Mathematical programming model of a ground lead prebunching operation

by Christopher Bradley Lofgren

A thesis submitted in partial fulfillment of the requirement for the degree of Master of Science in Industrial and Management Engineering
Montana State University

Abstract:
The recent increase in environmental awareness of top soil erosion resulting from forest harvesting, and the inflation of road building costs have caused aerial logging techniques to become more widely used. Because of the high capital investment associated with these techniques, prebunching is necessary to provide a load weight utilization factor which will result in profitable operation. The Radio Tir ground lead system provides an environmentally conscious and efficient method for bunching unit loads for aerial logging.

The operation of the Radio Tir was formulated into a mathematical programming model which solves for the operational variables given site, equipment, and operator parameters. The model is represented by four methods which can be specified by the user. Each of these methods was formulated as a nonlinear programming problem or a mixed-integer, nonlinear programming problem.

The model was translated into the Fortran IV (66) computer program which solves for the optimal bunching unit layout of one of the four methods, given user supplied parameter values.

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APPROVAL

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

The recent increase in environmental awareness of top soil erosion resulting from forest harvesting, and the inflation of road building costs have caused aerial logging techniques to become more widely used. Because of the high capital investment associated with these techniques, prebunching is necessary to provide a load weight utilization factor which will result in profitable operation. The Radio Tir ground lead system provides an environmentally conscious and efficient method for bunching unit loads for aerial logging.

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CHAPTER 1

INTRODUCTION

Throughout history man has used timber to meet needs such as shelter, fuel, and transportation. Today, man has discovered new and innovative uses for wood products which vary from combustible fuels to pharmaceuticals. Before its transformation into these end items timber must flow through a number of processes. The initial processes consist of removing trees from forests and then transporting them to a conversion site. When these operations are integrated they form a system defined as a harvesting system.

"A system comprises a group of components that are integrated and jointly contribute to some common objective" [1, page 49]. A system may be comprised of a conglomeration of smaller systems called subsystems, and at the same time be a part of a larger system. There are three conditions which must be met before a system can exist.

> 1. All components of a system must contribute to achievement of a common goal or objective.
>
> 2. There must be some hierarchy present within a system to assure coordination of activities and allow for specialization of system components.
>
> 3. The inputs into a system... must be introduced according to some plan. [1, page 49]

The primary objectives of a harvesting system are to prepare the trees for transportation, and to transport them to the conversion facility. There are four major components of the harvesting system: (1) timber cutting, (2) primary transportation, (3) loading, and (4) secondary transportation. An illustration of the harvesting system can be seen in Figure 1.

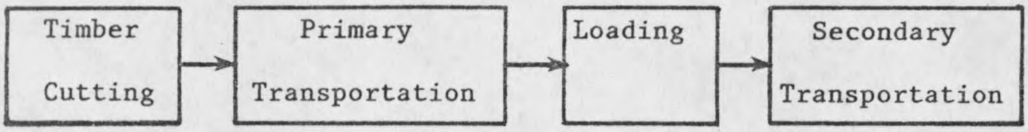

Figure 1. Harvesting System Flow Diagram

After the trees have been cut down (felled), the next component is primary transportation, defined as movement of the tree or log from stump to landing. This subsystem provides many opportunities for application of operations research techniques to determine the most efficient use of the labor and equipment used in primary transportation.

A machine which has gained increasing interest for its application in primary transportation is the Radio Tir. This machine is a small, six horsepower, gasoline powered, cable winch used for skidding small diameter timber. The Radio Tir is remotely operated by one person and is easily transported around the harvesting area. The Radio Tir is extremely effective in prebunching logs or trees into unitized loads which increase the efficiency of other primary transportation methods. This application of the Radio Tir will be developed in this thesis.

Primary Transportation

Two methods of primary transportation exist: (1) skidding, movement along the ground; and (2) yarding, movement of partially or totally suspended logs.

Skidding

Skidding is usually performed using either a wheeled skidder or a crawler tractor. An example of each is illustrated in Figures 2 and 3, respectively. Both the crawler and wheeled skidder are limited by slope (80 percent and 60 percent, respectively), and in unstable soil can create significant erosion problems.

Another form of skidding, called ground lead, involves dragging trees or logs along the ground using a cable winch. The winch is relatively light permitting easy mobility around the cutting unit (harvested area) with the result that soil disturbance is kept to a minimum, but its use is usually limited to small diameter timber.

Yarding

The second method of primary transportation is yarding. Yarding operations are classified into two categories; (1) cable, and (2) aerial. Cable logging can be separated into two categories: (1) highlead, and (2) skyline.

The highlead system is illustrated in Figure 4 and its operation is as follows:

> The yarder operator ... releases the brake on the mainline drum and applies power on the haulback drum. This moves the mainline and choker back to the logs. The turn (log)

Figure 2. Wheeled Skidder

Figure 3. Crawler Tractor

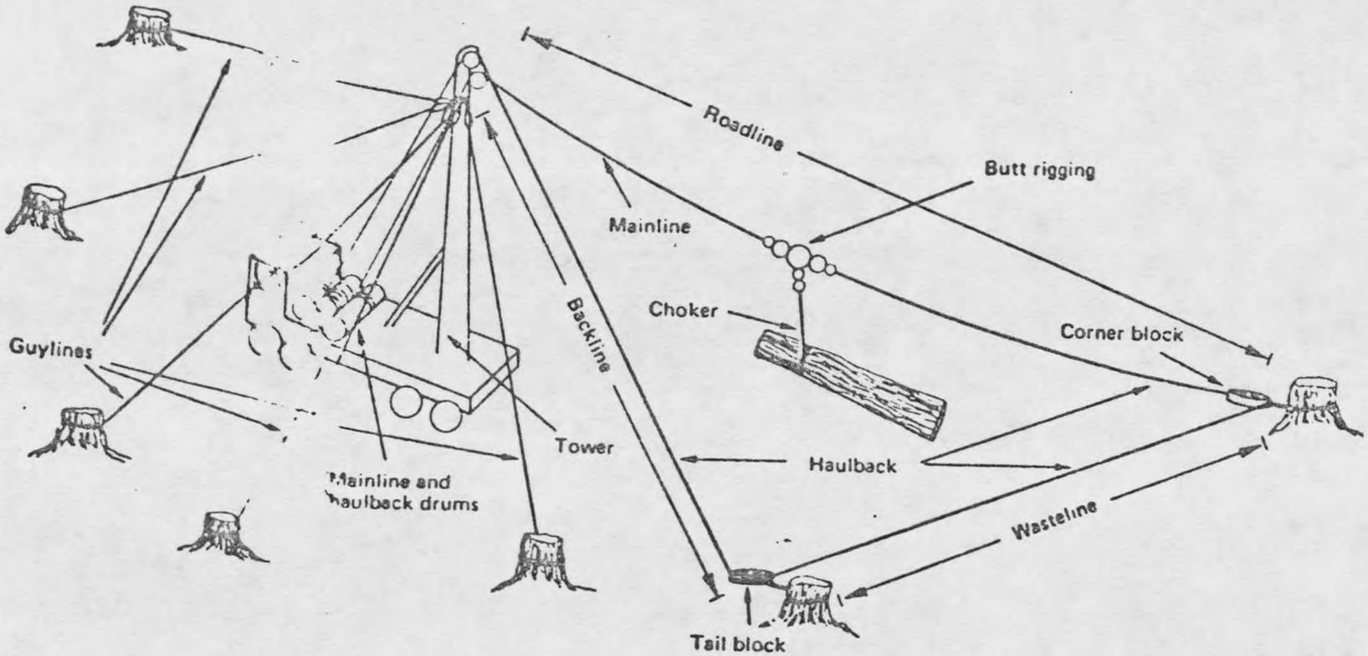

Figure 4. Highlead System [1]

> is set by the choker setter and the operator pulls the turn in. [1, page 194]

A turn is one complete trip or cycle involving one or more logs or trees. The area over which the main line runs is called the roadline. Since the spar, the tree or stump to which the corner block is attached, remains stationary, the roadline radiates in a circular pattern as seen in Figure 5.

A skyline system involves a wire rope that is suspended between two or more points, and a carriage which moves logs laterally to and longitudinally along the suspended cable. Operation of the system is similar to the highlead system except for extended perpendicular reach which results in more turns per setup. The skyline system is illustrated in Figure 6. In the lateral yarding stage, logs are drug along the ground parallel to the contour, while in the longitudinal stage the logs move perpendicular to the contours, partially or fully suspended.

Cable yarding systems are not limited by slope and are often the only viable means of harvesting where steep slopes and unstable soil preclude logging by other conventional means; but there is a high capital investment, operating cost, and road building associated with this method of primary transportation.

Aerial logging exists in two forms. One is helicopter logging and the other is balloon logging. The number of helicopters available for logging operations is limited by requirements for large payload capacities, although this varies with timber characteristics.

The significant factors of helicopter logging productivity are average cycletime, average load factor, and hours of utilization; but