Data gathering system for logging operations
by Donald Kane Londgren

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:
At the outset of work related to this thesis, a "grand system" for acquisition of logging operational data, was visualized. The major hypothesis submitted that a data gathering system for gathering facts about logging operations could be developed to describe these same logging operations to any desired degree of accuracy and detail. This hypothesis was neither proved nor disproved, but considerable support of a positive nature was presented.

In pursuing the major hypothesis four methods of data gathering--!) time lapse photography, 2) standard speed and slow motion movies, 3) stop watch time study, and 4) work sampling--were analyzed relative to the real world of logging.

Before an attempt could be made to create a system from these four data gathering methods, it was first necessary to examine each method relative to the logging environment. Of the four methods, time lapse photography was analyzed the most thoroughly because of advantages of this method found in other industries and due to the problems encountered in applying the method to logging.

Several pitfalls were encountered in the application of the four methods, including the following: 1. Logging has many more variables that must be considered than is typical of other industries.

2. Most logging operations" move frequently.

3. Data gatherers are faced with view obstructions, impediments to movement, and serious hazards.

Attempts to deal with these pitfalls are discussed in the thesis.

Following studies made to establish the feasibility of applying the four data gathering methods to logging, the costs of data gathering were examined and found to be considerably higher than similar data costs in other industries. This is due in part to the distance typically traveled and time consumed in reaching a logging site.

Finally, guides to planning a data gathering system using the four data gathering methods studied were presented. Although much data can be gathered using the four methods, and capabilities of the methods tend to overlap, certain types of data remain which cannot normally be acquired without application of additional data gathering tools and techniques.

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Head, Major Department

Chairman, Examining Committee

Graduate Dean

MONTANA STATE UNIVERSITY
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ABSTRACT

At the outset of work related to this thesis, a "grand system" for acquisition of logging operational data was visualized. The major hypothesis submitted that a data gathering system for gathering facts about logging operations could be developed to describe these same logging operations to any desired degree of accuracy and detail. This hypothesis was neither proved nor disproved, but considerable support of a positive nature was presented.

In pursuing the major hypothesis four methods of data gathering--1) time lapse photography, 2) standard speed and slow motion movies, 3) stop watch time study, and 4) work sampling--were analyzed relative to the real world of logging.

Before an attempt could be made to create a system from these four data gathering methods, it was first necessary to examine each method relative to the logging environment. Of the four methods, time lapse photography was analyzed the most thoroughly because of advantages of this method found in other industries and due to the problems encountered in applying the method to logging.

Several pitfalls were encountered in the application of the four methods, including the following:

1. Logging has many more variables that must be considered than is typical of other industries.
2. Most logging operations move frequently.
3. Data gatherers are faced with view obstructions, impediments to movement, and serious hazards.

Attempts to deal with these pitfalls are discussed in the thesis.

Following studies made to establish the feasibility of applying the four data gathering methods to logging, the costs of data gathering were examined and found to be considerably higher than similar data costs in other industries. This is due in part to the distance typically traveled and time consumed in reaching a logging site.

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CHAPTER I

CONCEPT OF A DATA GATHERING SYSTEM FOR LOGGING

THE HYPOTHESES

The major hypothesis underlying this study is that a data gathering system for collecting facts about logging operations can be developed to describe these same logging operations to whatever degree of accuracy and to whatever degree of detail an analyst may desire. The secondary and implicit hypothesis is that the accuracy and detail required will be accompanied by some "exponentially" increased costs that will resemble the curve in figure 1.

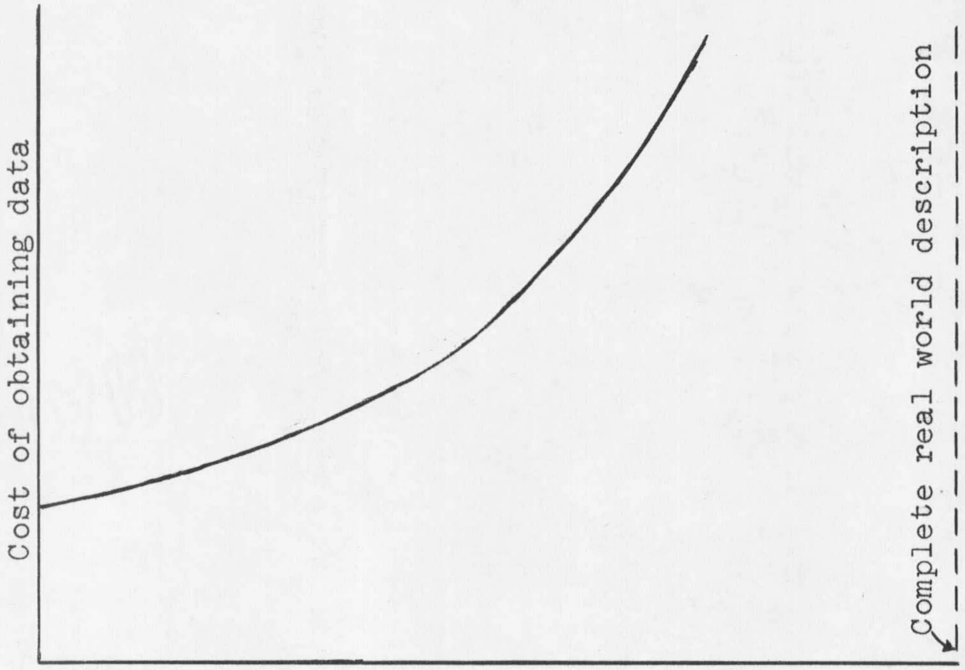

Figure 1: Hypothesized relationship of data cost to detail and accuracy.

To be economically useful, the "data gathering system" should be so developed that either periodically or continuously an estimate can be made of the accuracy and detail of accumulated data, giving consideration to the value of this data and the cost of gathering it.

LOGGING OPERATIONS

The five work operations to be considered here (felling, limbing, bucking, skidding, and loading) are each usually quite readily described from the standpoint of tasks accomplished and the sequence of events. In support of this statement, generalized descriptions are given in the following paragraphs for each of these operations. Most contemporary variations of these operations will fit these generalized descriptions.

A LOGGING OPERATION: FELLING

Felling, which is an operation to cut down a tree, is the first of several steps of logging. The tasks to be accomplished in felling are transportation of a cutting tool or machine to a selected tree and using this tool or machine to sever the tree close to the ground in a manner such that the tree will topple to the ground. It is conceivable that the future could bring forth a means of severing a tree other than sawing. Suitable adjustment to fit such methods should cause no major problems of task description. It is logical to assume that felling also includes control of direction (or at least partial control) of the tree top's travel to earth when the operation is performed by a skilled worker using currently predominant methods.

SEQUENCE OF WORK EVENTS: FELLING

A common sequence of events of felling a tree is described by the following list:

1. Select the tree to be felled,
2. Transport cutting tool or machine to tree,
3. Determine direction for tree's fall,
4. Use cutting tool or machine to make necessary cuts at base of tree, commonly:
    a. Saw a notch and back cut with power saw,
    b. Shear tree with large mechanical shear,
5. Remove cutting tool and stand clear of falling tree.

These events are repeated with variations in degree for each tree that is felled.

Items not included in this basic list of events, but which are not insignificant to the operation of felling include 1) travel to and from the cutting area, and 2)sharpening and repair of the cutting tool or machine. The lists of events describing other operations will, likewise, omit certain supporting tasks. They may also warrant consideration in a data gathering system, but the major operations will be studied first.

A LOGGING OPERATION: LIMBING

Limbing is the operation of removing limbs from the marketable portion of a tree's stem. The tasks of limbing are 1) transporting a cutting tool or machine to a tree and along the tree's stem, and 2) using the cutting device to sever the limbs.

SEQUENCE OF WORK EVENTS: LIMBING

The sequence of separate events which describe in general the operation of limbing follows:

1. Select the tree to be limbed,
2. Transport cutting tool or machine to tree,
3. Transport cutting tool or machine along stem of tree,
4. Use the cutting tool or machine to sever limbs as they are encountered.

These events are repeated for each tree that is limbed.

A LOGGING OPERATION: BUCKING

Bucking is the operation of cutting trees to log lengths. A special case of "bucking," in which that portion of a tree's top which has a diameter too small for commercial use is removed, is commonly called "topping." The tasks of bucking are transporting a cutting tool or machine to a tree and along the tree's stem, measuring "required" log lengths, and using the cutting device to cut the tree to log lengths.

SEQUENCE OF WORK EVENTS: BUCKING

A common sequence of events involved in bucking a tree follows:

1. Select the tree to be bucked,
2. Transport a "measuring device" and a cutting tool or machine to tree,
3. Measure log length while transporting cutting tool or machine along stem of tree,
4. Cut through tree at the appropriate point(s),
5. Repeat steps 3 and 4 until entire tree is cut into required log lengths.

These events are repeated for each tree that is bucked.

A LOGGING OPERATION: SKIDDING

Skidding, the operation in which logs are moved from the felling point to a loading area commonly termed a "deck," involves the tasks of operating some device or a machine so that it will pick up or "get" the logs, singly or in groups, and transport them to the desired location for loading. In this study, skidding is intended to include all methods of moving logs from the cutting area to the loading area. Those methods which lift one end of the log when it is moved, and methods with other variations, will not be placed in a separate category as is sometimes done in logging terminology.

SEQUENCE OF WORK EVENTS: SKIDDING

A sequence of events for a typical mechanized skidding operation can be generally described as follows:

1. Guide skidding machine, or a part of it, to area of log or logs to be skidded,
2. Select log to be skidded,
3. Attach cable or hook from skidding machine to the selected log,
4. Repeat steps 2 and 3 until the desired number of logs for one "drag" have been attached,
5. Transport a "drag" of logs to loading area,
6. Release the logs.

These events are repeated for each log or "drag" of logs.

A LOGGING OPERATION: LOADING

Loading is the operation of placing logs on a hauling device, commonly a truck, for transportation to the mill. The tasks involved are the operation and control of a loading machine such that it will pick up logs and place them in desired positions on the hauling unit.

SEQUENCE OF WORK EVENTS: LOADING

The sequence of events to describe generally the loading operation follows:

1. Select logs to be loaded,
2. Operate machine so it will reach for or travel to selected logs,
3. Cause machine to grasp logs,
4. Operate machine so it will pick up logs,

5. Operate machine so it will move logs and position them on the hauling unit,

6. Cause machine to release logs.

It is to be recognized that in some operations only one log is handled each cycle. The sequence of events in the list is repeated as many times as necessary for each "hauling unit" that is loaded.

LOGGING OPERATION DESCRIPTIONS CLARIFIED

Descriptions of operations as presented here do not provide for a breakdown into standard time study elements. The variations that occur increase almost geometrically as an operation description is presented in greater detail. Even these generalized descriptions may not be broad enough to encompass all methods, current or future, of performing the basic logging operations.

As an example, consider event number 3 of the felling operation, "determine direction for tree's fall." A power chain saw is in common current use for making the necessary cuts at the base of the tree. These cuts represent the feller's most useful means for controlling the direction of the tree's fall. To determine the direction in which the tree will fall, the feller must consider such things as the "lean" of the tree (angle with the vertical), amount and position of branches, direction and intensity of the wind, and the slope of the ground. These factors are frequently not constant as the feller goes from one tree to the next. Occasionally the wind is not even constant during felling of a single tree; cases have been observed where a saw has become wedged in the tree while making a back cut because the wind direction changed.

Considering the various directions in which he can make the tree fall on the basis of factors beyond his control, the feller determines the direction in which he will try to make the tree fall. He then decides how he will cut the tree so that it will fall in the chosen direction. This decision must be made for each tree.

If instead of a chain saw a large machine with a shear and the means for positive control of the tree's direction of fall is used, only one decision may be necessary for the direction of felling an entire block of trees, making the decision process negligible for individual trees.

It is possible to show that many of the other events for each operation will be subject to increasing numbers of variations as elements become more detailed. (5, chap. 1 & 2) Because of this it is not feasible in this paper to discuss in detail all of the possible method variations that could be analyzed for the five logging operations being considered.

EXTENT TO WHICH REAL WORLD IS TO BE DESCRIBED

It is anticipated that data sufficient to describe logging operations in complete detail and with precise accuracy would, if it is possible to gather that much data, cost an astronomical amount of money. There are, however, many practical situations that do not require such completeness of detail and preciseness for every part of an operation.

If the data gathering system is not to provide a complete real world description of all details of every operation to which it is applied, then precisely what and how much information should be gathered? At least two factors must be considered to intelligently answer this question. First, what is the intended use of the data; and second, what means, if any, are available for gathering the desired data.

WHAT DATA IS DESIRABLE

There are many possibilities as to what information could be required. In this sytem, only data that can be used to determine or reduce production costs of an operation or group of operations will be considered. We must, of course, be concerned with the cost per unit of production at some production level.

Since the data gathering system is to provide data that will aid in the determination of costs or that can be analyzed in an effort to reduce costs, and since we are concerned with these costs as they relate to production, the data gathering system should provide:

1. A means of measuring factors affecting costs,
2. A means of measuring productivity rate,

3. A means for measurement and description of factors that have a significant controlling influence on productivity rates.

OBSERVATION, MEASUREMENT, AND RECORDING OF THE FACTORS THAT AFFECT LOGGING COSTS

The factors that commonly affect costs of any production operation include men and machines required to perform the operation and the time elapsed during each cycle of the operation. Idle time also affects the cost.

The number of men and brief machine descriptions are readily obtained by observation. Reasonably complete machine descriptions are often available from the manufacturer's advertising literature. More complete descriptions of both men (such as skill requirements and skill levels) and machines can usually be prepared if increased benefits warrant the increased expense.

Measurement of cycle times can be readily accomplished by one of the time study techniques. Cycle times in many logging operations, unlike the operations in many industries, appear to be subject to large variations. To quantitatively relate cycle time variations to the causes of the variations demands special attention to pertinent data in a data gathering system. A single fixed "cycle time" standard, for most logging operations, is expected to have little practical value.

Compensation rates for logging in the lodgepole pine areas are usually available on inquiry, but are commonly based on board feet of merchantable timber delivered to the mill. This measure is subject to natural and human factors that make its use as a measure of productive effectiveness inconsistent. Consequently, in actual practice costs per board foot for logging operations tend to be inconsistent even for a particular combination of methods, men, and machines.

MEASUREMENT OF PRODUCTIVITY RATE

Sawlogs are normally bought and sold on a board foot basis, and it is common for production workers to be paid on the same basis. This would therefore appear to be a logical unit of production measurement for data gathered for analysis.

The board foot as a unit of production measurement does, however, present problems. For most logging operations it appears difficult, if not impossible, for one observer to make the necessary measurements in the time available during a cycle if interference with production is to be avoided.

For many operations, production effort and effectiveness are not readily related to board foot production rates. This leads to the conclusion that comparisons of operation alternatives on the basis of board foot production rates will have questionable value. Establishing costs on a board foot basis, though valid for a particular situation, may be next to useless as a tool for prediction of future costs in a slightly different situation.

Productivity rates, should, perhaps, be established on a work element basis. For example, times required to make the necessary cuts to fell trees of various sizes could be determined; rates of travel between trees could be determined for fellers carrying various sizes of saws over various slopes, and so on with each element having a productivity rate established on the basis of influencing factors having the greatest effect in each case.

MEASUREMENT AND DESCRIPTION OF FACTORS THAT HAVE A SIGNIFICANT CONTROLLING INFLUENCE ON PRODUCTIVITY RATES

Determination of such things as time to make the necessary cuts to fell trees of various sizes will require certain measurements in addition to elapsed time values. For example, in this case it is necessary to measure the tree size (particularly its diameter). In other words, it is necessary to measure the controlling influences if they are to be related to productivity rates.

METHODS OF DATA GATHERING

Four data gathering methods are to be considered in this thesis. They are 1) time lapse photography, 2) standard and slow motion movies, 3) time study, and 4) work sampling. The greatest amount of attention will be devoted to time lapse photography which already appears to be a promising tool.

CHAPTER II
TIME LAPSE PHOTOGRAPHY
A PERTINENT TIME AND MOTION STUDY TECHNIQUE
FOR DATA GATHERING IN THE FIELD

Time lapse photography is a modified motion picture technique, involving the use of a special movie camera. The camera is modified so that, in the original photography, a greater than normal time interval elapses between successive frames. It is commonly used for visualizing and recording the normally invisibly slow processes. (A well-known example of the use of time lapse photography is the visualizing of the opening of a flower bud.) (10,p.13)

In the later 1940's (9,p.13) time lapse photography began to find industrial application in a newly developed work analysis tool called memomotion study.

Memomotion study is a motion and time study technique invented by Marvin E. Mundel. (8,p.1786) In the words of Mundel:

> "Memomotion study is the name given to the special form of micromotion study in which motion pictures are taken at unusually slow speeds. Sixty frames per minute (one per second) and one hundred frames per minute are the speeds most commonly used. Like all micromotion study, it is primarily another means of performing the second step of the logical method, 'analysis,' with man activity, and requires three phases: filming, film analysis, and graphic presentation. Memomotion may also be used to study the flow of material or the use of materials-handling equipment in an area, or to study simultaneously the man work, equipment usage, and flow of material. The information contained on the film may be analyzed

> in numerous ways and alternative presentations of the data in graphic form are possible, depending on the objectives of the study."
> (18,p.301)

The logical method of which Mundel speaks involves the application of the following steps:

1. Aim (determination of objective),
2. Analysis,
3. Criticism,
4. Innovation,
5. Test,
6. Trial,
7. Application.

Discussion of the method can be found in Mundel's book, Motion and Time Study, Principles and Practice. (18,p.27-28)

"Time lapse photography" is the first of the three phases (namely, filming) that Mundel points out as being required for memomotion study. It is the device by which data are gathered when memomotion study is used for operation analysis.

Time lapse photography, when used as the first phase of memomotion study, is simply a means of briefly recording on film the essential "elements" (standard industrial engineering definition) of an operation cycle. This technique is subject to several limitations, but it also has numerous advantages (where favorable circumstances exist) over other motion and time study techniques. The advantages and limitations of time lapse photography will be discussed in later sections of this chapter.

Known applications of this technique in other industries are discussed below.

USE OF TIME LAPSE PHOTOGRAPHY IN MANUFACTURING AND OTHER INDUSTRIES

Time lapse photography, in its relatively new memomotion study application, is primarily useful in studying any of, or any combination of, the following: (18,p.301-302)

1. Long cycles,
2. Irregular cycles,
3. Crew activities,
4. Long period studies.

It has been successfully used in a wide variety of other industries prior to its trial at Montana State University as a tool for data gathering in the study of logging operations. (The author has found no evidence of previous application of time lapse photography to the study of logging operations.)

The following list will serve to illustrate the wide range of activities where time lapse photography has been used as a means of gathering data for analysis of the operations: (18,p.302)

1. Gas company street work,
2. Twenty-four-man steel casting mold line
3. Prefabricated house section manufacture,

4. Railroad car humping in a classification yard,
5. Aircraft service on the ramp at a commercial airport,
6. Dry-salt meat packing line,
7. Stripping at delivery end of a cutting press,
8. Package handling at a packing-house sorting center,
9. Two-man welding crew on water heater assembly line,
10. Municipal garbage handling,
11. Dental activity,
12. Household activities,
13. Department store clerks,
14. Fifty-man paper making-machine repair crew,
15. Ice house crew,
16. Railroad car loading crew.

To multiply the significance of the wide range of activities where time lapse photography has been used, the _ways in which it has been used_ also cover a broad area of approaches as illustrated by the following list of "fields of application": (21,p.208)

1. Production allowances,
2. Irregular work cycles for the indirect and related production groups,
3. Crew operations and long cycles,