An exploratory analysis of skidding in the Rocky Mountain area with emphasis on crawler tractor skidding
by LeRoy Conrad Stevens

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Industrial Engineering
Montana State University

Abstract:
When the first plans related to this thesis were laid out, a large Monte Carlo simulation program adapted to a computer was foreseen that would relate all of the variables affecting the skidding operation. After only a short period of time in the field it became obvious that, due to the time limit and limited funds, this approach was not feasible for a Master's thesis. This author estimates it would take at least five years of full-time work to accomplish the original objective.

Because the original objective was not feasible, a more practical approach was taken. This approach was to present the thesis in two sections.

The first section discusses some of the advantages and disadvantages of non-crawler tractor skidding machines in common use in the Rocky Mountain area. Information for this part of the thesis was attained primarily through personal interviews with logging contractors and operators.

The second and major section of this thesis is devoted to a parametric analysis of the principal variables affecting the economic skidding capabilities of some crawler tractors in the Rocky Mountain area.

The principal variables chosen were the following: 1. Tractor size 6. Operator efficiency
2. Soil 7. Number of men
3. Slope 8. Log type
4. Number of logs per turn 9. Size of logs
5. Distance 10. Altitude Data to be used for the parametric analysis were collected by utilizing continuous stop watch studies with some modification to fit the needs of the analysis.

Time was used as the dependent variable in determining the effect of the principal variables.

After basic times and factors were determined for the variables, they were related to the costs of running different crawler sizes. This was accomplished by determining cost curves for different combinations of variables.

The most important conclusion is that although large crawlers cost more per hour to operate than small or medium crawlers, they generally yield the lowest cost per thousand board feet for skidding logs. It is also shown in this thesis that as the number of men increases, skidding costs increase, and as the number of logs per turn decreases, skidding costs decrease.

AN EXPLORATORY ANALYSIS OF "SKIDDING" IN THE ROCKY MOUNTAIN AREA WITH EMPHASIS ON CRAWLER TRACTOR SKIDDING

by

LEROY CONRAD STEVENS

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

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Approved:

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To Mr. Gerald Seay and Mr. John Heaney go my sincerest thanks for helping in the data collection.

To my typists go my thanks.

Finally to my family goes my humblest appreciation for their gentle urging and assurance when progress faltered.

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ABSTRACT

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CHAPTER I

INTRODUCTION

HISTORICAL BACKGROUND OF THE PROBLEM

The forest products industry is one of the major industries in the Rocky Mountain area. In Montana the forest products industry is the third largest industry following mining and agriculture. (8, p. 3)

The forest products industry may be divided into two major activities:

1. Harvesting of the raw material and its transportation to the mills.
2. Manufacture of the raw material into finished products for the consumer.

The harvesting of the raw material and its transportation to the mills is known as the logging industry. The forest products industry is no different from any other industry in that it must produce a quality product at the lowest possible cost to be competitive. The cost of logging is so high in areas where steep slopes and small stems prevail that often times a less expensive, equally suited material can be found to substitute in place of wood. The Rocky Mountain States and western Montana in particular have many areas characterized by substantial volumes of small stemmed trees, such as lodgepole pine growing on steep slopes.

To help the logging industry a long range forest engineering program has been set up to develop systems to economically harvest the timber in areas characterized by steep slopes and small stems.

This long range program is designed to develop new logging methods and improve existing methods.

Before new logging methods can be developed and existing methods improved, a knowledge of the economic capabilities of the present methods must be obtained. After this knowledge is obtained it can be used to develop plans for future engineering research studies.

The skidding operation (i.e. movement of the logs from the stump to the landing) was selected as the area of the logging industry to study because:

1. Considerable work has been done on the logmaking operations. (9)
2. Skidding follows logmaking in the logging system.
3. Skidding represents one of the biggest costs in the logging industry.

STATEMENT OF PROBLEM

After spending some time observing skidding in the field it becomes obvious that there are nearly as many different variations of skidding methods as there are logging contractors. There is little agreement among these contractors concerning the best method. This should be expected because of the differences in soils, slopes, stand densities, personal preferences, and many other variables inherent in the logging industry.

In the Rocky Mountain area four basic skidding methods are in common use. The basic methods are:

1. Crawler tractors
2. Rubber-tired tractors
3. Jammer skidders
4. High lead skidders.

Each basic method has its own advantages and disadvantages.

There are two major objectives of this thesis. They are:

1. To present preliminary conclusions reached concerning non-crawler tractor skidding (i.e. rubber-tired tractors, jammer skidders, and high lead skidders),

2. To present an exploratory analysis of the effect of the principal variables affecting some crawler tractor skidding in the Rocky Mountain area.

Data collection was confined to eleven weeks during the summer of 1965. Due to the large number of variables inherent in the logging industry, it was impossible to gather enough data on all the basic skidding methods to make a thorough analysis comparing the basic methods. Therefore, it was decided to talk to the logging contractors to determine what the major limitations and advantages are of the basic non-crawler tractor skidding methods. Pictures, advantages, and limitations of these non-crawler tractor skidding machines will be presented.

The major part of this thesis will be devoted to a parametric analysis to determine the effect of the principal variables on the economic skidding capabilities of some crawler tractors in the Rocky Mountain area. A partial list of variables affecting crawler tractor skidding includes:

1. Tractor size
2. Soil (coefficient of traction)
3. Use of an arch
4. Tree-length versus log-length skidding

5. Size of logs
6. Number of logs per turn
7. Slope of terrain
8. Season of the year
9. Operator efficiency
10. Condition of equipment
11. Use of a choker setter
12. Altitude
13. Ownership of equipment
14. Log scale used
15. Stand density
16. Skidding distance
17. Type of chokers used
18. Type of landing
19. Felling practices
20. Branch road spacing
21. Brush density and height
22. Silvicultural requirements
23. Non-effective time
24. Resistances (grade, sliding, and rolling).

Time did not permit gathering enough data to compare all of the above variables. Therefore, those variables which contribute the most to the economic effectiveness of the crawler tractor skidding methods were considered. After considerable reading and discussions with individuals who understand the logging industry, it was decided that the following variables are the principal ones affecting crawler tractor skidding:

1. Tractor size
2. Soil (includes brush density, soil moisture content and rockiness of the soil)
3. Slope
4. Number of logs per turn
5. Distance
6. Operator efficiency
7. Number of men
8. Log type
9. Size of logs
10. Altitude.

The major objective of this thesis may then be said to determine the inter-relationships among the above principal independent variables and dependent variables (time and cost). This information will then be used to determine which crawler tractor yields the lowest skidding cost per thousand board feet for a given combination of variables.

CHAPTER II

LOGGING IN GENERAL

THE LOGGING SYSTEM

Logging in the Rocky Mountain area is done by both independent contractors and people who work directly for the mills.

An independent contractor is known as a "gyppo" in the logging industry. A gyppo owns his own equipment and agrees to deliver the logs to the mill for a stated amount. This amount is generally so much per thousand board feet (e.g. $28.00 per MBF). Having gyppo contractors deliver the logs to the mill is an advantage for the mill owners because they need not have so much money invested in equipment. The major disadvantage for the mill owners is that they do not have good control of the logging operations when they let gyppo contractors do the actual logging. In the Gallatin National Forest and much of southwestern Montana most of the logging is done by gyppo contractors. In northwestern Montana and other areas where larger trees prevail, the mills often buy their own equipment and do their own logging.

The logging system may be divided into four major interrelated processes. These processes are:

1. Logmaking
2. Skidding
3. Loading
4. Hauling.

Logmaking is the process of transforming the standing tree into log sizes that will meet the mill requirements. In the Rocky Mountain area most mills require 16, 25, and 32 foot log lengths.

The logmaking process includes three major operations which are felling, limbing, and bucking.

Felling is the operation of cutting down the standing tree. This operation is generally performed with a power chain saw.

Limbing is the operation of removing live limbs and large knots from the stem. Limbing nearly always follows the felling operation and is generally performed with the same implement. With the advent of smaller power chain saws some fellers now cut down the tree with a large saw and limb with a small saw. Dead limbs need not be removed because they will break off during the skidding operation.

Bucking is the operation of cutting the stem into acceptable log lengths (i.e. 16, 25, and 32 foot lengths) which the mills require. If the stem is not bucked until after it has been skidded, but before loading, this is called "hot logging" by many logging contractors. If the tree is not bucked at all before it reaches the mill, the logging industry refers to this as tree-length logging. Of the 13 logging operations visited during the data collection period only one contractor was engaged in tree-length logging. Whether or not a contractor engages in this type of logging depends primarily on the mill's ability to handle the longer stems.

The second process of the total logging system is skidding. This thesis deals with the skidding process so, at this time, skidding will merely be defined as the movement of the logs from the stump to the landing.

The third process of the total logging system is loading. Loading is the process of transferring the logs from the woods deck to a vehicle for transportation to the mill. In the Rocky Mountain area trucks are the most common vehicle used for transportation.

Three major pieces of equipment are in common use in the Rocky Mountain area for the loading process. They are:

1. Heel boom loader
2. Air tongs loader
3. Front end loader.

A heel boom loader is a small mobile crane that often has a boom attached to a manufactured cab and engine. This type of loader is rated by the manufacturer according to its stated capacity to excavate so many yards of earth with a certain size bucket. Common sizes in the Rocky Mountain area are 3/8, 1/2, and 5/8 yards. A heel boom loader utilizes a set of tongs which is set on the individual logs by a person known as a tong setter. The machine operator then butts the log against the boom for stability of the log, and then places the log on the truck. Often the tong setter or the truck driver has to get on top of the load to release the tongs. This can be dangerous as individuals on the load frequently will walk under a log still controlled by the machine operator. An advantage of a heel boom loader is that it can also be used as a jammer skidder. Jammer skidding is discussed in Chapter III.

An air tongs loader is also a small mobile crane rated in the same manner as a heel boom loader. An air tongs loader utilizes a set of

air operated tongs for loading. Only one man, the operator of the loader, is needed to load with this type machine. An air tongs loader is safer than a heel boom loader because it is not necessary to manually set and release the tongs. A major disadvantage of this type of loader is that it does not have the versatility of a heel boom loader because it cannot be used as a jammer skidder. Many of the small gyppo contractors in the Rocky Mountain area load only three or four loads a day requiring about two to three hours working time. The remaining time an air tongs loader is idle and therefore not fully utilized.

A front end loader used in the woods is generally mounted on a crawler tractor. This type of loader will load a truck faster than a heel boom or an air tongs loader because it can load several logs at a time. A higher initial investment is required for a front end loader than for a heel boom or an air tongs loader. A relatively large and level landing area is required for the operation of this type of loader. Among the larger logging contractors (i.e. those who load at least ten loads per day) this type of loader seems to be the most popular.

Hauling is the final process in the logging system. Hauling includes the transportation of the logs to the mill, unloading the logs, and returning to the logging area for another load. As previously stated, trucks are commonly used for the transportation of the logs. Unloading is a function of the mill and is most commonly done with a large rubber-tired front end loader.

The total logging system is portrayed with a flow process chart in Figure 1.

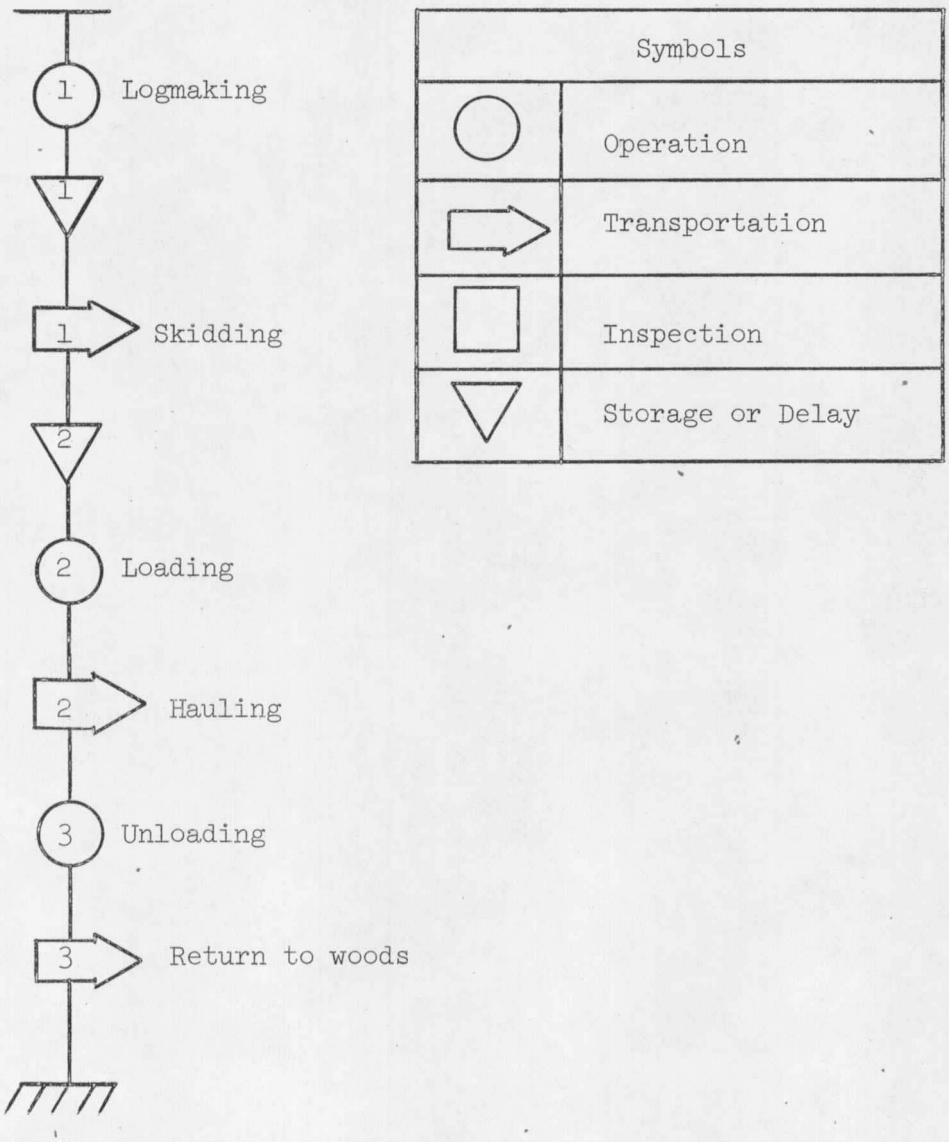

Figure 1. Flow process chart of logging operations.

SKIDDING PROCESSES NOT IN COMMON USE IN THE ROCKY MOUNTAIN AREA

Skidding has previously been broadly defined as the movement of the logs from the stump to the landing. Actually two terms are used to characterize the movement of the logs from the stump to the landing. These terms are skidding and yarding. Skidding is defined as "any method of moving logs from the stump to the landing wherein the logs are skidded along the ground." (4, p. 14) Yarding is defined as "any method of moving logs from the stump to the landing when the logs are in part or wholly lifted from the ground." (4, p. 14)

In this thesis only the term skidding will be used regardless whether the logs are skidded along the ground or are partly or wholly lifted from the ground during the movement from the stump to the landing. This is justified because most of the people in the logging industry use the two terms synonymously.

As previously stated there are four basic methods of skidding in the Rocky Mountain area which are:

1. Crawler tractors
2. Rubber-tired tractors
3. Jammer skidders
4. High lead skidders.

These basic methods are discussed in the next chapter. The remaining portion of this chapter is devoted to acquainting the reader with still other skidding methods in use or being developed in the logging industry.

Helicopters have been proposed for skidding logs from steep rugged terrain. (7, p. 1) A helicopter equipped to carry an external load of

4,000 pounds was tested in Canada in February, 1963. Test results are as follows:

(7, p. 9)

Assumptions:

1. Skidding distance = 3,000 feet
2. Wood weight = 12 pounds/board foot
3. Automatic release at landing takes .10 minutes
4. Hooking in woods takes .50 minutes
5. Aircraft cost = $350.00/hour

Representative cycle times:

Hooking time	= .50 minute
Unhooking time	= .10 minute
Inbound time	= 2.79 minutes
Outbound time	= 2.31 minutes
Total cycle time	= 5.70 minutes

Calculations:

Volume per turn = 4,000 lbs./12 lbs. per B.F.
= 333 board feet

$$\text{Number of turns per hour} = \frac{60 \text{ minutes/hour}}{5.70 \text{ minutes/turn}} = 10.5$$

Number of board feet per hour = 10.5 turns/hour
x 333 board feet/turn = 3,500

$$\text{Skidding cost per MBF} = \frac{\$350.00/\text{aircraft hour}}{3{,}500 \text{ board feet/hour}}$$
$$= \$.10/\text{board foot} = \$100.00$$

By comparison it costs approximately $10.00 per thousand board feet to skid using more conventional equipment such as crawler tractors. From the above helicopter trial it is obvious that this type of skidding is not practical for the present.

Balloons are being tested because of the high aircraft cost (i.e. $350.00/hour for a Sikorsky S58 helicopter) involved in helicopter logging.

If air-born logging (i.e. either helicopter or balloon logging) becomes economically possible, three very distinct advantages will be obtained. These are:

1. The ground will not be disturbed excessively during the skidding operation; thus, the soil will not be nearly so susceptible to erosion after the logging is completed.
2. Fewer roads will be required thus reducing the erosion problem.
3. There will be a method of skidding from areas not accessible by any means other than air.

Animals are still in use in some logging areas as a method of skidding. Horses or mules are used economically when either light timber stands or other factors make volume production impossible.

COMBINED PROCESSES

Machines are being developed to combine some of the processes in the logging system. As far as this author can ascertain, none of these machines are in common use in the Rocky Mountain area. Nevertheless, they should at least be presented to acquaint the reader with some of the newer developments in the logging industry since these machines or variations of them may be used in the Rocky Mountain area in the future.

A combine is now available that will fell, limb, buck, and bind the stems into cords. It is called the Busch Combine. A Busch Combine is essentially a four-wheel drive rubber-tired tractor fitted (13, p. 51) with hydraulic knives used for felling and bucking. Limbing and

measuring devices are also incorporated in a manner such that all phases of preparing the stick are done in one continuous manner. After a cord is harvested the combine binds the cord and drops it behind the machine to be picked up later. This combine would have limited use in the Rocky Mountain area as it is for areas with level ground and heavy stands of medium or large size trees. A Busch Combine costs approximately $37,000.00.

The Vit Feller Buncher was developed in 1957 and 1958 to fell the trees and skid them whole to the landing where another machine limbs and bucks them. The Vit Feller Buncher fells the trees with a hydraulically driven chain saw and collects them on an overhead rack for delivery to the landing. It is basically a crawler tractor that utilizes an overhead rack rather than chokers for skidding trees. Its cost is approximately $15,000.00. A Bombardier Processing Unit (BPU) is used in conjunction with the Vit Feller Buncher. The BPU is a lattice-like structure almost 100 feet long which performs the following functions: (13, p. 55)

1. The tree is pulled through a limbing device.
2. The tree proceeds by conveyer to a stop plate set for different log lengths.
3. A large circular saw bucks the tree after which the logs fall onto the ground.

Another new prototype machine is a Pope Harvester. A Pope Harvester is an attachment for the C-frame of a crawler tractor. The Harvester mounted on a large crawler tractor is a mobile machine (13, p. 58)

which severs the tree from the stump, carries it upright to the landing, limbs it, bucks it, and deposits the logs on the ground. Mounting a Harvester on a crawler tractor does not alter the basic tractor and can be removed at any time restoring the tractor to its original form. A Harvester is basically two jaws and a hydraulically operated chain saw used for felling and bucking. In operation the operator drives the machine up to a tree, grasping it with the main jaw, and severs the tree with the chain saw. The unit then moves to the landing and rotates the tree to a horizontal position. The second set of jaws moves along the tree removing the limbs. Next the tree is held by the limbing jaw and pushed through the main jaws removing the remaining limbs and positioning the tree for bucking. The chain saw rotates for the bucking cuts, makes the cuts, and the logs fall to the gound. It has been estimated that this Harvester could be manufactured on a production basis for about $10,000.00 per unit.

CHAPTER III

NON-CRAWLER SKIDDING MACHINES IN COMMON USE IN THE ROCKY MOUNTAIN AREA

The three major non-crawler type skidding machines in common use in the Rocky Mountain area will be discussed in this chapter. The presentation of any particular manufacturer's equipment does not constitute an endorsement, but is presented only as an illustration of the equipment commercially available.

RUBBER-TIRED SKIDDERS

Rubber-tired skidders are gaining an important place among skidding machines used in the Rocky Mountain area. These skidders, equiped with large pneumatic tires, offer good flotation making them better than crawlers for skidding in muddy or boggy areas and on level to moderate slopes with little slash. Crawler tractors generally have a great amount of difficulty operating in muddy or boggy areas because of their weight and poor flotation. Rubber-tired skidders have a top speed of about 21 miles per hour compared to about seven miles per hour for conventional crawler tractors.

Many of the larger logging companies that wish to reforest their land after logging are using rubber-tired skidders for skidding on level ground because these skidders do not disturb the soil as much as crawlers.

It was the opinion of most of the interviewed loggers that rubber-tired skidders yield higher production and lower maintenance costs than

conventional crawlers in areas of level to moderate slopes, little slash, and in muddy or boggy areas.

The limitations of rubber-tired skidders may be summarized by saying these skidders lack versatility. These skidders are generally limited to level to moderate slopes (i.e. up to 15%) and little slash. Rubber-tired skidders presently are not used to build roads in logging areas.

Photographs, specifications, and a summary of data collected for two rubber-tired skidders in use in the Rocky Mountain area are shown on pages 18 through 21. Because the sequence of operations for rubber-tired tractor skidding is the same as for crawler tractor skidding, the flow process chart for both methods will be presented later.