Simulation of the loading and hauling subsystems of a logging system
by Leonard Roy Johnson

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Industrial and Management Engineering
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Abstract:
The logging system consists of five subsystems; namely, felling, bucking, skidding, loading, and hauling. Productivity of the felling and bucking subsystems depends largely upon the skill of the men doing the work and can be subjected to a minimum amount of analysis. Skidding represents a materials handling system that is being subjected to a great deal of technical analysis. Loading and hauling, however, stand in need of investigation. Both are materials handling systems that need analysis of the best equipment for a particular situation.

This thesis presents a simulation model that investigates the many variable combinations existing in the loading and hauling subsystems . Development of the model required two steps: (1) identi- fication of the events and activities common to loading and hauling subsystems and (2) definition of owning and operating costs relevant to the two sub-systems. Calculation of relevant costs resulted in the criteria used to compare the numerous variable combinations. The criteria is a ratio of investment to output expressed in dollars per thousand board feet of merchantable timber. Identification of appropriate events and activities allowed use of the simulation language, GASP II, in testing various alternatives.

The result of this investigation is a fully developed model capable of testing alternatives of the many logging situations in existence. Since any "best" combination depends upon the particular logging situation being simulated, no general conclusion regarding a single best combination can be made. Specific results depend on proper data supplied by a model user. The model developed here will then solve for the results requested by the user.

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Signature Leonard Roy Johnson

Date June 5, 1970

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SUBSYSTEMS OF A LOGGING SYSTEM

by

LEONARD ROY JOHNSON

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ABSTRACT

The logging system consists of five subsystems; namely, felling, bucking, skidding, loading, and hauling. Productivity of the felling and bucking subsystems depends largely upon the skill of the men doing the work and can be subjected to a minimum amount of analysis. Skidding represents a materials handling system that is being subjected to a great deal of technical analysis. Loading and hauling, however, stand in need of investigation. Both are materials handling systems that need analysis of the best equipment for a particular situation.

This thesis presents a simulation model that investigates the many variable combinations existing in the loading and hauling subsystems. Development of the model required two steps: (1) identification of the events and activities common to loading and hauling subsystems and (2) definition of owning and operating costs relevent to the two sub-systems. Calculation of relevent costs resulted in the criteria used to compare the numerous variable combinations. The criteria is a ratio of investment to output expressed in dollars per thousand board feet of merchantable timber. Identification of appropriate events and activities allowed use of the simulation language, GASP II, in testing various alternatives.

The result of this investigation is a fully developed model capable of testing alternatives of the many logging situations in existence. Since any "best" combination depends upon the particular logging situation being simulated, no general conclusion regarding a single best combination can be made. Specific results depend on proper data supplied by a model user. The model developed here will then solve for the results requested by the user.

CHAPTER 1

LOGGING, MODELS, AND SIMULATION

The timber industry is one of the oldest in the world. Timber has long been used for shelter, transportation, and for other human needs. Before timber can be utilized for any of these needs, however, conversion from a standing tree to a log must take place. The total process composes a portion of what is now known as the timber and wood products industry. The total system consists of several subsystems, one of which is the subsystem for conversion of trees to logs and the subsequent transportation of these logs to some location for further processing. This subsystem, known as the logging subsystem, shall be considered in this thesis as a system in itself.

LOGGING HISTORY

At some time in the history of the logging system there evolved five distinct steps which allowed a standing tree to be converted to a log and later transported to a conversion mill. Felling and bucking make up the first two subsystems of the logging system and together compose the logmaking portion of the logging system. The felling subsystem consists of conversion of a standing tree to either a tree-length log or a log-length log, which is cut to a certain specified length.

Transportation of the logs from the processing point to a cleared area, called a landing, must follow felling and bucking. This intermediate transportation takes place in the skidding subsystem. At the landing, loading of long-distance carriers takes place. The loading process occurs in the loading subsystem, a subsystem which also performs a materials handling function. The final subsystem of the logging system encompasses the long-ranged transportation of the logs from the landing to a conversion mill. Transportation for this subsystem, known as the hauling subsystem, usually takes place on either a logging truck with trailer or a railroad car. In some instances some or all of the hauling may take place in water, which would be the case when logs are floated in a river. Although these five subsystems were essentially established early in the life of the logging industry, technical analysis within the industry has been developed only recently.

The technical analysis was needed to evaluate some of the alternative equipment and methods in terms of cost savings which they could offer the logging contractor. The analysis was complicated by a rash of variables which were difficult to describe and quantify. Hence, in many cases during equipment investigation, the analysis was restricted to a certain geographical location. The general state of logging analysis also had been restricted to certain specific subsystems of the logging system and generally to certain geographical areas. A great deal of research in the Northern Rocky Mountain region dealt with the skidding subsystem. The logmaking subsystems, felling and bucking, depend almost entirely upon the man doing the work. In the loading and hauling subsystems little research has been done to date, and analysis pertaining to equipment choice and system design would be of great benefit. These two phases of the logging system will be analyzed in this thesis.

A technical analysis in any area may be approached from one of two directions. One alternative is to gather data and then design a model to fit and utilize the data. The second alternative involves formulation of a model of the system being analyzed and then gathering of the data necessary to obtain results from the model. The latter alternative probably finds some use in all models. There must be some knowledge of the desired objective and of the direction to that objective in all types of analyses. The degree of model development depends upon several factors, the primary one being the problem of collecting real information and data.

Analysis of the loading and hauling subsystems takes the form of a fully developed model for which little actual data is currently available. Much of the data necessary for utilization of the model will fit only a particular location and logging site. Thus, it is the responsibility of the user to supply information pertinent to his individual problem. Once the user makes an effort to obtain the input data for the model, and thus is forced to make an investigation of his present system, he will be in a better position not only to use and apply the model, but also to make intelligent decisions concerning the total logging system.

If the reader finds information unavailable at this point, he may refer to the data used in the case studies presented later in the thesis. These data are estimates and general averages for the Northern Rocky Mountain region. However, the results presented in the case studies should not be taken as general conclusions for the region without first examining the data used to reach the conclusions. As in all mathematical models, the results will be no more valid than the input used. Even a perfect model could not transform incorrect input into valid results.

Hopefully, this model can be of value in both the academic and logging communities. For this reason terms and symbols common to the logging industry and those common to mathematical model building will both be extensively defined.

MODELS

A beginning of this clarification process demands a more complete definition of the word model. Models of any type attempt to represent reality. They duplicate real world situtations, perhaps on a different scale or for a lower cost.[1] A map, for example, is a model of the land area it represents. Most models used in business and industry, however,

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[1] Ruddell Reed, Jr., "Simulation by Monte Carlo," TAPPI, (January, 1966), 28-32.

take form as mathematical representations of man-machine systems. A mathematical model uses mathematical equations to express relationships among critical elements of the system under study. A model, once formulated duplicates the actual operation of the system through some type of model manipulation. The model user applies results from the manipulation to aid him in making correct decisions.

SIMULATION

Manipulation of mathematical models may take place in several ways. Simulation is one method used to manipulate models and is utilized in this thesis. Simulation involves an effort to reproduce the actual operation of the system, usually over some period of time. Every system consists of a set of parameters including the input, output, processes, feedback-control, and certain restrictions. The parameters are related to each other by certain bonds called relationships. In the mathematical model the mathematical equations express that these relationships.[2] The processes of a system generally consist of certain specific activities. A simulation model duplicates the occurrence of each system activity and the effect the activity will have on other parts of the system. The end of a system activity signals the beginning

[2] Stanford L. Optner, System Analysis for Business and Industrial Problem Solving (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1965), pp. 26-27.

of a new activity. If a user knows exactly what occurs at the beginning and ending of each activity within an actual system, he can duplicate the system with a simulation model. The beginning and ending of system activities are known as events.[3] For example, if the log carrier arrived at the landing to be loaded, the subsequent activity would be loading. The beginning and ending of the loading activity would be marked by two events. The arrival of the carrier would signal the beginning of the loading activity. The end-of-loading event would signal the end of the loading activity, which would occur after the log carrier was loaded.

Since most system activities consume time, a simulation model generally duplicates the actual system over a certain period of time. For example, the loading of log carriers might be simulated for a week to find the total number of carriers loaded. This would be accomplished by specifying the results and effects of two events; namely, arrival of carriers and end-of-loading of carriers. The arrival event marks the beginning of loading and also schedules the time for completion of loading, or the end-of-loading event. The end-of-loading event marks the end of loading and schedules the next arrival event.

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[3]A. Alan B. Pritsker and Philip J. Kiviat, Simulation With GASP II (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1969), pp. 1-19.

The simulation model is developed by specifying the various activities of the system, by determining what events mark the beginning and ending of activities, and finally by designing a set of relationships among events of the system. A description of the simulation model for the loading and hauling subsystems consists largely of an event description. All models must, however, have some objective and criteria by which decisions are made. The objective of this entire study aims at giving the logging contractor a better base for making decisions regarding equipment selection and system design.

The simulation model developed here allows for comparisons of various loader types, number and quality of trucks, and general system designs by indicating which combination gives the least total cost expressed in dollars per unit of productivity.

SUMMARY

Although the actual simulation model can be described in terms of its events and activities, clear understanding of the model demands a more complete description of the variables and cost structure of the loading and hauling subsystems. The succeeding chapters deal with these subject areas. A description of the model and presentation of the case studies follow the chapters just mentioned.

CHAPTER 2

LOGGING AS A SYSTEM

The logging system exists as a subsystem of the timber and wood products industry. As a subsystem, its input arrives from another subsystem of the industry just as its output is delivered to still another subsystem. Input to the logging subsystem arrives from the planning phase of the timber and wood products industry. This system includes forestry research and forest utilization. Consideration of conservation, tree size and maturity, and the regrowth of trees will result in an output of the planning system dictating which trees the logging system can process. This immediately determines the location of the logging site and the maximum volume of merchantable timber. These inputs serve as constraints and restrictions to the logging system.

Output of the logging system is used in a conversion phase of the timber and wood products industry. The conversion phase takes form as one of a variety of processing mills. The mill function may be as simple as fencepost production or as complex as paper processing. Different processing mills require various sizes and types of logs placing still another constraint upon the logging system.

Although the basic logging system remains the same for all locations, volumes, and log destinations, the basic equipment types will vary. This