportation)

Activity	Percentage Distribution
Travel Unloaded	26%
Loading	10
Loading Delay	5
Travel Loaded	34
Unloading	4

Unloading Delay	10
Other Delays	11

(Productive Time-74%, Non-productive Time-26%)

In this example it is obvious that reducing loading and unloading delays would significantly increase productivity. Work sampling can be very precise and like the continuous time study it can be used in the development of production standards.

The method of recording operations chosen depends on the time available, desired precision, and study objectives among other factors. Daily production reports are helpful and inexpensive, but an in-depth study requires the services of an independent observer conducting continuous time studies or work samples. The work sample is easier and more flexible, but continuous time studies may be more exact. Preliminary examinations of operations, and conversations with foremen and crews will allow priority areas for study to be targeted.

Analyze Operation and Implement Improvements

The next step in methods improvments after recording the operation is to analyze the operation. Some problems or areas of lost time may be obvious by simply looking at the continuous time study or work sample. There are also graphic techniques useful for analyzing operations. As mentioned earlier, the development of standard costs for control centers is useful for budgeting and productivity analysis.

The example of log loading presented in the continuous time study illustration can be used as an illustration of how standard costs can be developed. The continuous time study yielded a normal standard log loading time of .86 minutes per log. Methods outlined in the section on planning harvesting system configurations could be used to calculate the hourly owning and operating cost of the control center (Appendix D)(Miyata,1980). Suppose the calculations indicated owning and operating costs of $25/hour or $.42/minute. The following table could be constrcted to give standard costs for the loading control center for various volumes per acre:

Loading Cost per Thousand Board Feet

Avg. Volume/Log	Logs/MBF	Time to Load	Loading Cost/MBF
330	3	2.58	$1.08
200	5	4.30	1.79
100	10	8.60	3.58
50	20	17.20	7.17

Graphical methods such as the time bar diagram and flow process chart illustrated in Appendix E (Conway,1968c), are ways to organize the information from a continuous time study or work sample so that the control centers can be analyzed more carefully. Both methods are aids designed to help the manager answer the following key questions:

1. Why is it done this way?
2. Is this the best way to do it?
3. What are some alternatives?

Methods improvement is largely controlled by the state of mind. Every element should be questioned. Performing an operation in a certain manner because that is the way it has always been done is not a satisfactory justification. The manager should create an atmosphere that encourages foremen and crew to be constantly looking for new or better methods. Obviously, the manager should develop a close working relationship with these people and consult them often.

The final and most important step in methods improvement is implementation. Hours of time and energy spent recording and analyzing operations and developing new methods are useless unless the improvements are effectively implemented. Close cooperation between managers and operators is essential. Cooperation should start at the beginning of operations recording and continue all the way through implementation of improved methods. An operator who is included in all phases of the operations analysis will be more committed to effective implementation of any resulting improvements. Methods improvement is a team effort.

Break-Even Analysis

Break-even analysis was discussed earlier as a method of sensitivity analysis. It is also a useful tool for operations analysis. The procedure can determine the minimum required production of a given chance by equating revenue and cost. The solution can be found by trial and error by altering production amounts and calculating the resulting revenue and costs, or it can be found algebraically using the following equation by plugging in the parameters and solving for X:

$$a + bX = cX$$

X = Production amount units

a = Fixed costs

b = Variable costs

c = Price received per production unit

For example suppose a manager is considering taking a harvesting contract involving 4,000 tons of logs for which he will receive \$14/ton. He calculates his operating costs for the contract to be \$5/ton. He estimates the contract will take one month to complete during which time he will incur \$30,000 in fixed costs(depreciation, interest, insurance). Break-even analysis can be used to determine how low production could drop and still cover all costs:

$$a + bX = cX$$

$$30{,}000 + 5X = 14X$$

$$30{,}000 = 9X$$

$$X = 3{,}333 \text{ tons}$$

The manager knows that he must produce at least 3,333 tons to break-even on the contract.

Equipment Replacement

The objective in equipment management should be to operate each machine so that life time average total costs per unit of time or output are minimized. There are several approaches to the decision to repair or replace equipment. Some methods such as the service-life method and policy-life method do not require extensive cost records, but they also may not yield sound decisions. The service-life method simply means to run the equipment until it simply cannot be repaired. This method should only be used for non-essential infrequently used equipment such as a lowboy. The policy-life method sets certain time periods for replacement regardless of individual maintenance history. An example would be a decision to replace haul trucks every six years. This method may be satifactory if considerable research goes into setting the guidelines.

There are other methods for making the repair-replace decision that rely on cost records. They will generally yield better results than the previously described methods. One method of using cost records to make the decision is to compare the estimated cost of retaining the old machine for another year to the estimated average lifetime cost of an equivalent new machine. If the old machine's expected cost is higher the machine should be replaced. Another commonly used method is to allow any individual repair as long as its costs does not exceed the difference between the current market value of the machine in good repair and its salvage value, as long as the cumulative repair costs do not exceed some upper limit, such as, one and a half times purchase price.

What if the harvesting manager is considering replacing the old machine with one that is considerably different, such as replacing cable skidders with grapple skidders? The methods previously described are not well suited to this decision. One popular method that is often used for this type decision is the payback method. This method calculates the amount of time necessary for the cost savings to sum to the value of the initial investment. The accounting rate of return method is sometimes used for the repair-replace decision. It is calculated by dividing the average annual savings by the average investment. The payback and accounting rate of return methods are popular, but they ignore the time value of money, which is the reality that distant savings or cashflows are worth less than immediate savings or cashflows. The net present value or internal rate of return methods are the best methods for analyzing the repair-replace decision because these methods include the time value of money in the analysis. Both methods are based on a system of discounting annual cash inflows and outflows to a present value basis and then comparing the costs and benefits(Horngren, 1984)(Brigham, 1985).

An illustration of a typical replacement analysis may clarify some of the methods presented . In this example the manager is considering replacing an old cable skidder with a new grapple skidder. Consider the following basic information:

Basic Information

	New Machine	Old Machine
Current Value	$70,000	$28,000
Est. Service Life	5 yr.	5yr.
Age	0	3yr.
Salvage Value	$14,000	$10,000

(discount rate-12%, corporate tax rate-40%)

For siplicity we will assume that straight-line depreciaton is used. We will also assume that the manager has estimated that the new machine will save $10,000 annually. Net outflows at the time of the investment are calculated first:

Net Outflows(time=0)

Cost of New Machine	$70,000
Market Value of Old Machine	($28,000)
Total Initial Outflow	$42,000

Net inflows or savings for the new machine's life are calculated next. Total net inflows are the sum of after-tax savings, depreciation tax savings, and salvage value:

Net Inflows

	t=1	t=2	t=3	t=4	t=5
After-tax Save	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000
Dep. New Mach.	14,000	14,000	14,000	14,000	14,000
Dep. Old Mach.	10,000	10,000			
Change in Dep.	4,000	4,000	14,000	14,000	14,000
Dep. Tax Save	1,600	1,600	5,600	5,600	5,600
Salvage Value(new machine)					14,000
Total Net Inflow	7,600	7,600	11,600	11,600	25,600
Dis. Net Inflow	6,786	6,059	8,257	7,372	14,526

[After-tax savings= 10,000 x (1-.40)]

(Depreciaton tax savings= change in dep. x .40)

(t=year)

Net present value is calculated by the following formula, the positive NPV indicates that the old machine should be replaced:

NPV = Discounted Net Outflows - Discounted Net Inflows

NPV = 42,000 - 6,786 - 6,059 - 8,257 - 7,372 - 14,526

NPV = 1,000

The internal rate of return is determined by trial and error by substituting different discount rates until the discounted net inflows equal the net outflows. In this example IRR = 12.8%. The payback period can be calculated from the net inflows as 4.14 years [(42,000 - 7,600 - 7,600 - 11,600 - 11,600) / 25,600].

Obviously, the most sophisticated method of analysis is useless if the cost estimates upon which they are based are not accurate. Current, well defined, and accurate cost records are essential to making sound investment decisions.

Operations Research

Large, complex forest harvesting operations can benefit from more complex management techniques. Linear programming has been widely used to help solve complex allocation problems(Anderson et.al., 1985). There are some special linear programming algorithms: the transportation algorithm, the assighnent algorithm, and the network models(shortest route, maximal flow, and minimal spanning tree), that are especially suited to transportation problems(Anderson et.al., 1985).

Forest harvesting simulation models(Goulet et.al., 1979), (Stuart, 1981), (Cubbage and Granskog, 1982), are being used more and more for operations analysis. They are very detailed and attempt to account for all of the complex variables involved in a harvesting system. Currently, these models are not "user oriented" and require a fairly large computer system and a computer specialist to operate them. The next breakthrough in forest harvesting operations analysis may be development of "user friendly" simulation models for use with microcomputers.

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APPENDIX A

EQUIPMENT UTILIZATION PERCENTAGES

Machine	Percentage Rate
Chain saw	50
Big stick loader	90
Shortwood hydraulic loader	65
Longwood hydraulic loader	64
Uniloader	60
Front end loader	60
Cable skidder	67
Grapple skidder	67
Shortwood prehauler	64
Longwood prehauler	64
Feller-buncher	65
Chipper	75
Slasher	67

(Miyata,1980)

APPENDIX B

AVERAGE MACHINE RATES FOR FOREST HARVESTING EQUIPMENT-1984

(Werblow and Cubbage,1986)

Average machine rates for forest harvesting equipment, 1984.

					Cost per operating hr					
						Operating				
Equipment	Delivered price	Salvage value	Ownership period (yr)	Estimated usage per yr (hr/mi)	Fixed	Fuel & lubricant	Maintenance & repair	Tire/ track	Total operating	Total
Chainsaw—straight blade	$ 550	$ 0	1	1200	$ 0.53	$ —	$ —	$ —	$ 3.50	$ 4.03
Feller bunchers										
Three-wheeled	52,000	13,000	3	1300	16.30	2.18	3.04	1.32	6.54	22.84
Sm. rubber-tired, 65–82 hp	75,000	18,750	3	1300	23.51	4.01	6.07	.66	10.74	34.25
Med. rubber-tired, 83–100 hp	85,000	21,250	4	1300	22.25	4.18	6.13	.66	10.97	33.22
Lg. rubber-tired, 110–130 hp	109,500	27,375	4	1300	28.66	6.53	7.90	1.42	15.85	44.51
Limited area tracked	188,200	47,050	5	1300	41.99	6.95	6.90	8.50	22.35	64.34
Cable skidders										
70–80 hp	50,700	12,675	4	1300	13.46	3.43	4.09	.69	8.21	21.67
80–100 hp	60,100	15,025	4	1300	15.96	4.16	4.58	.73	9.47	25.43
100–120 hp	68,000	17,000	5	1200	17.28	5.32	5.01	1.15	11.48	28.76
120–140 hp	72,500	18,125	5	1200	18.42	5.61	5.71	1.14	12.46	30.88
140+ hp	98,700	24,675	5	1200	25.09	7.15	7.22	1.93	16.30	41.39
Grapple skidders										
70–90 hp	70,500	17,625	4	1300	18.73	38.3	5.76	.69	10.28	29.01
110–130 hp	89,200	22,300	5	1200	22.68	5.83	6.20	1.14	13.17	35.85
130+ hp	115,800	28,950	5	1200	29.44	7.55	8.25	1.92	17.72	47.16
Other skidders										
Tracked cable skidder	115,000	28,750	5	1200	29.23	5.80	9.03	1.60	16.43	45.65
Clambunk skidder	225,000	56,250	5	1200	57.20	8.43	16.88	2.30	27.61	84.81
Farm tractor skidder	36,300	9,075	5	1000	11.08	4.23	2.80	.72	7.75	18.83
Forwarders										
80–100 hp shortwood forwarder	63,500	15,875	4	1300	16.87	4.32	5.25	1.03	10.60	27.47
120–130 hp longwood forwarder	75,700	18,925	4	1300	20.11	5.39	6.70	1.03	13.12	33.23
Slasher/delimber										
Sm. hyd. slasher—chain	11,500	0	4	1300	3.17	—	—	—	1.16	4.33
16" Iron gate delimber	2,400	0	5	1500	.46	—	—	—	.15	.61
Loaders										
Bigstick cable loader	3,700	0	5	720	1.49	—	—	—	2.50	3.99
Sm. hyd. knuckleboom (9,000–15,000 lb max lift)	27,300	6,825	5	1000	7.38	3.05	8.40	—	11.45	18.83
Med. hyd. knuckleboom (15,000–23,000 lb max lift)	60,000	15,000	5	1000	16.20	3.49	9.42	—	12.91	29.11
Lg. hyd. knuckleboom (23,000–33,000 lb max lift)	83,000	20,825	5	1000	22.50	4.94	12.50	—	17.44	39.94
Trailer to mount loader	4,500	1,125	5	1000	1.22	—	—	—	.60	1.82
Whole-tree chippers										
Med. W-T chipper (18"–20", 300–400 hp)	137,200	34,300	5	1500	25.15	13.71	10.75	.40	24.86	50.01
Lg. W-T chipper (20"–23", 500+ hp)	229,000	57,250	5	1500	41.98	23.48	15.70	.40	39.58	81.56

(cont'd)

				Estimated	Cost per operating hr					
						Operating				
Equipment	Delivered price	Salvage value	Ownership period (yr)	usage per yr (hr/mi)	Fixed	Fuel & lubricant	Maintenance & repair	Tire/ track	Total operating	Total
Road work equipment										
Small tracked dozer—80 hp	60,800	15,200	5	1200	13.93	4.23	4.04	3.33	11.60	25.53
Med. tracked dozer—140 hp	125,500	31,375	5	1200	28.76	7.29	7.76	5.58	20.63	49.39
Road grader—135 hp	116,400	29,100	8	1250	19.27	6.55	5.57	.95	13.07	32.34
Trucks										
Dead tandem bobtail	19,500	4,875	3	24,000	.41	.28	.25	.08	.61	1.02
Live tandem bobtail	27,500	6,875	4	24,000	.48	.32	.26	.08	.66	1.14
Diesel truck—tractor	70,000	17,500	5	60,000	.43	.23	.21	.07	.51	.94
½-ton pickup	9,000	2,250	3	25,000	.16	.09	.04	.01	.14	.30
1-ton service/crew truck	30,000	7,500	3	25,000	.50	.13	.11	.02	.26	.76
Trailers										
Shortwood	11,000	2,750	8	50,000	.05	—	—	—	.07	.12
Double-deck log	10,500	2,625	8	50,000	.04	—	—	—	.07	.11
Pole	10,000	2,500	8	50,000	.04	—	—	—	.07	.11
Chip van	19,000	4,750	8	37,500	.10	—	—	—	.09	.19
25-ton lowboy	14,000	3,500	10	10,000	.26	—	—	—	.07	.33

APPENDIX C

PERCENTAGE RATES FOR ESTIMATING HOURLY MAINTENANCE AND REPAIR COSTS

Machine	Percentage Rate
Crawler tractor	100
Agricultural wheel tractor	100
Cable skidder	50
Grapple skidder	60
Cable loader	30
Hydraulic loader	50
Chainsaw	100
Feller-buncher	50

(Miyata,1980)

APPENDIX D

EXAMPLE OF INDIVIDUAL MACHINE COST CALCULATIONS

(Miyata,1980)

Example 11.— A contractor wishes to estimate the fixed and operating cost of a rubber-tired skidder costing $45,000 (F.O.B. factory price).

Preliminary Data and Determinations

- Description of equipment—diesel, 115 hp, 10 gallons of crankcase capacity, 120 hours between oil changes.
- Diesel fuel, $.60/gallon.
- Engine oil, $2.00/gallon.
- Interest 12%, insurance 3%, taxes 3%.
- Labor cost $7.00/hour (including the employer's contribution)
- Initial investment (P):

Purchase cost (without a grapple)	$45,000
Extra attachment cost (grapple)	$ 6,000
Sales taxes (4%)	$ 2,040
Freight cost (5 cents per pound) (shipping weight 15,000 lbs. × .05)	$ 750
Less tires cost	$-7,000
P =	$46,790

• Salvage value (S) (20% of P)	$ 9,358
• Economic life (N)	3 yrs
• Scheduled operating time (SH)	2,000 hr/yr
• Utilization (see tabulation, page 3)	67%
• Productive time (2,000 × 67%)(H)	1,340 hr/yr.

Fixed Cost

- Depreciation (D) = (P−S)/N = ($46,790 − $9,358)/3 yr = $12,477.33/yr.
- Interest, insurance, and taxes (18% × AVI)[10] = .18 × $34,312.67 = $ 6,176.28/yr.

(1) Fixed cost per year = $18,653.61

(2) Fixed cost per Productive Time = $ 13.92

Operating Cost (based on productive time)

- Maintenance and repair: (60% (see tabulation, page 8) × D)/1,300 = $ 5.59
- Fuel: (0.037 × 115 hp × .60) = $ 2.55
- Lubricants:
  Engine oil ((.0005 × 115) + (10/120)) × $2.00 = $ .28
  Other lubricants (50% of engine oil) .14
  = $ .42
- Tire ($7,000 × 1.15)/3,000 = $ 2.68

(3) Operating Cost Per Productive Time = $ 11.24

Fixed Operating Cost per Productive Time (excluding labor cost)

(2) + (3) = $13.92 + $11.24 = $25.16

Labor Cost per Productive Time

$7.00/SH × (2,000 SH/1,340 H) = $10.45

Fixed and Operating Cost of Equipment per Productive Time With Labor Cost = $35.61

---

[8] *Average value of yearly investment (AVI)*

$$AVI = \frac{(P-S)(N+1)}{2N} + S = \frac{(40,000-8,000)(5+1)}{2(5)} + 8,000 = 27,270/\text{yr.}$$

[9] *$7.00/SH is based on the scheduled operating time. Operating cost in this example is based on productive time. Thus, multiplying $7.00/SH by 2000/1300, we can obtain the labor cost per productive time (H).*

[10] $$AVI = \frac{(P-S)(N+1)}{2N} + S = \frac{(46,790-9,358)(3+1)}{2(3)} + 9,358 = 34,312.67$$

APPENDIX E

(Conway, 1968c)

ILLUSTRATION OF TIME BAR DIAGRAM AND FLOW PROCESS CHART

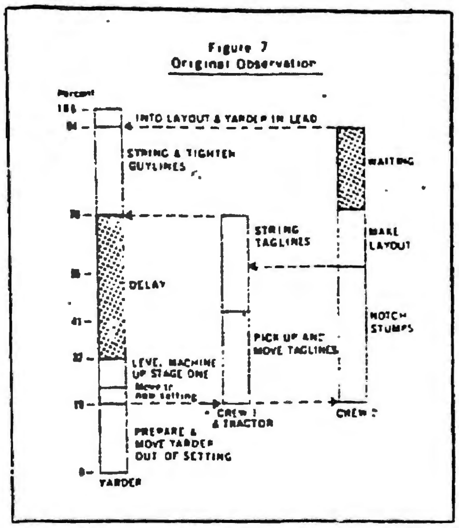


Figure 7
Original Observation

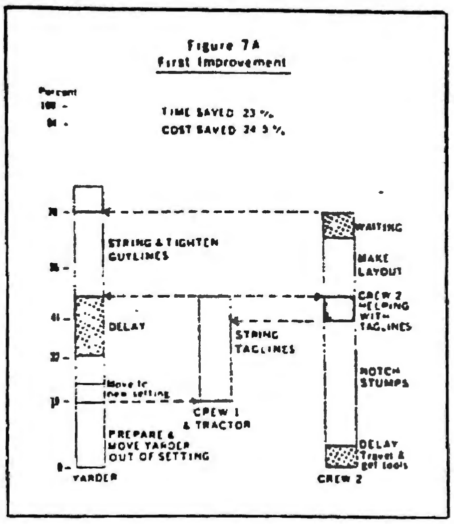


Figure 7A
First Improvement

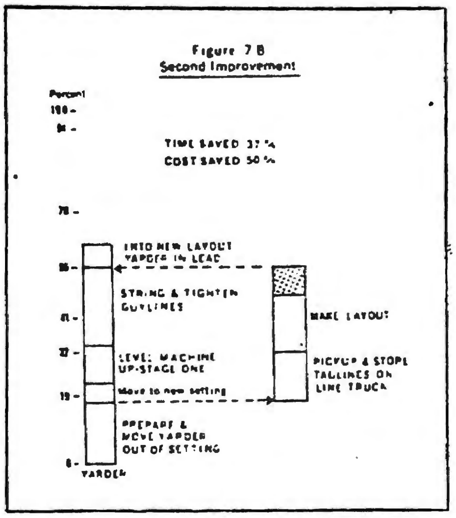
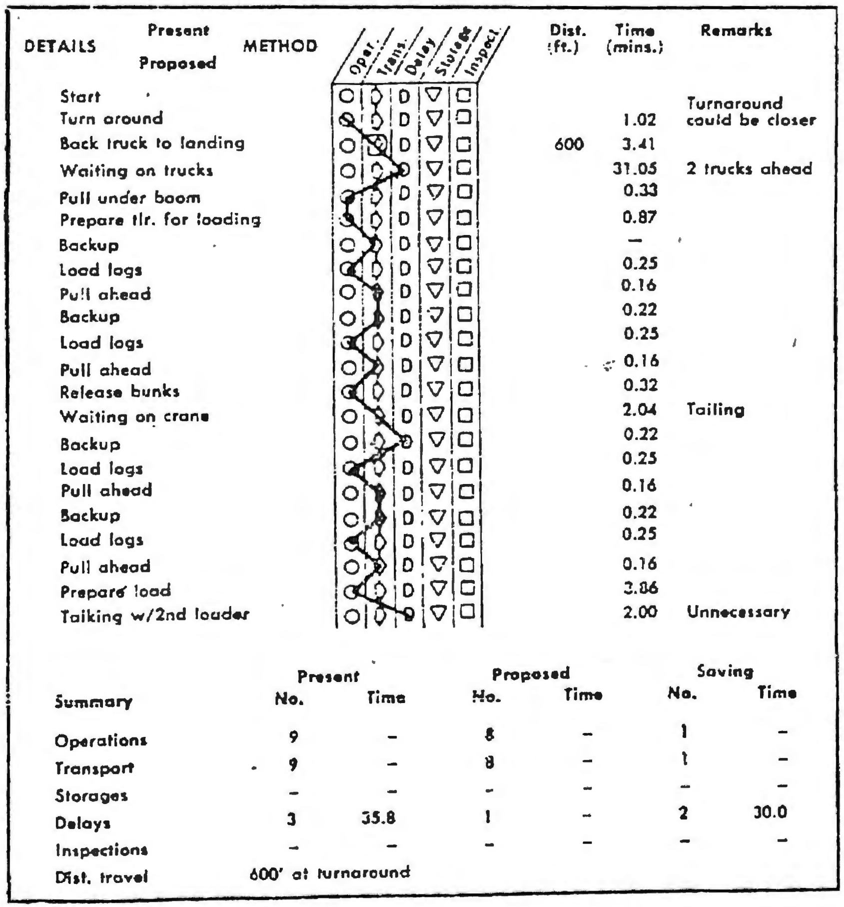
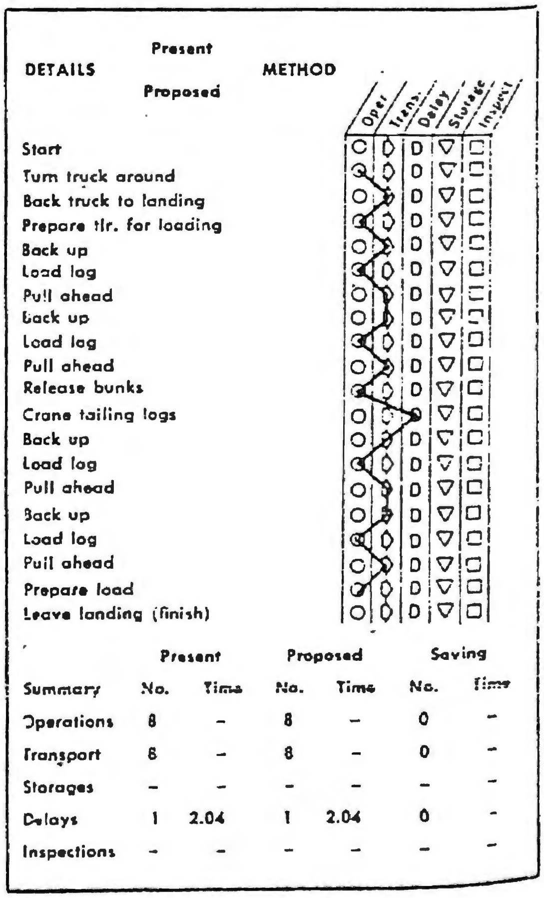


Figure 7 B
Second Improvement



DETAILS Present Proposed METHOD	Oper.	Trans.	Delay	Storage	Inspect.	Dist. (ft.)	Time (mins.)	Remarks
Start	○	◇	D	▽	□			Turnaround
Turn around	○	◇	D	▽	□		1.02	could be closer
Back truck to landing	○	◇	D	▽	□	600	3.41	
Waiting on trucks	○	◇	D	▽	□		31.05	2 trucks ahead
Pull under boom	○	◇	D	▽	□		0.33	
Prepare tlr. for loading	○	◇	D	▽	□		0.87	
Backup	○	◇	D	▽	□		—	
Load logs	○	◇	D	▽	□		0.25	
Pull ahead	○	◇	D	▽	□		0.16	
Backup	○	◇	D	▽	□		0.22	
Load logs	○	◇	D	▽	□		0.25	
Pull ahead	○	◇	D	▽	□		0.16	
Release bunks	○	◇	D	▽	□		0.32	
Waiting on crane	○	◇	D	▽	□		2.04	Tailing
Backup	○	◇	D	▽	□		0.22	
Load logs	○	◇	D	▽	□		0.25	
Pull ahead	○	◇	D	▽	□		0.16	
Backup	○	◇	D	▽	□		0.22	
Load logs	○	◇	D	▽	□		0.25	
Pull ahead	○	◇	D	▽	□		0.16	
Prepare load	○	◇	D	▽	□		3.86	
Taiking w/2nd loader	○	◇	D	▽	□		2.00	Unnecessary

	Present		Proposed		Saving	
Summary	No.	Time	No.	Time	No.	Time
Operations	9	-	8	-	1	-
Transport	9	-	8	-	1	-
Storages	-	-	-	-	-	-
Delays	3	35.8	1	-	2	30.0
Inspections	-	-	-	-	-	-
Dist. travel	600' at turnaround					



DETAILS Present Proposed METHOD	Oper.	Trans.	Delay	Storage	Inspect.
Start	○	◇	D	▽	□
Turn truck around	○	◇	D	▽	□
Back truck to landing	○	◇	D	▽	□
Prepare tlr. for loading	○	◇	D	▽	□
Back up	○	◇	D	▽	□
Load log	○	◇	D	▽	□
Pull ahead	○	◇	D	▽	□
Back up	○	◇	D	▽	□
Load log	○	◇	D	▽	□
Pull ahead	○	◇	D	▽	□
Release bunks	○	◇	D	▽	□
Crane tailing logs	○	◇	D	▽	□
Back up	○	◇	D	▽	□
Load log	○	◇	D	▽	□
Pull ahead	○	◇	D	▽	□
Back up	○	◇	D	▽	□
Load log	○	◇	D	▽	□
Pull ahead	○	◇	D	▽	□
Prepare load	○	◇	D	▽	□
Leave landing (finish)	○	◇	D	▽	□

	Present		Proposed		Saving	
Summary	No.	Time	No.	Time	No.	Time
Operations	8	-	8	-	0	-
Transport	8	-	8	-	0	-
Storages	-	-	-	-	-	-
Delays	1	2.04	1	2.04	0	-
Inspections	-	-	-	-	-	-