AN ABSTRACT OF THE PAPER OF

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Title: Short Distance Transportation in the Mixed Peat Swamp Forests of Sarawak, Malaysia

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The peat swamp forests of Sarawak are an important resource in the context of the socio-economic development of the state. Logging is the main activity in these forests. In the absence of an economical mechanized system, the method of harvesting has evolved into a highly organized effective manual system. Though the method itself is well-known, there is still a dearth of quantitative data especially with respect to the mixed peat swamp forests of Sarawak.

A timestudy was conducted in two forest reserves near Simunjan in the First Division of Sarawak. The primary objective was to quantify the logging system with special emphasis on the skidding component. Other components that were studied include felling and bucking, skid track construction, debarking and loading. Both the one- and two-skid team crews were studied, with emphasis on the

former. Both continuous timing and fixed interval activity sampling techniques were used.

The skidding component was the key element controlling the overall production of the logging operation. It is comprised of five basic work elements, namely outhaul, load, sling, inhaul and unload. Load and inhaul were the largest work elements accounting for 30 percent or more of the basic cycle time. The basic cycle time ranged from 63-88 percent of the total cycle time depending upon the skidding potential of a crew. The skidding potential is a measure of a crew's aggressiveness. Skid distance and log weight were found to be significant variables accounting for more than 60 percent of the variation in cycle time. Crew aggressiveness and variability in skidding potential could however counteract the effect of skid distance and log weight. The incidence of delays and their frequency may also be attributed to these factors. Hence, skid distance, log weight and skidding potential of crews control the skidding productivity of the system. On the whole the logging operation in the Mixed Peat Swamp Forest is a low-energy system of less than 13500 kilojoules per hour with an average productivity of 1.42 m^3 per person day.

SHORT DISTANCE TRANSPORTATION IN THE MIXED PEAT SWAMP FORESTS OF SARAWAK, MALAYSIA

by

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SHORT DISTANCE TRANSPORTATION IN THE IN THE MIXED PEAT SWAMP FORESTS OF SARAWAK, MALAYSIA

I. INTRODUCTION

The freshwater peat swamp forests are an important revenue earner for Sarawak (Yong and Cheong, 1976). It occupies 3.6 million acres which constitutes some 16% of the total area under forest and 22% of the permanent forests in Sarawak. The only form of human activity in these forests is logging, which led to the growth of the present saw-milling industry. Almost 40% of the log production in Sarawak over the last decade has come from the peat swamp forests (Anon, 1981). The logging sector accounts for 69% of those employed in the timber industry; more than 50% of this employment is generated by peat swamp logging (Anon, 1981; Cheong, 1979). The peat swamp forest resource is therefore regarded as an important contributor to the socio-economic development of the state.

The ground surface of the forest is composed of water-logged peat, the depth of which varies from a few feet to 22 feet (50 feet in the case of inland swamps). The low load bearing capacity of peat has precluded the use of con-ventional logging equipment. In the absence of low ground pressure vehicles and presence of abundant and cheap labor, the method of harvesting these forests has evolved into a highly organized, effective manual system. It is called the 'kuda-kuda' system and it is the only method by which the peat swamps are harvested in Sarawak. In fact, certain regions in Sarawak like Pusa, Saribas, Dalat and Mukah are reputed for their peat swamp loggers.

The logging system may be divided into two major phases: (1) Extraction and (2) Transportation. Extraction includes:

(i) Falling and bucking

(ii) Short distance transportation

(iii) Loading

Transportation includes:

(i) Railway swing, which occurs from the landing to the log pond

(ii) River transportation, when the logs are rafted and towed to the mill.

The extraction phase is wholly manual. Trees are felled and bucked by means of chainsaws. They are crosscut into 17-20 feet log lengths. Each log is loaded onto a wooden sled called the 'kuda-kuda' and dragged on wooden tracks to the loading ramps. The logs are manually debarked, scaled and loaded onto rail carriages. The transporation phase is mechanical. The locomotive, powered by a 30-45 HP diesel engine, swings the logs (50-75 logs per trip) to the log pond. They are sorted and are either rafted and towed down to the mill or loaded into a barge.

Although the method of harvesting has been generally described in several references (Symthies, 1951; FAO, 1974; Zulkifli, 1978), there is very little quantitative information on the system itself, especially at the component level. For instance, the kinds and distribution of work elements of the various logging components, the relative productivity of each and how one is balanced with another, are relatively unknown. This study is an attempt to quantify the various components of the Peat Swamp Logging System with special emphasis on the skidding activity.

OBJECTIVE OF THE STUDY

The primary objective is to quantify the skidding component and determine how it interacts with the rest of the extraction components. Hence, the goals are:

1. To identify the work-elements of the skidding component and their time structure.
2. To derive predictive production equations for skidding.
3. To determine a crew's skidding production potential in this system.
4. To quantify and obtain production data on felling, bucking, skid track construction, debarking and loading.
5. To specify how a system balance of the logging operation can be obtained.

SCOPE OF THE STUDY

This is an exploratory study and hence, it is essentially observational in nature. Only the components in the extraction phase are studied in detail, with emphasis on skidding. The study was carried out in the Mixed Swamp Forest.

Data on skidding were collected in two logging blocks. However, the data for the system balance were based on only one logging block. Two crew types were studied viz, (i) one-skid team crew and (ii) two-skid team crew. The one-skid team crew (Crew 1) was comprised of 13 men whereas the two-skid team crew (Crews 2A and 2B) had 22 men.

Cost data are not reported in this study because they were difficult to obtain and the loggers were paid on a piece-rate basis. The study was conducted during a period of 10 person-weeks.

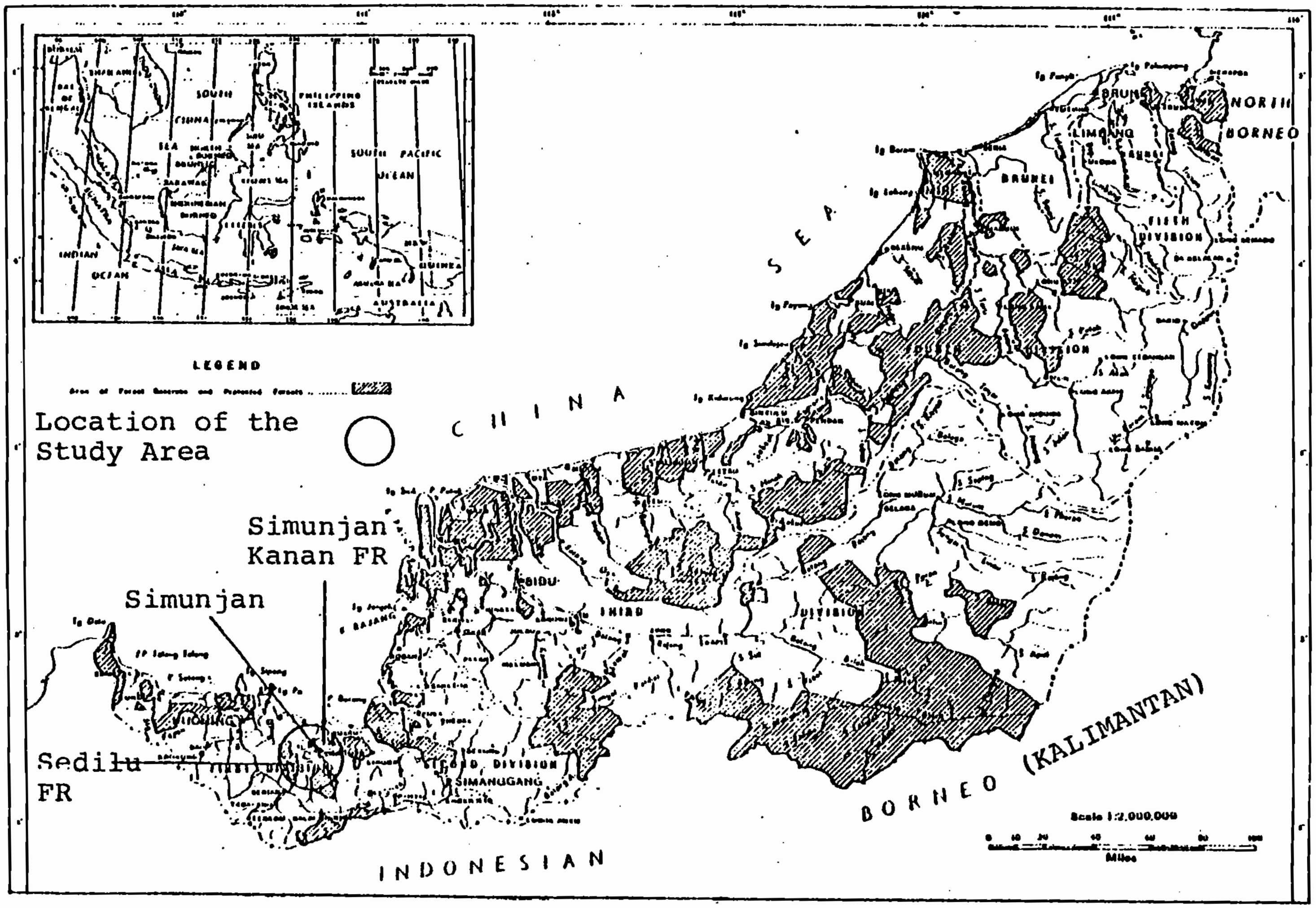
LOCATION AND DESCRIPTION OF THE STUDY AREA

The study was conducted in two forest reserves near Simunjan in the First Division of Sarawak (Figure 1). The canopy of the primary forest stands is uneven and dense and is essentially multi-storied in composition. The dominant trees may have heights of between 100 to 140 feet and diameters of 22 inches to well over 32 inches (FAO,1974). It is characterized by the Gonystylus-Dactycladus-Neoscortechnia association (Whitmore, 1975). It is selectively-cut and has a rotation of 45 years.

By selective cut it is meant that only the commercial species are removed. About 10 to 15 trees may be cut per acre. The average productivity of these Forest Reserves was estimated to be 800-1250 cubic feet of commercial logs per acre. These forests are wild forests. They come under management only after harvesting. There is only a single entry or harvest within the rotation period. The species of trees encountered in the study are given in Appendix 1.

Crew 1 was in the Sedilu Forest Reserve. Crew 2A and 2B were in the Simunjan Kanan Forest Reserve.

FIGURE I. MAP OF SARAWAK SHOWING THE LOCATION OF THE STUDY AREA



II. LITERATURE REVIEW

Logging in peat swamp forests of Sarawak by manual means, has been in existence since prewar (World War II) days. It has not changed much since then. Symthies (1951) identified three methods of skidding the logs from stump to railside:

(i) the simple rolling method. This is perhaps the earliest method to be used. Generally, preferred by unskilled workers, it consists of rolling the log by hand over a track of two stringers.

(ii) the kuda-kuda method. A wooden sled is used in this method. The log is loaded onto the sled and pulled over a track of stringers and crosspieces.

(iii) the gallingan method. This method enables longer and heavier logs to be skidded, for which the above two methods are unsuitable. It neither involves rolling the log nor a sled. The log is pushed in the direction of its longitudinal axis over short sections of stringers.

Skidding distances are necessarily short in these methods. This requires a high density of railways or tramways.

The use of light gauge tramways has been cited to be an instrumental factor in harvesting the peat swamps (Symthies, 1951; Durgnat, 1952). Logs are skidded to either side of the tramway. Once a strip has been logged, the rail lines are shifted to another strip. The low cost of this two-feet gauge tramways allows for short skidding distances that makes manual skidding effective.

Mechanized means of skidding logs has been attempted. Yap (1966) used a single-drum mechanized winch (converted from a locomotive, 16-20 HP diesel engine), with a 1/2-inch diameter wire rope, 330 feet long to drag the loaded sled (kuda-kuda) to the railside. Production increased by more than 50%. However, the cost-effectiveness of this method was not reported. Wood (1967) described a skyline extraction system that was attempted in the Alan Peat Swamp Forest. A double-drum yarder (30-42 HP) with a 3/4-inch skyline and 1/2-inch operating lines in a tightline configuration was used. The external yarding distance was 15 chains and lateral yarding distance, 1-1/4 chains. Logs were yarded to the railside from either side. However, it was found to be more expensive and less productive than manual logging. Wood also reported that in the 1950's a steam-driven yarder was used but proved to be too expensive. The mechanical feasibility of such systems have been established. It is the economical infeasibility that precludes their adoption.

The Food and Agriculture Organization (FAO) (1974) had carried out an extensive study of peat swamps of Sarawak. The conclusions of the study with respect to the manual logging operations are summarized below.

(i) the logging system does not require a large capital outlay;

(ii) it has insignificant operation costs;

(iii) the strategic location of these forests being adjacent to export outlets allows the economics of log production to be extremely favorable;

(iv) being a very highly labor intensive system, the logging cost is likely to increase only if there is an extreme shortage of skilled or semi-skilled workers;

(v) there is little likelihood to have any major change in the logging system or in the techniques used since the nature of the swamp precludes the use of high capital intensive systems and the low cost of log production does not appear to warrant change.

The manual system thus persists. Subsequent documentation of this sytem soon followed (Letourneau, 1975; Zulkifli, 1978; Ahmad, 1979). Ahmad's study (1979) was on the Alan Peat Swamp Forest and it was the first attempt to quantify the skidding component. He observed that the skidding distance and log volume were the two most important variables affecting cycle time, constituting 67 percent of the total variation. However, no quantitative information is available on the logging operation in the Mixed Peat Swamp Forest.

III. DESCRIPTION OF THE SKIDDING COMPONENT

PRE-SKIDDING OPERATIONS

Each license area (concession) is divided into logging blocks of 15 acres (Figure 2). The rail line is laid out between blocks to facilitate yarding from both sides.

Each logging block is worked by one crew. Typical crew size ranges from 10-22 persons, depending upon the work organization of the crew. One-skid team crews generally are comprised of 10-14 persons, whereas two-skid team crews are comprised of 20-22 persons. The one-skid team crew is the general practice. The sled-pulling team for both crews is comprised of six persons (Table 1).

TABLE 1. CREW SIZE AND NUMBER OF SKID TEAMS

Crew Type	No. of Sled-Pulling Teams	No. of Persons per Team	No. of Persons in Other Activities	Total No. of Persons
Single Skid Team Crew	1	6	4-3	10-14
Two-skid Team Crew	2	6	8-10	20-22

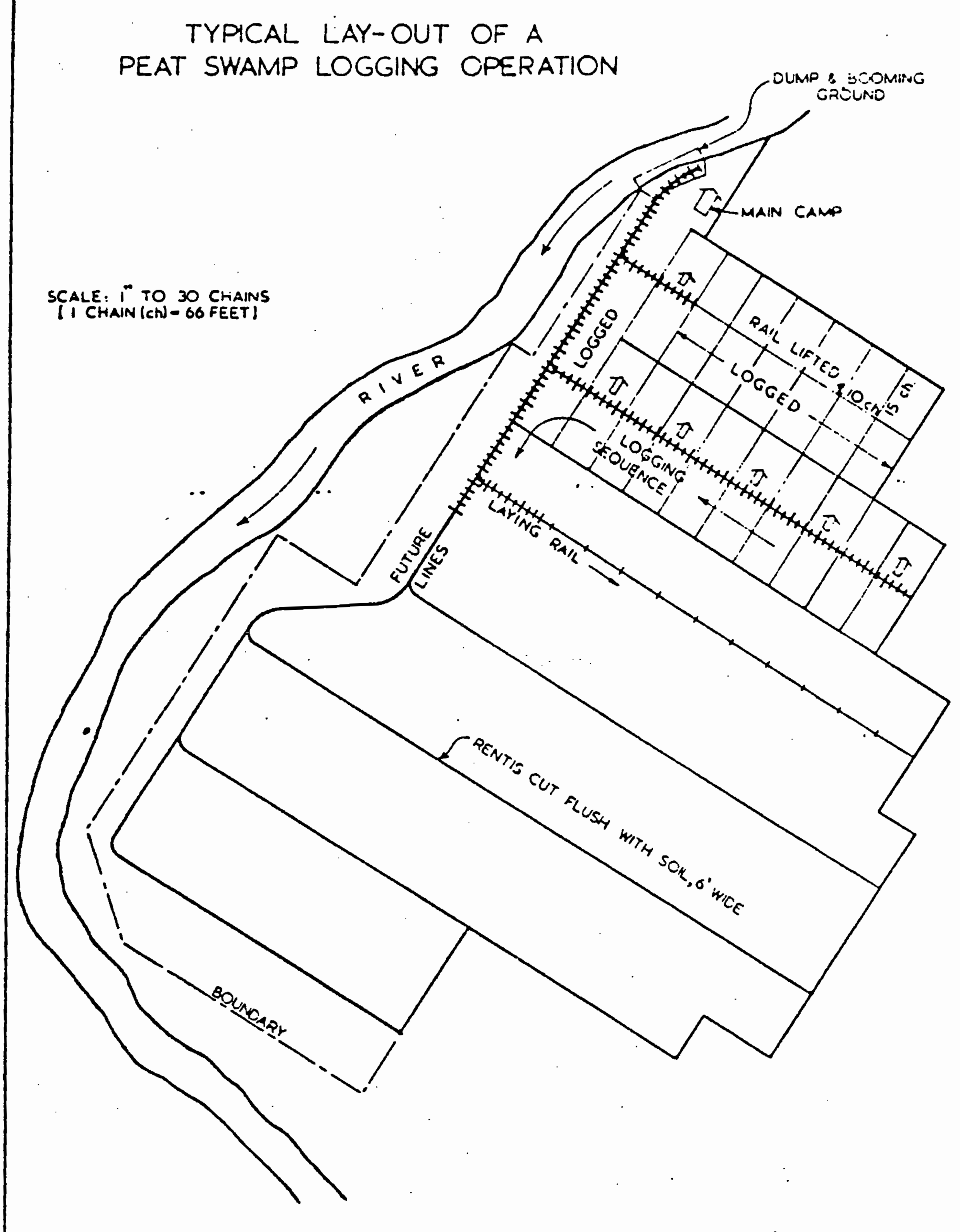
Before skidding can begin, the crew builds loading ramps and the main skid tracks (kuda-kuda tracks). The loading ramp is 50 to 60 feet in length and 8 to 11 feet in width. It is built perpendicular to the rail line and the fore-end is at a height level with the rail carriage (Figure 3). It is inclined for the first 15 to 20 feet from the rear end and becomes level through the fore-end. It is made of poles 12 to 18 inches in diameter and 30 to 50 feet in length. The number of loading ramps can range from four to six but initially only three are constructed.

The kuda-kuda tracks are simply wooden tracks constructed out of wooden poles and stringers (Figure 5). Generally, a single main skid track is built in the middle of the logging block (Figure 4). However, if the logging block carries a large volume (more than 50,000 $feet^3$), two main skid roads are constructed (Ahmad, 1979).

The "right-of-way" is cleared to a width of 6 to 8 feet. Stringers, 6 to 8 inches in diameter, 12 to 15 feet in length, are placed approximately 6 feet apart. Crosspieces, 3 to 6 inches in diameter are then overlaid at approximately 18 inches apart. A notch is made on each stringer to secure each crosspiece. The bark on the upper surface of the crosspiece is removed in order to reduce friction while dragging the sled. In addition, lubricating oil is applied on the upper surface of the crosspieces to enhance this effect and render the movement of the sled easier.

Once the construction of loading ramps and kuda-kuda tracks is completed, felling begins. Felling, skidding and branch skid track construction begin from the rear end of the block and progress towards the landing. The secondary or branch skid tracks are constructed or extended to whereever the trees have been felled. They are constructed parallel to the felled tree to facilitate easier loading. These branch skid tracks are however, temporary. They are removed and used elsewhere down the block once they have served their purpose at a given location. Branch skid tracks are usually of lower standard in terms of construction relative to the main skid track. The fewer the number of logs from a given location, the poorer the quality of branch skid tracks leading to that location.

FIGURE 2

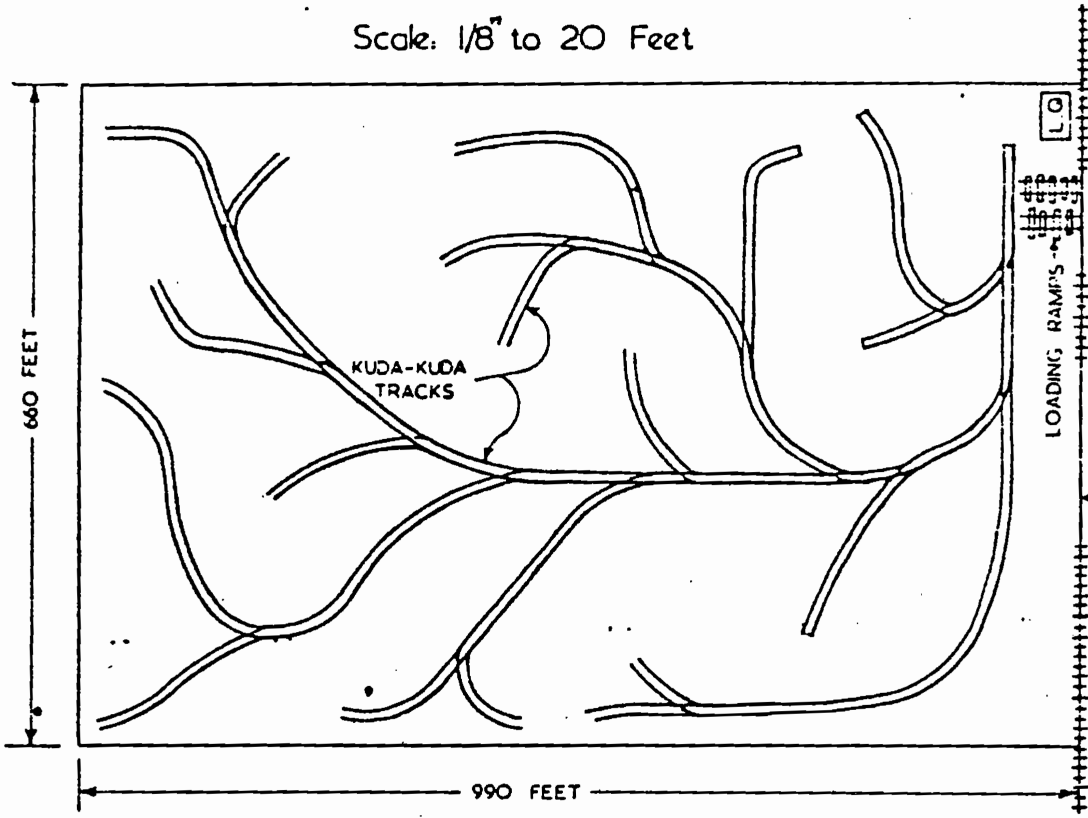


(Source-FAO, 1974)

TYPICAL BLOCK LAYOUT SHOWING RAIL LINE, KUDA KUDA TRACKS and RAMPS

FIGURE 4

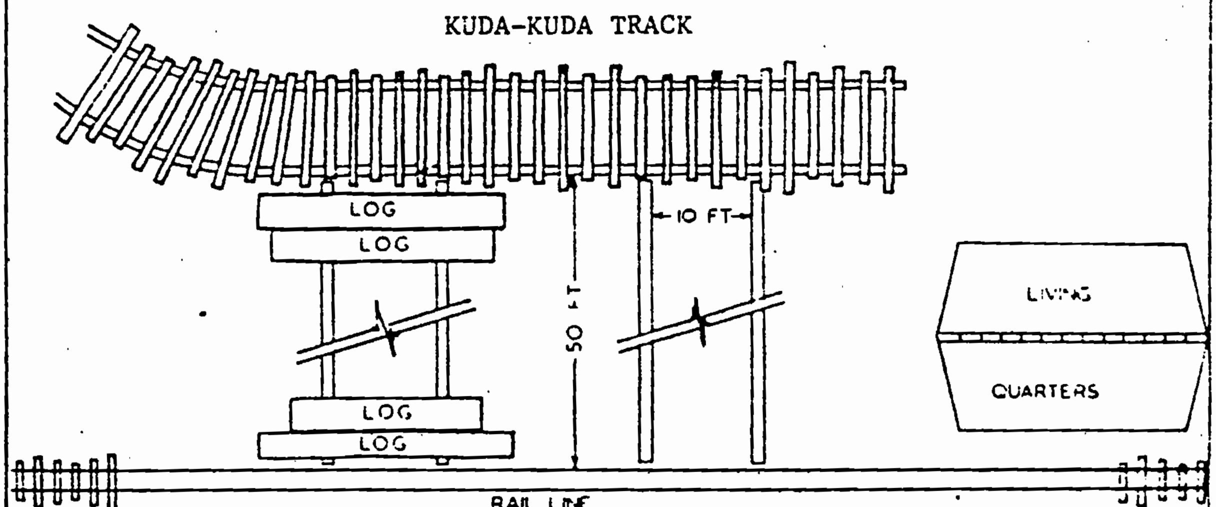
Scale: 1/8" to 20 Feet



DETAIL AT LOADING AREA

FIGURE 3

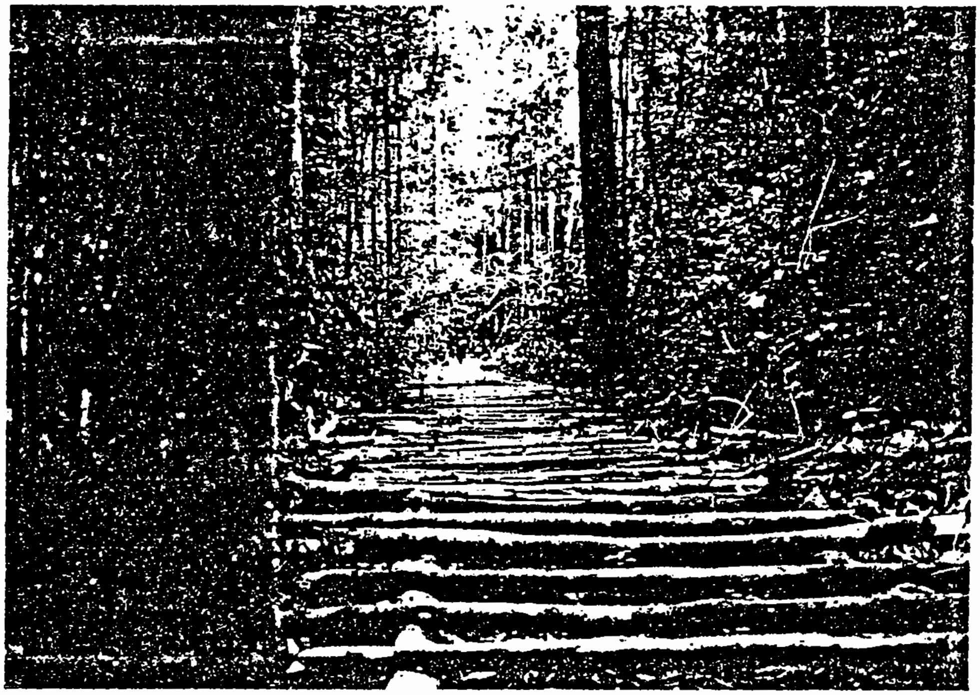
Scale: 1" to 16 Feet



(Source-FAO, 1974)

FIGURE 5. A TYPICAL MAIN SKID TRACK

IN A PEAT SWAMP FOREST



SKIDDING

Logs are skidded on a wooden runnered sled (kuda-kuda) one at a time (Figure 6). The sled is 10 feet in length and 3 feet in width. It has six canvas slings attached at regular intervals, three from either side of the sled. The skidding cycle is as follows:

1. Outhaul: Begins the instant the sled leaves the landing ramp and ends when it stops on the main or branch skid track for another turn. Usually two men drag the sled in the outhaul.

2. Loading: This element actually consists of two distinct operations, namely, (i) preloading activities and (ii) actual loading itself.

2.1 Preloading activities: These activities facilitate the actual loading operation. Preloading begins when the empty sled stops on the skid track at the stumpsite.

2.1.1 poles set-up: Two poles are first secured vertically into the ground against the sled to prevent it from moving while loading. Another two poles are laid inclined from the location of the log to the deck of the sled.

2.1.2 collection of peavies: Peavies and poles have to be collected from the location of the previous turn. (They are usually left after the loading). Until this stage only two men are involved.

2.1.3 lead adjustment: The log is adjusted into a parallel lead with respect to the sled. The whole team is involved in this activity.

2.2 Loading: Begins with rolling of the log.

2.2.1 rolling: The log is rolled, wedged and pushed up the inclined poles on to the sled deck, by means of poles and peavies.

2.2.2 reorientation: Once on the sled, the log is adjusted and positioned to make it remain stable so that it is not easily dislodged from the sled.

2.3 Preinhaul activities: Before the inhaul begins, the poles are removed. The runners of the sled are brushed with oil and the slings are taken up. The canvas sling is placed around the shoulder of each man, three men on either side of the sled. An axe is driven into the front end at the log which serves as a steering, especially around corners.

2.4 Inhaul: Begins when the sled is given a jerk, by pulling in unison, to get into motion. The subsequent momentum is maintained by each man exerting his full energy in accordance with a well-timed sequence (Letourneau, 1975). Experience of the crew is crucial in effecting a uniform motion of the inhaul. It ends when the sled stops at the loading ramp.

2.5 Unload: This consists of two distinct activities.

2.5.1 preunloading activities: These activities facilitate the unloading activity.

2.5.1.1 unslinging: The slings are removed off their shoulders.

2.5.1.2 poles-set up: Two poles are laid inclined on to the loading ramp.

2.5.2 unloading: The log is rolled and pushed up the poles on to the loading ramp by means of peavies and poles. Once the log is on the loading ramp, two men will drag away the sled for another turn. Meanwhile, the four men continue to roll and deck the log on the loading ramp.

FIGURE 6a. SKIDDING A LOG ON THE KUDA-KUDA (SLED)

FIGURE 6b. AN ILLUSTRATION OF AN EMPTY KUDA-KUDA

IV. STUDY PROCEDURES AND MEASUREMENTS

SKIDDING

A continuous timestudy was conducted for the skidding component. The time of each element was measured using a digital watch. The times were then expressed to the nearest 1/100 of a minute.

The dependent variable was time. The following were the work elements measured:

Outhaul: This is the time required for the sled to be dragged from the loading ramp to the location of the next turn. The activity begins when the men start dragging away the sled and ends when they stop at the next turn.

Load: This is the time required to load a log on to the sled. It begins when the men begin the preloading activities and ends when the log is finally loaded on to the sled and the poles are taken away.

Sling: This is the time required for the men to take up the slings and position themselves to pull.

Inhaul: This is the time required for the team to drag the loaded sled from stumpsite to the loading ramp. It begins when the team initiates a jerk to get the loaded sled into motion. It ends when the sled stops at the loading ramp.

Unload: This is the time required for the team to unload the log on to the loading ramp. It begins when the sled stops and the men take the slings off their shoulders. It ends when the sled is dragged away for the next turn.

<u>Delays:</u> Delays were noted and recorded whenever they occurred throughout the skidding cycle. They were categorized as follows:

1. Operational delays: These delays are common to the operation, viz:
   - 1.1. waiting for crew before loading.
   - 1.2. lubricating: the sled and crosspieces are applied with oil.
   - 1.3. clearing obstacles, such as stumps, brush, etc.
   - 1.4. dislodgement of crosspieces that stops the cycle or element.
2. Personal delays: These include rest, etc.
3. Other delays: These are unique delays that cannot be categorized in either of the above. For instance, a crew member trips or falls; a fallen tree or branch across the skid track; or if the sled goes off the skid-track and the log is dislodged.

The independent variables that were measured were (i) skidding distance and (ii) volume of log. Skidding distances were measured along the skid tracks by means of a 66-foot tape. To facilitate easier measurements, the tracks were marked at every 50 feet. Log measurements were also obtained by tape; the length and the diameters of both ends were measured. Log volumes were subsequently used to obtain the weight of the logs.

FELLING

A continuous timestudy was used to quantify the felling component. The felling elements were measured to the 1/100 minutes.

The dependent variable was time. The following were the elements measured:

Travel: This is the time required for the faller to walk from one tree to another. It begins when he starts to walk to the next tree. It ends when he reaches the tree.

Prefelling activities: This is the time required for the faller to inspect the tree, decide on the lay, clear brush and make an escape route. It begins as soon as he reaches the tree and ends when he starts the chainsaw and begins to make the notch.

Felling: This is the time required for the faller to make the notch and backcut. It begins when he begins to make the notch. It ends when be begins to walk to the next tree.

Delays: These are categorized as (1) operational delays; (2) equipment delays; (3) personal delays and (4) others.

1. Operational delays include:

1.1. refueling the chainsaw

1.2. walking-in and -out to get fuel or from rest to felling location

1.3. wedging

1.4. filing

2. Equipment delays include:

2.1. adjustment of chain

3. Personal delays include:

3.1. Rest, etc.

4. Others.

4.1. hang-ups

4.2. aborted trees

4.3. clearing for skid trail or cutting stumps

4.4. stops for safety reasons

The independent variables that were measured were (i) travel distance (ii) diameter of tree. The travel distance from tree to tree was estimated. The diameter of the tree was measured at the cut of the stump, using a tape. The height of the tree was not measured due to limitation in personnel.

BUCKING

Bucking was studied in less detail than skidding partly due to personnel limitation and because it was not the primary focus of interest. The work-elements were, however, identified.

Scale: It is the time required to scale a bole into log lengths.

Cross-cut: This is the time required to buck a log.

Delimb: It is the time required in delimbing.

Walk: There are miscellaneous movements throughout the activity. For instance, walking to buck after delimbing; moving after a rest; walking to a more convenient working position, etc. This element denotes the duration of these movements.

Delay: This includes operational, machine and personal delays.

Only the number of logs bucked was recorded.

CONSTRUCTION OF BRANCH SKID TRACKS

This was also studied in less detail than skidding. The work elements were however, identified.

Clearing of trail: This is the time required to clear the trail. It involves manual clearing (using machetes) and sometimes, aided by the chainsaw.

Collection of materials: This is the time required to obtain pole-size stringers and crosspieces. The stringers and crosspieces are either freshly cut or obtained from previously used skid tracks.

Actual construction: This is the time required to align the stringers, make notches and place the crosspieces.

Delays: Includes activities other than the above elements.

However, all these activities occur simultaneously. One man is involved in getting the stringers, one in clearing brush, and other collecting crosspieces or making them. Since there was a large amount of movement involved, the activity was timed as a whole. The dependent variables were thus (i) total (basic) time or productive time and (ii) delays. The length of skid trail constructed was measured.

DEBARKING

A fixed interval activity sampling technique was used to measure debarking. The timestudy man was very new to production studies. The activity sampling technique is easy to understand and conduct. Observations were taken at every 1/2-minute interval.

The work elements that were timed are as follows:

Debark: This is the time required to actually remove the bark off the log. It begins when the worker starts removing the bark with an axe and ends when he stops.

Roll: This is the time required to roll the log to get to the remaining part of the log. It begins when the worker positions a peavy over the log. It ends when he had rolled the log and lays the peavy aside.

Discard: This is the time required to discard the bark from the loading ramp. It begins when the worker collects the bark and ends when he resumes some other activity.

Delays: This includes personal delays and unique delays.

The independent variables that were measured were (i) log length (ii) log diameter. The species of each log was also recorded.

LOADING

This was also studied in less detail than skidding. Fixed interval activity sampling technique was used to observe and record the work elements at every 1/2-minute interval. The work elements are as follows:

Load: This is the time required for the crew to load a log on to the rail carriage. It involves rolling and pushing the log on the loading ramp on to the carriage. Each carriage accomodates two or three logs. It begins when the men begin to roll or push the log. It ends when a given carriage is fully loaded.

Position: This is the time required for the locomotive to move and position the next empty carriage in place for loading. It begins when the carriages begin to move. It ends when the locomotive stops.

Delays: These include locomotive delays and crew delays.

STATISTICAL METHODS

All statistical analyses were conducted using the Statistical Interactive Programming System (SIPS), run on the Oregon State University CDC 3300 Computer (Cyber Operating System). Descriptive statistics were computed for both dependent and independent variables in all the components.

Regression analyses were carried out using the data on skidding cycles. The primary objective of the regression analysis was to determine, if there is a significant relationship between the skidding elements (time) and the independent variables; and if so, to quantify the relationship. The ultimate objective, however, is to obtain significant predictive equation for the basic cycle time. The general linear regression model is as follows (Neter and Wasserman, 1974):

$$Y_i = \beta_1 + \beta_1 X_{i1} + \beta_2 X_{i2} \cdots + \beta_{\rho-1} X_{i,\rho-1} + \varepsilon_i$$

where,

$\beta_0, \beta_1, \cdots, \beta_{\rho-1}$ are parameters (regression coefficients),

$X_{i1}, \cdots, X_{i,\rho-1}$ are known constants (independent variables)

ε_i, normal error terms that are independent $N(0, \sigma^2)$

Y_i, the ith dependent variable

i-1,2..., n.

In quantifying the relationship, the significance of each independent variable is denoted by the P-value, as it is included into the regression model. The coefficient of determination, R^2 indicates how well the independent variable(s) explain the variation in the dependent variable.

Model analysis was carried out to determine the "best" model for the basic cycle time regression equation.

V. RESULTS

SKIDDING CYCLE

The time distribution of the skidding elements for the various crews are given in Tables 2-5. The basic cycle times for Crews 1, 2A and 2B are: 14.13, 13,69, 12.98 minutes, respectively. The gross cycle times for these crews are 22.43, 15.49 and 16.39 minutes. The basic cycle time thus constitutes 63, 88 and 79 percent of the total cycle for these crews (Appendix 2). These data by themselves do not indicate the differences in crew performance, because they represent unique crew types distances skidded and log weights (thus, volume and species) encountered in the logging block. However, they do indicate how a typical manual skidding cycle is structured in the Mixed Swamp Forest. The largest skidding element is loading, constituting 30-40% of the basic cycle time, followed by inhaul, accounting for about 30% (Appendix 3). To provide a further insight of the skidding cycle, the speeds of outhaul and inhaul elements and the production per hour are given in Table 5. The average outhaul speed was slightly more than 3 feet per second (ft/s) for all the crews. Crews 2A and 2B were slightly faster (2.5 ft/s) in their inhaul compared to Crew 1 (2 ft/s).

TABLE 2. SUMMARY OF SKIDDING ELEMENTS - CREW 1

(n* = 62)

Skidding Element	Average Time in Minutes	Range in Minutes	Coefficient of Variation %	% of Basic Time	% of Gross Time
Outhaul	2.40	0.52-4.60	46	17	11
Load	5.46	0.98-12.88	44	39	24
Sling	0.83	0.07-4.87	82	6	4
Inhaul	4.24	0.70-11.62	52	30	19
Unload	1.20	0.65-2.35	31	8	5
Delay	8.30	0.00-26.02	34	--	37
Basic Time	14.13	5.94-26.06	45	100	63
Gross Time	22.43	6.36-43.77	79	--	100

Independent Variables	Average	Coefficient of Variation %	Minimum	Maximum
Skid Distance (feet)	493	42	84	857
Log Weight (pounds)	1952	34	894	4114

*n = number of observations

TABLE 3. SUMMARY OF SKIDDING ELEMENTS - CREW 2A

(n = 37)

Skidding Element	Average Time in Minutes	Range in Minutes	Coefficient of Variation %	% of Basic Time	% of Gross Time
Outhaul	3.05	1.47-5.20	27	22	20
Load	5.14	1.37-11.05	51	38	33
Sling	0.41	0.05-1.05	66	3	3
Inhaul	4.02	1.27-7.68	35	29	26
Unload	1.07	0.23-2.52	45	8	7
Delay	1.80	0.00-20.10	210	--	12
Basic Time	13.69	7.33-22.81	27	100	88
Gross Time	15.49	7.33-31.23	34	--	100

Independent Variables	Average	Coefficient of Variation %	Minimum	Maximum
Skid Distance (feet)	569	24	254	868
Log Weight (pounds)	1562	44	389	3173

TABLE 4. SUMMARY OF SKIDDING ELEMENTS - CREW 2B

(n = 44)

Skidding Element	Average Time in Minutes	Range in Minutes	Coefficient of Variation %	% of Basic Time	% of Gross Time
Outhaul	3.08	1.30-5.90	34	24	19
Load	4.23	1.12-11.65	54	33	26
Sling	0.48	0.02-0.98	57	4	3
Inhaul	3.94	1.26-8.20	41	30	24
Unload	1.25	0.23-3.08	47	10	8
Delay	3.39	0.00-23.65	143	--	21
Basic Time	12.98	5.54-23.40	31	100	79
Gross Time	16.37	6.59-46.52	47	--	100

Independent Variables	Average	Coefficient of Variation %	Minimum	Maximum
Skid Distance (feet)	529	27	228	824
Log Weight (pounds)	1828	38	739	4084

TABLE 5. SUMMARY OF AVERAGE OUTHAUL AND INHAUL SPEEDS, AND PRODUCTION RATES FOR ALL CREWS

	Average	Coefficient of Variation %	Minimum	Maximum
Crew 1				
Outhaul Speed, ft/s	3.49	15	1.24	4.70
Inhaul Speed, ft/s	2.06	28	0.79	3.43
Logs/hr	3.3	49	1.4	9.4
Volume	107			
Crew 2A				
Outhaul Speed, ft/s	3.22	25	1.86	5.13
Inhaul Speed, ft/s	2.50	24	1.41	4.32
Logs/hr	4.3	31	1.9	8.2
Volume (ft^3/hr)	111			
Crew 2B				
Outhaul Speed, ft/s	3.05	30	1.38	6.05
Inhaul Speed, ft/s	2.48	33	0.90	4.89
Logs/hr	4.3	40	1.3	9.1
Volume (ft^3/hr)	146			

SKIDDING POTENTIAL

Fiske and Fridley (1975) defined a new parameter called the tractor potential (E), as a means of quantifying the capabilities of a skidder (rubber-tired or track). E, measured in kilopounds feet per hour, is defined as:

$$E = \frac{W\ D}{T_W + T_R}$$

where, W = turn weight in pounds

D = skid distance in feet

T_W = inhaul time

T_R = outhaul time

In the context of manual skidding, E may be defined as the skidding potential, as a means of quantifying the performance capability of a skidding crew. The skidding potentials for the various crews are presented in Table 6.

TABLE 6. SKIDDING POTENTIAL, E (kip.ft/hr) OF CREWS

	Average	Coefficient of Variation	Minimum	Maximum
Crew 1	8695	35%	4595	16660
Crew 2A	7655	46%	1879	15546
Crew 2B	8255	33%	4227	15756

E addresses only the outhaul and inhaul elements. The skidding cycle consists of other subcycle elements (load, unload, etc.), besides outhaul and inhaul. Hence, a slightly modified but better performance parameter will be the basic skidding potential (E_b). E_b is defined as:

$$E_b = \frac{W\,D}{T_c}$$

where, W = turn weight in pounds

D = skid distance in feet

T_c = basic cycle time

The basic skidding potentials of the various crews are summarized in Table 7.

TABLE 7. BASIC SKIDDING POTENTIAL (kip. ft/hr) OF CREWS

	Average	Coefficient of Variation	Minimum	Maximum
Crew 1	3993	44%	895	8672
Crew 2A	4007	51%	972	10406
Crew 2B	4492	34%	1810	7264

The efficiency of a crew is reflected in the percent delays. Incorporating an efficiency factor, e_L, with E_b, provides a new performance indicator, the net skidding potential E_n:

$$E_n = e_L \frac{W\,D}{T_c}$$

where, W = turn weight in pounds

D = skid distance in feet

T_c = basic cycle time

e_L = efficiency factor as defined by percent delay

The net skidding potentials are summarized in Table 8.

TABLE 8. NET SKIDDING POTENTIAL, E_n (kip. ft/hr) OF CREWS

	Average	Coefficient of Variation	Minimum	Maximum
Crew 1	2668	48%	895	7000
Crew 2A	3601	48%	690	8536
Crew 2B	3753	38%	1461	7166

There is no significant difference between the three crews in terms of E and E_b (Appendix 4). However, E_n is significantly higher for Crews 2A and 2B than Crew 1.

FELLING

Felling data pertains only to the logging block worked by Crew 1. The felling elements are summarized in Table 9.

TABLE 9. SUMMARY OF FELLING ELEMENTS (n - 112)

Element	Average Time in Minutes	Coefficient of Variation %	Range in Minutes	% of Basic Time	% of Gross Time
Travel	0.65	133	0.0-6.11	15	8
Prefell	1.14	92	0.0-7.48	25	14
Fell	2.70	82	0.50-17.48	60	32
Delay	3.84	191	0.0-45.92	--	46
Basic Time	4.49	62	0.77-19.96	100	54
Gross Time	8.33	98	1.04-47.20	--	100

Independent Variables	Average	Coefficient of Variation %	Minium	Maximum
Diameter (inches)	23.3	26	12	46
Travel Distance (feet)	50	164	0.00	500

The average total time to fell a tree was about 8 minutes, delay constituting some 46% of the time. The fell-element accounts for nearly one-third of the total felling time. On the average about 7 trees were felled per hour.

BUCKING

The work-elements are summarized in Table 10.

TABLE 10. SUMMARY OF WORK-ELEMENTS OF BUCKING

(n = 37)

Element	Total Time in Minutes	% of Basic Time	% of Gross Time
Scale	1.93	5	1
Cross-cut	22.79	59	15
Delimb	8.50	22	5
Walk	5.51	14	4
Basic Time	38.53	100	24
Delay	113.82		75
Gross Time	152.34		100

The average diameter and length of logs were 18.5 inches and 17 feet, respectively. The average number of logs bucked per hour was about 15.

BRANCH SKID TRACK CONSTRUCTION

The productive and delay times of skid track construction are presented in Table 11.

TABLE 11. BRANCH SKID TRACK CONSTRUCTION BY TIME AND LENGTH

Sample No.	Length (feet)	Productive Time in Minutes	Delay in Minutes	Total Time in Minutes	% Productive Time	Average Length (ft) Constructed Per Hour
1	243	166	145	311	53	47
2	134	137	40	177	77	45
3	85	92	60	152	61	34
4	259	300	115	415	72	37
5	173	226	87	313	72	33

The average rate of construction was about 30-50 feet per hour.

DEBARKING

The times of debarking work-elements are summarized in Table 12. The average time taken to debark a log, (average length 17 feet and diameter, 17 inches) was about 15 minutes.

TABLE 12. SUMMARY OF DEBARKING ELEMENTS

(n = 61)

Element	Average in Minutes	Coefficient of Variation %	Range in Minutes	% of Basic Time	% of Gross Time
Debark	9.0	57	1.5-26.5	86	62
Roll	1.0	85	0.0-4.0	9	7
Discard	0.5	176	0.0-3.0	5	3
Delay	4.0	273	0.0-32.0	--	28
Basic Time	10.5	55	2.0-32.5	100	72
Gross Time	14.5	64	2.0-41.5	--	100

Independent Variables	Average	Coefficient of Variation in %	Minimum	Maximum
Length (ft)	17.16	16	11.17	23.33
Diameter (in)	17.42	22	10.20	29.16

The debark element is the largest subactivity, accounting for more than 80% of the basic time, or more than 60% of the total time.

LOADING

The work-elements are summarized in Table 13. An average of 25 logs were loaded per loading activity. Each loading activity would take slightly more than an hour.

TABLE 13. SUMMARY OF LOADING ELEMENTS

(n = 7 loading activities)

Element	Average Time in Minutes	Coefficient of Variation in %	Range in Minutes	% of Basic Time	% of Gross Time
Load	35	25	20-45	80	49
Position	9	44	5-16	20	12
Delay	28	40	10-46	--	39
Basic Time	44	19	32-56	100	61
Gross Time	72	23	42-90	--	100

Independent Variable	Average	Coefficient of Variation in %	Minimum	Maximum
Number of logs loaded	25	15	18	28

REGRESSION ANALYSIS OF SKIDDING CYCLE

D = skid distance in feet

W = log weight in pounds

n = number of observations

P = the probability of getting a coefficient value of the independent variable as big or bigger than that obtained, when in fact the null hypothesis is true.

R^2 = the coefficient of determination, which is a measure of the proportion variation in the dependent variable explained by the independent variable(s).

CREW 1 (n = 62)

1. Outhaul (minutes)

Ho. $\beta_1 = 0$: outhaul $\neq$ f (D)

Ha: $\beta_1 \neq 0$: outhaul = f (D)

Outhaul = - 0.098726

+ 0.00507162(D) $P << 0.0005$

$R^2 = .9231$

This is very strong evidence that outhaul is a function of skid distance.

2. Load (minutes)

Ho: $\beta_1 = 0$: load $\neq$ f (W)

Ha: $\beta_1 \neq 0$: load = f (W)

Load = - 2.28693

+ 0.00162758 (W) $P < 0.005$

$R^2 = .2073$

There is a significant effect of log weight on load time but it only accounts for 21% of the variation. The other 79% of the variation is explained by variables not included in the model.

3. Inhaul (minutes)

$H_o: \beta_1 = 0$: inhaul $\neq$ f (D,W)

H_a. $\beta_1 \neq 0$ and, or $B_2 \neq 0$: inhaul = f (D,W)

Inhaul = - 0.973310

+ 0.00795974 (D) $P \ll 0.0005$

+ 0.000657286 (W) $P < 0.005$

$R^2 = .6783$

The variables were added by the stepwise procedure. With skid distance alone in the model, it accounted for 64% of the total variation. Both skid distance and log weight accounted for 68% of the total variation.

4. Unload (minutes)

$H_o: \beta_1 = 0$: unload $\neq$ f (W)

$H_a: \beta_1 \neq 0$: unload = f (W)

Unload = - 0.649663

+ 0.000280884 (W) $P \ll 0.0005$

$R^2 = .2516$

This is good evidence that log weight does influence unload time but it accounts for only 25% of the total variation.

5. Basic Turn (Cycle) Time (Minutes)

$H_o: \beta_1 = \beta_2 = 0$: turn time $\neq$ f (D,W)

$H_a: \beta_1 \neq 0$; and/or, $\beta_2 \neq 0$: turn time = f (D,W)

Basic Turn Time = 1.98758

+ 0.0146771 (D) $P \ll 0.0005$

+ 0.00251086 (W) $P \leq 0.0005$

$R2 = .6139$

This is very strong evidence that both skid distance and log wieght significantly influence turn time. With skid distance alone in the model it accounted for 50% of the variation. The regression coefficients for basic turn time may also be obtained by the summation of the respective regression coefficients of all the elements. Adding thus:

	β_0	D β_1	W β_2
Outhaul	- 0.0987276	0.00507162	-
Load	2.28693	-	0.00162758
Inhaul	- 0.973310	0.00795974	0.000657286
Unload	0.649663	-	0.000280884
Total	1.864554	0.01303136	0.00256575

These aré approximately equal to those of the actual basic cycle, viz:

$\beta_0 = 1.98758$; $\beta_1 = 0.0146771$; $\beta_2 = 0.00251086$

The slight differences observed between these two sets of values are due to the fact the actual basic turn time is comprised of five elements (including sling), whereas, the results from the summation procedure are from only four elements.

Crew 2A (n = 37)

1. Outhaul (minutes)

$H_0 : \beta_1 = 0$: outhaul $\neq$ f (D)

$H_a : \beta_1 \neq 0$: outhaul = f (D)

Outhaul = 1.04610 + 0.00352494 (D) $F < 0.0005$; $R^2 = .3589$

Skid distance affects outhaul time significantly, but it contributes to only 36% of the variation.

2. Load (minutes)

$H_0 : \beta_1 = 0$: load $\neq f(W)$

$H_a : \beta_1 \neq 0$: load $= f(W)$

Load = 3.36649

+ 0.00113266 (W) $P < .10$

$R^2 = .0883$

Log weight appears to be only slightly significant on load time, accounting for just 8% of the variation.

3. Inhaul (minutes)

$H_0 : \beta_1 = \beta_2 = 0$: inhaul $= f(D,W)$

$H_a : \beta_1 \neq 0$; and/or, $\beta_2 \neq 0$: inhaul $= f(D,W)$

Inhaul = - 0.0948317

+ 0.00552860 (D) $P < 0.0005$

+ 0.000621666 (W) $P < 0.05$

$R^2 = .5055$

Skid distance is the more significant variable, accounting for 43% of the total variation.

4. Unload (minutes)

$H_0 : \beta_1 = 0$: unload $\neq f(W)$

$H_a : \beta_1 \neq 0$: unload $= f(W)$

Unload = 0.928841

+ 0.0000924340 (W) $P = .4435$

$R^2 = .0169$

Log weight has no significant effect on unload time.

5. Basic Turn Time (minutes)

$H_0 = \beta_1 = \beta_2 = 0$: turn time $\neq f$ (D,W)

$H_a = \beta_1 \neq 0$; and/or $\beta_2 \neq 0$: turn time = f (D,W)

Basic Turn Time = 7.09505

+ 0.00639306 (D) $P < 0.05$

+ 0.00189444 (W) $P < 0.05$

$R^2 = .2423$

Skid distance and log weight are only moderately significant with respect to basic cycle time, contributing to only 24% of the total variation. Skid distance accounted for 14%.

CREW 2B (n = 44)

1. Outhaul (minutes)

$H_0 : \beta_1 = 0$: outhaul $\neq f$ (D)

$H_a : \beta_1 \neq 0$: outhaul = f (D)

Outhaul = 0.809996

+ 0.00428542 (D) $P < 0.0005$

$R^2 = .3273$

Skid distance is a very significant variable, accounting for 33% of the total variation.

2. Load (minutes)

$H_0 : \beta_1 = 0$: load $\neq f$ (W)

$H_a : \beta_1 \neq 0$: load = f (W)

Load = 1.78682

+ 0.00133716 (W) $P < 0.05$

$R^2 = .1650$

This is only a moderate evidence that log weight significantly affects load time. It explains only 16% of the total variation.

3. Inhaul (minutes)

$H_0 : \beta_1 = \beta_2 = 0$: inhaul $\neq f$ (D,W)

$H_a : \beta_1 \neq 0$; and/or $\beta_2 \neq 0$: inhaul = f (D,W)

Inhaul = - 1.01909

+ 0.00421491 (D) $P < 0.001$

+ 0.00149295 (W) $P < 0.0005$

$R^2 = .5751$

Both skid distance and log weight significantly affect inhaul time. However, log weight is the more significant variable, accounting for 44% of the total variation.

4. Unload (minutes)

$H_0 : \beta_1 = 0$: unload $\neq f$ (W)

$H_a : \beta_1 \neq 0$: unload = f (W)

Unload = 0.674304

+ 0.000317764 (W) $P < 0.05$

$R^2 = .1417$

This is only a moderate evidence that log weight has a significant influence on unload time. It contributes to only 14% of the total variation.

5. Basic Turn Time (minutes)

$H_0 : \beta_1 = \beta_2 = 0$: turn time $\neq f$ (D,W)

$H_a : \beta_1 \neq 0$; and/or $\beta_2 = 0$: turn time = f (D,W)

Basic Turn Time = 1.67364

+ 0.0109705 (D) $P < 0.005$

+ 0.00300920 (W) $P < 0.0005$

$R^2 = .4421$

Skid distance and log weight are significant variables explaining 44% of the total variation. Log weight alone accounts for 29%.

Table 14, summarizes the relative significance of the independent variables with respect to the dependent variables. Independent variables associated with a P-value less than or equal to .01 are categorized to be very significant; a P-value greater than .01 but lesser than, or equal to .05, to be moderately significant; a P-value greater than .05 but lesser than or equal to .10, slightly significant; and a P-value, greater than .10, not significant.

TABLE 14. SUMMARY OF RELATIVE SIGNIFICANCE OF SKID DISTANCE AND LOG WEIGHT TO SKIDDING ELEMENTS

Skidding Element	Crew 1	Crew 2A	Crew 2B
Outhaul	D***	D***	D***
R^2	.92	.36	.33
Load	W***	W*	W**
R^2	.21	.09	.16
Inhaul	D*** W***	D*** W**	D*** W***
R^2	.68	.51	.58
Unload	W***	Wns	W**
R^2	.25	--	.14
Basic Turn Time	D*** W***	D** W**	D*** W***
R^2	.61	.24	.44

*** very significant

** moderately significant

* slightly significant

ns not significant

MODEL ANALYSIS

This analysis was conducted on the regression equation of the basic cycle time for Crew 1 only as it had a predictable regression coefficient of determination (R^2=.61). Model analysis seemed appropriate as the scatter plots of the dependent variables with skid distance appeared to show a possible non-linear relationship (Appendices 5 and 6). An aptness test was conducted on the linear model of inhaul against skid distance. It was found that a linear model is inappropriate only to a fair extent ($.05<P<.10$). The apparent non-linearity may not be attributed to skid distance alone. Log weight could have been correlated with skid distance. However, the correlation between log weight and skid distance was small ($r=.22$). Basically, three kinds of models were examined: the original linear regression model and two non-linear regression models.

Model 1 is a straight linear regression model. Since turn time appears to increase non-linearly with skid distance, a host of curvilinear models may be fitted. The problem is to determine which curvilinear model is to be fitted. It appears that the turn time increases exponentially with skid distance from the scatter plot. Neter and Wasserman (1974) also note that the logarithmic transformation is useful when no particular curvilinear model is suggested by theoretical or apriori considerations, but the scatter plot suggests that a logarithmic transformation would linearize the regression relation. This was the basis for Model 2. However, analysis also showed that the error variance of the independent variables to be nonconstant. In order to stabilize the error variance and improve the normality of the independent variables, a square-root transformation was used. This was the basis for Model 3.

Model 1 : $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2$

where: Y = T = basic cycle time in minutes

X_1 = D = skid distance in feet

X_2 = W = log weight in pounds

1.1 T = 6.00898

+ 0.0164593 (D)

$R^2 = .4990$

1.2 T = 1.98758

+ 0.0146771 (D) $P << 0.0005$

+ 0.00251086 (W) $P < 0.0005$

$R^2 = .6139$

In this model, skid distance alone accounts for about 50% of the variation in turn time. Skid distance and log weight explains 61% of the variation.

Model 2 : $\ln Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2$

2.1 Ln T = 1.97688

+ 0.00124025 (D)

$R^2 = .5367$

2.2 Ln T = 1.68735

+ 0.00111193 (D) $P << 0.0005$

+ 0.000180777 (W) $P < 0.0005$

$R^2 = .6496$

$$\therefore T = e^{\beta_0 + \beta_1 D + \beta_2 W}$$

This model implies that turn time increases exponentially with increasing skid distance and log weights. Both these variables account for 65% of the total variation in the logarithm of turn time.

Model 3 : $\text{Ln } Y = \beta_0 + \beta_1 X_1^{\frac{1}{2}} + \beta_2 X_2^{\frac{1}{2}}$

3.1 Ln T = 1.48210

+ 0.0511691 ($D^{\frac{1}{2}}$)

$R^2 = .5468$

3.2 Ln T = 0.834824

+ 0.0461147 ($D^{\frac{1}{2}}$) $P << 0.0005$

+ 0.0173759 ($W^{\frac{1}{2}}$) $P << 0.0005$

$R^2 = .6789$

$$\therefore T = e^{\beta_0 + \beta_1 D^{\frac{1}{2}} + \beta_2 W^{\frac{1}{2}}}$$

This model implies that turn time is related exponentially to the square root of the skid distance and log weight. These variables in these form account for about 68% of the total variation in the logarithm of turn time.

Table 15 summarizes the three kinds of models.

TABLE 15. SUMMARY OF REGRESSION MODELS

Model	R^2
1. $T = \beta_0 + \beta_1 D + \beta_2 W$	.61
2. $T = e^{\beta_0 + \beta_1 D + \beta_2 W}$	.65
3. $T = e^{\beta_0 + \beta_1 D^{1/2} + \beta_2 W^{1/2}}$	.68

Model 3 is the best model as it does describe the actual relationship between turn time and the independent variables. Residual analyses further support the above relationship (Appendices 8 and 9). Nevertheless, it must be cautioned that the improvement of Model 3 over Model 1 is only seven percent. Model 1 is easier to work with and may be used for prediction without any serious loss in accuracy. The 95-percent confidence interval about the linear regression line is given in Appendix 10. The standard error of the mean basic turn time was 0.62 minutes.

PRODUCTION RATE OF SKIDDING

Using the regression models and the following data, the skidding production rate is estimated (Table 16):

average skid distance = 510 feet (Appendix 11)

weave factor = 1.1 (Appendix 12)

average log weight = 1950 pounds

average percent delay = 37

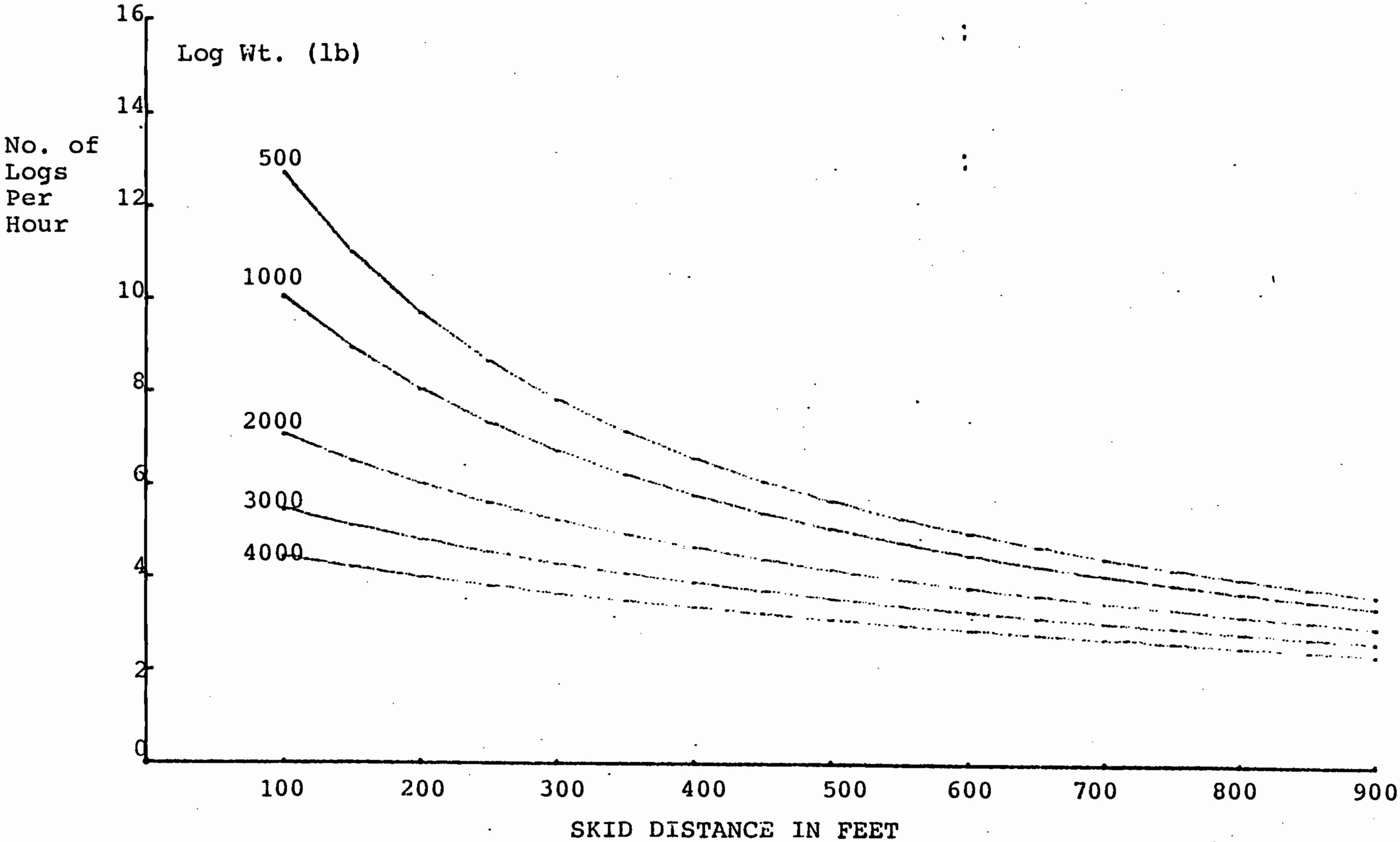
effective hour = 60 (1-.37) = 37.8 min.

TABLE 16. SUMMARY OF PRODUCTION RATES DERIVED FROM REGRESSION MODELS

	Model 1	Model 2	Model 3
Basic Turn Tim in Min.	15.1	14.35	14.8
No. of Logs Per Hour	2.5	2.6	2.55
Volume Per Hour in Ft^3	81	84	83

It may be observed that all three models give similar results for average values of skid distance and log weight. Figure 7 shows the expected basic production rate as deduced from Model 1. Note that this production rate does not take the delays into account. The production rates are not developed for Models 2 and 3, as the exponential relationship remains to be verified. Further, Model 1 is simpler to apply.

FIGURE 7. BASIC PRODUCTION RATE OF SKIDDING



An alternative means of estimating the average production rate is by using the concept of skidding potential:

$$E = \frac{W\ D}{T_W + T_R}$$

$$\frac{E}{D} = \frac{W}{T_w + T_r} = P \text{ kip/hour}$$

where P is the production rate

$\therefore$ the maximum production rate, $P_{max} = \frac{E_b}{D}$

$\therefore$ the net production rate, $P_{net} = \frac{En}{D}$

Hence, given that the skidding potential of a system is known, then the average production rate may be readily estimated for a given skid distance. The average ideal, maximum and net production rates, for an average skid distance of 510 feet (with a weave-factor of 1.1) are presented in Table 17.

TABLE 17. SUMMARY OF ESTIMATED AVERAGE PRODUCTION RATES BASED ON SKIDDING POTENTIAL

	P	P_{max}	P_{net}
Crew 1			
kip/hr	15.5	7.1	4.8
ft^3/hr	258	119	79
Crew 2A			
kip/hr	13.6	7.1	6.4
ft^3/hr	227	119	107
Crew 2B			
kip/hr	14.7	8.0	6.7
ft^3/hr	245	133	112

Considering Crew 1, the net production rate (79 ft^3/hr) is an underestimation as compared to those given by the regression models but the deviation does not appear to be large. However, note that the net production rate of the two-skid team is about 1.4 times that of Crew 1.

The skidding cost per hour is deduced in Appendix 11 for Crew 1. The average cost distribution of a typical peat swamp logging operation is shown in Appendix 12.

SYSTEM BALANCE

The average production rates for all the components by Crew 1 are summarized in Tables 18 and 19. The skidding component has the least production rate (Appendix 15).

TABLE 18. SYSTEM BALANCE FOR CREW 1

Component	Production Rate					
	Average No. of Logs Per			Average Volume in Ft^3 Per		
	Hour	Day	Week	Hour	Day	Week
Felling	30	120	240	986	3944	7888
Bucking	15	60	240	493	1972	7888
Skidding	2.5	20	140	82	657	4601
Debarking	4	30	210	114	855	5985
Loading	21	30	210	597	855	5985

TABLE 19. SYSTEM BALANCE FOR CREW 1

BY PERSON-UNIT TIME

Component	Production Rate					
	Average No. of Logs Per Person			Volume in Ft^3 Per Person		
	Hour	Day	Week	Hour	Day	Week
Felling	15	60	120	493	1972	3944
Bucking	15	60	240	493	1972	7888
Skidding	0.42	3.33	23	14	110	756
Debarking	4	30	10	131	986	6902
Loading	2.1	3	21	69	99	690

DELAY ANALYSIS

The skidding component being the primary focus of interest, a detailed analysis of its delay elements was conducted. Tables 20, 21 and 22 summarize the proportion of delays occurring in each work element for Crews 1, 2A and 2B respectively.

TABLE 20. SUMMARY OF DELAYS OCCURRING IN THE VARIOUS ELEMENTS OF THE SKIDDING CYCLE

- CREW 1 (78 cycles) -

Skidding Element	Total Time in Minutes	Average Time Per Cycle in Minutes	Percentage
Outhaul	66.98	0.86	10
Load	298.59	3.83	46
Sling	23.81	0.31	4
Inhaul	208.13	2.67	32
Unload	6.68	0.09	1
Other	49.75	0.64	8
Total	653.90	8.38	101*

*Rounding error

TABLE 21. SUMMARY OF DELAYS OCCURRING IN THE VARIOUS ELEMENTS OF THE SKIDDING CYCLE

- CREW 2A (41 cycles) -

Skidding Element	Total Time in Minutes	Average Time Per Cycle in Minutes	Percentage
Outhaul	20.40	0.50	26
Load	27.05	0.66	34
Sling	--	--	--
Inhaul	20.25	0.49	25
Unload	--	--	--
Other	11.85	0.29	15
Total	79.55	1.94	100

TABLE 22. SUMMARY OF DELAYS OCCURRING IN THE VARIOUS ELEMENTS OF THE SKIDDING CYCLE

- CREW 2B (52 cycles) -

Skidding Element	Total Time in Minutes	Average Time Per Cycle in Minutes	Percentage
Outhaul	56.13	1.08	27
Load	83.62	1.61	40
Sling	--	--	--
Inhaul	59.48	1.14	29
Unload	--	--	--
Other	7.42	0.14	4
Total	206.65	3.97	100

The largest proportion of delays occurred in the loading element for all the crews, 34-46% of the total delays (Appendix 16). The inhaul element had the second largest proportion of delays, 25-32%. The least amount of delays occurred in the sling and unload work elements. Crew 1 had the largest delay time per cycle compared to Crews 2A and 2B.

The kinds of delay encountered by each crew would shed light on the apparent differences between the crews. These are summarized in Tables 23, 24 and 25.

TABLE 23. SUMMARY OF SKIDDING DELAYS

BY CATEGORY - CREW 1

Delays	Frequency No.	Total Time in Minutes	Average Time in Minutes	Percentage
Operational	160	289.56		46
Cutting pole stumps	35	66.09	1.89	10
Clearing brush	5	18.87	3.77	3
Repositioning crosspieces	27	44.00	1.63	7
Collecting poles and peavies	5	10.99	2.20	2
Waiting for crew	24	67.32	2.81	10
Lubrication	43	48.28	1.12	7
Stopping at curves	10	15.48	1.55	2
Sling adjustments	5	2.55	0.51	0.4
Sled adjustments	6	24.98	4.16	4
Personal	28	49.75		8
Others	23	89.63		14
Obstacles on tracks	1	2.78	1.78	0.4
Sled slips off tracks	5	50.43	10.09	8
Tree felling	7	1.38	0.20	0.2
Skid trail construction	7	29.33	4.19	4
Slips	3	5.71	1.90	0.9
Unexplained Delays	246	216	0.88	33
Total	457	653.94		101*
Average No. of Delays/Cycle	5.9			

*Rounding error

TABLE 24. SUMMARY OF SKIDDING DELAYS

BY CATEGORY - CREW 2A

Delays	Frequency No.	Total Time in Minutes	Average Time in Minutes	Percentage
Operational	46	45.38		57
Cutting pole stumps	3	4.88	1.63	6
Repositioning cross-pieces	17	11.63	0.68	15
Waiting for crew	2	1.87	0.94	2
Lubrication	1	1.62	1.62	2
Stopping for curves	4	3.13	0.78	4
Sled adjustments	1	1.75	1.75	2
Removing poles	1	1.08	1.08	1
Helping other crew	1	7.22	7.22	9
Queue	16	12.20	0.76	15
Personal	9	11.85	1.32	15
Others	6	22.32		19
Obstacles on tracks	3	6.50	2.17	8
Sled slips off the tracks	1	1.85	1.85	2
Tree felling	2	6.97	3.48	9
Unexplained delays	12	7.00	0.58	9
Total	73	79.55		100
Average No. of Delays/Cycle	1.8			

TABLE 25. SUMMARY OF SKIDDING DELAYS BY CATEGORY - CREW 2B

Delays	Frequency No.	Total Time in Minutes	Average Time in Minutes	Percentage
Operational	84	108.58		53
Cutting pole stumps	3	4.43	1.48	2
Repositioning crosspieces	40	28.63	0.72	14
Collecting poles and peavies	2	1.62	0.81	0.8
Waiting for crew	7	18.47	2.64	9
Lubrication	1	0.85	0.85	0.4
Stopping at curves	4	2.90	0.73	1
Clearing	1	7.32	7.32	3.5
Sled Adjustments	5	5.47	1.09	3
Removing poles	1	0.67	0.67	0.3
Helping other crew	2	16.90	8.45	8
Queue	18	21.32	1.18	10
Personal	5	7.42	1.48	4
Others	18	30.68		14
Obstacles on tracks	5	2.23	0.45	1
Sled slips off tracks	10	11.25	1.12	5
Tree felling	3	17.20	5.73	8
Unexplained Delays	45	59.65	1.33	29
Total	152	206.65		100
Average No. of Delays/ Cycles	2.9			

The kinds of delays were similar in all the three crews except that the two-skid team crews had two unique delay elements, namely, 'queuing' and 'aiding the other crew.' Queuing would mean that one crew had to wait for the other crew to unload or load or begin moving first, before they could proceed. In terms of frequency, operational delays accounted for 35, 72 and 55 percent for Crews 1, 2A and 2B, respectively. For Crew 1, 'cutting pole stumps', repositioning crosspieces, 'waiting for crew' and 'lubrication' were the major operational delays both in frequency and time. For Crew 2A, 'repositioning crosspieces' and 'queuing' were the major ones. In the case of Crew 2B, besides 'repositioning crosspieces' and 'queuing', 'waiting for crew' was also a major operational delay at least in time. The skidding elements in which these major operational delays occur for the three crews are given in Table 26.

TABLE 26. MAJOR OPERATIONAL DELAYS

AND THE AREAS OF OCCURRENCE

Delay Time in Minutes

Skidding Element		Cutting Pole Stumps	Repositioning Crosspieces	Waiting for Crew	Lubri-cation	Queuing
	Crew 1		19.82			
Outhaul	Crew 2A		2.37			3.45
	Crew 2B					1.12
	Crew 1	66.09	7.65	67.32	15.82	
Load	Crew 2A		6.85			2.33
	Crew 2B		21.18	18.47		3.02
	Crew 1					
Sling	Crew 2A					
	Crew 2B					
	Crew 1		16.53		32.46	
Inhaul	Crew 2A		2.41			6.42
	Crew 2B		7.45			17.18
	Crew 1					
Unload	Crew 2A					
	Crew 2B					

'Cutting pole stumps' and 'waiting for crew' had invariably occurred in the load element. 'Lubrication' (Crew 1) occurred in both the load element (33%) and inhaul element (67%). 'Repositioning crosspieces' had occurred in outhaul, load and inhaul elements. For Crew 1, this delay accounted for 45%, 17% and 38% in outhaul, load and inhaul elements respectively. For Crew 2A, the distribution was 20%, 59% and 21% respectively. For Crew 2B, this delay occurred only in the load and inhaul elements, 74% and 26%, respectively. On an average, the number of operational delays per cycle were 2.1 (3.8 minutes), 1.1 (1.1 minutes) and 1.6 (2.1 minutes), for Crews 1,2A and 2B respectively.

Unexplained delays accounted for about a third of total delay time in Crews 1 and 2B. Overall, the average number of delays per cycle were 6, 2 and 3 for Crews 1, 2A and 2B respectively.

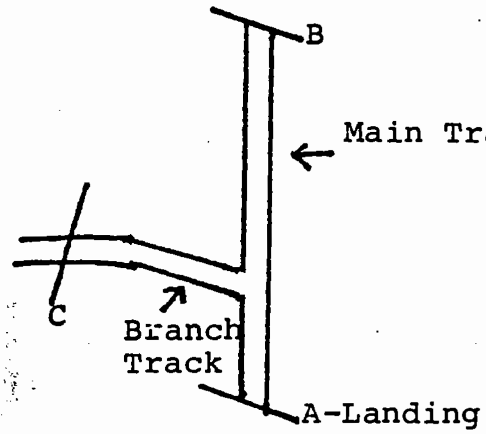
VI. DISCUSSION OF RESULTS

It was generally believed that the inhaul element was the most time-consuming activity in the skidding cycle of this manual system. Though this may be true for very long skid distances, on the average, the loading element is the largest work element. Loading is comprised of several sub-elements: positioning and securing the sled; laying out poles inclined on to the sled; getting poles and peavies; wedging, pushing and rolling the log; 'fighting' against hang-ups and reorienting the log once it is on the sled. All these activities entail movements and pauses, which contribute to the long loading period. The loading activity is a function of log size and crew aggressiveness. Log weight is a significant variable. It is very significant for Crew 1 but only slightly or moderately significant for the two-skid team crews. This difference may be attributed to crew aggressiveness and crew work habits. To begin with, Crews 2A and 2B were more aggressive than Crew 1 and that reduced the effect of log size on loading time. Added to this, whenever a very large size log was to be loaded, the other team would aid in the loading activity. Therefore, large log sizes do not necessarily imply longer loading times. The situation is different for a one-skid team crew. Only six men are available to contend with any log size that they may encounter. Hence, a heavier log will significantly increase their loading time.

The loading element, being the largest in the skidding cycle and also being independent of skid distance, can nullify the effect of skid distance on basic cycle time, especially when the distances are short. The coefficient of determination of the basic time with respect to skid distance was .61; the R^2 value for 'load-free' basic time with respect to skid distance was .74.

Inhaul, is the second most important work-element. Skid distance is the most important variable influencing inhaul time, followed by log weight. Inhaul increases exponentially with skid distance. Unlike mechanical energy, muscle energy cannot be sustained at a high level for long periods. The power to drag the loaded sled can decrease sharply with long skid distances which probably explains the exponential relationship. This was true for only Crew 1. Crews 2A and 2B, though they had increasing inhaul times with increasing distance, did not exhibit a similar relationship. This might be due to their aggressiveness and would require a greater skid distance to elicit a similar effect. Nevertheless, the variation in inhaul times with skid distance must be recognized. It is not unusual to observe the inhaul time for a shorter skid distance to be greater than that for a longer skid distance given the same log size. Two main reasons can be adduced to explain this variation. First, crew performance itself can be very variable from cycle to cycle: muscle energy cannot be expended consistently for very turn. Second, if the branch skid track constitutes a greater portion of the skid distance, a longer inhaul time may be expected (Figure 8).

FIGURE 8. EFFECT OF BRANCH AND MAIN SKID TRACKS ON INHAUL TIMES



Even if the distance CA<BA, inhaul time on CA can be greater than that on BA, given same turn size.

CA = branch track + main track
BA = main track

Branch skid tracks are generally constructed to a lower standard than main skid tracks. More delays were observed to occur on the branch tracks than on the main tracks. In the case of Crew 1, nearly 80% of the delay time in inhaul occurred on the branch skid tracks.

Log weight was the next significant variable in this element. However, its ability to explain the variation in inhaul time was low. Variation in crew performance from cycle to cycle is the primary reason. Contrary to expectations, inhaul times for some cycles that had lighter logs were greater than some that had heavier logs for the same skid distance. Variability in log size was not large enough to overcome or counteract fully, the effect of crew variability from cycle to cycle, except perhaps in the case of Crew 2B. But Crew 2A was working in the same logging block as Crew 2B and should have had similar results. The apparent reason seems to be that Crew 2A had been skidding relatively lighter logs than Crew 2B and the effect of log weight was not very evident.

It was for the same reason (lighter logs) that log weight was not significant in the unloading element for Crew 2A. Crews 1 and 2B were skidding heavier logs and log weight was found to be significant in unloading. However, the low predictability value by log weight alone points again to variability in crew performance. The unload element accounted for 5-8% of the total cycle time.

The sling element accounted for 3-4%. Being independent of any physical variables, it is expected to remain constant from crew to crew.

Outhaul, with an average time of 2-3 minutes per cycle, is strongly influenced by skid distance. Its predictability value is high for Crew 1 but low (<40%) for the two-skid team crews. A wide range of skid distance is necessary to elicit a good correlation with outhaul time. Crew 1 had a range of 773 feet; Crews 2A and 2B, 614 and 596 feet, respectively. The wide range appears necessary to overcome performance variability inherent in the system.

Basic turn time ranged from 60 to more than 80 percent of total cycle time for the three crews. Skid distance and log weight significantly influence turn times. However, their ability to explain the variation in cycle time is only important for Crew 1 (R^2 = .61), and less so for Crews 2A (R^2 = .24) and 2B (R^2 = .44). The apparent reason is due to the interaction between two factors: variability in crew performance from cycle to cycle and variation in the independent variables. The range of skid distance (feet) and log weights (pounds) for Crews 1, 2A and 2B were 733, 3220; 614, 2784 and 596, 3345, respectively. Correlation was high between turn time and skid distance for Crew 1 and low for the other two crews. In fact, in a preliminary study the correlation between cycle time and distance was found to be weak over the range of 230-850 feet but improved remarkably over the range of 100-960 feet. There was low correlation between turn time and log weight for Crews 1 and 2A, but relatively higher for Crew 2B. The latter had been skidding logs of a wider range in weight than the other crews. It is certainly crucial to sample a wide range of an independent variable in order to outweigh the variability in crew performance to find a good correlation, given that a relationship exists. Skid distance can be sampled over a wide range in a given logging block. Log weight does not lend itself to be manipulated easily, as tree sizes tend to be uniform in the logging block. A such it could not counteract the variability in crew performance.

Crew performance may be quantified by skidding potential. The concept of skidding potential is simply this: the rate of work done. The coefficient of variation of skidding potential exceeds 30% for all the crews. E varied from 4600-16700, 1900-15500 and 4200-16000 kip. ft/hr for Crews 1, 2A and 2B, respectively. The variation was even greater for the basic (E_b) and net (E_n) skidding potentials. Hence, the rate of work done (power) by each crew was so variable, that it had the tendency to counteract the effect of skid distance and log size. Net skidding potential may be used to compare crew aggressiveness. On the average Crews 2A and 2B were more aggressive than Crew 1. This was indeed apparent in the field. The two-skid team crew members were well-built, more experienced and better organized than Crew 1.

Skidding potential may also be used to characterize a logging system as it provides a common denominator for different systems. A ground-based logging system in the hill forests of Sarawak, using a D6-crawler tractor, has an average skidding potential in the range of 60,000-80,000 kip. ft/hr. By contrast the manual system in the peat swamp forest is a low energy system with an average skidding potential of less than 10,000 kip. ft/hr.

Interestingly, skidding potential is a function of skid distance and log weight, the very two independent variables that significantly influence the skidding cycle. Ahmad (1979) also concluded that skid distance and log size to be significant, in his study in the Alan (*Shorea albida*) Forest. However, instead of log weight, he used log volume in his regression equation, as he measured the logs of the same species (*Shorea albida*). His multiple linear regression model implied that skid distance and log volume explained 68% of the variation in cycle time. In the present study, the multiple linear model (Crew 1) explained 61% of the variation in turn time. The relationship was not strictly, linear, however. Two exponential models of the form ($Y = A e^{f(Xn)}$) were tested and found to be a better alternative in describing the skidding cycle. The 'best' model implies that the basic cycle time varies exponentially with the square root of distance and log weight. This model explained 68% of the total variation in the cycle time. Hence, 32% of the variation is explained by some other variables not measured or included in the model.

Skid distance and log size are basic variables affecting the skidding component, cycle by cycle. Nevertheless, it must be recognized that the skidding component, for any given crew, is set against a background of conditions. These conditions though, are usually independent of skidding cycle, their influence on the overall skidding activity can be quite substantial.

One such condition is the alignment of the skid track. It does influence the inhaul time. The more curves it has, the larger the inhaul time. The frequency of delays due to loss in momentum also increases. This effect may be accentuated by another factor: the quality of track construction. A poorly constructed track is associated with one or more of the following characteristics:

(i) frequent displacement of crosspieces from the notches during the inhaul and outhaul elements, thus causing delays;

(ii) brush in between crosspieces that act as obstacles;

(iii) crosspieces not lubricated;

(iv) unstable track due to non-uniform stringers or uneven ground surface, that causes it to slope at some sections.

Such a track only makes it difficult or time-consuming in skidding. When a small size log is skidded, these factors do not appear to be conspicuous. The problem arises with large size logs. Once the momentum is reduced or lost, it takes time to regain it. The end result of such a track is a high frequency of delays. A continuous, unbroken inhaul element has a shorter duration than one that is interspersed with delays, for a given distance and log size. Delays, thus, can exaggerate the effect of skid distance which probably explains the exponential relationship with inhaul time. The quality of skid track, therefore, cannot be overemphasized. For instance, Crew 1 had 83% of the crosspiece delays during inhaul and outhaul compared to Crews 2A and 2B (41% and 26%, respectively). Field observation did show that the skid tracks of the latter crews were superior than those of Crew 1.

Much of the delays are actually a function of crew work habits, work organization and experience, which may collectively be categorized under crew aggressiveness. At this point, the concept of crew aggressiveness has to be explored. It must be recognized that this is a difficult parameter to quantify. However, the attributes of an aggressive crew can be cited to characterize such a crew. An aggressive crew is one that is experienced, efficient, well-organized, and stable (i.e., it has a low crew turn-over rate). It always has a production target in mind. It has fewer delays and higher net skidding potential.

For instance, the crew that clears the brush and obstacle stumps well, has generally fewer delays. This was the case for the two-skid team crew which had four to six men to work on skid track construction. The job was well done compared to Crew 1 which had only two men working on it. Field observation did indicate that the number of men assigned to track construction did influence the quality of track.

The same applies in the case of cutting pole stumps which invariably occurred in the load element. Crew 1 had the highest frequency of this delay compared to Crews 2A and 2B. Crew 2B, however, had crosspieces delay as the largest delay element in the loading activity. The reason is that the crew used the crosspieces as levers to load the log, after which they replaced them back on the track.

Another effect of work habits of crews is reflected in delays due to lubrication. Since the crosspieces were not properly lubricated, Crew 1 would stop frequently during the inhaul and brush the sled runners with oil. About 67% of the delay time due to lubrication for Crew 1 occurred in the inhaul. The other 33% was in the load element. The work habit of the two-skid team crew was markedly different such that this delay was relatively minor. Firstly, most of the crosspieces were fairly well lubricated. Secondly, the crew would invariably lubricate the sled runners before the inhaul, almost simultaneously with slinging. This removed the need to lubricate during the inhaul.

One fairly common delay in the loading element, especially with respect to Crew 1, was 'waiting for crew members.' In the outhaul, two men would pull the sled to the point of next turn, while the other four decked the log. Should decking be slow, these two men would wait for the others to join them. In addition the waiting time is lengthened if the skid distance is long. Decking is a function of log size and crew aggressiveness. Although Crews 2A and 2B had this delay, it was not as frequent as that of Crew 1. In addition, poles and peavies may be left at the location of a previous turn which entails their collection, which constitutes a delay.

One distinct, common delay with two-skid crews is queuing. This is one condition, one-skid team crews, like Crew 1 need not face. Logging crews may consist of either one-skid team or two-skid teams. Therefore, it depends whether a one-skid team or a two-skid team crew works in a logging block for the work environment is quite different for each.

In addition, physical factors like stand density, stand volume, tree size, and species composition indirectly affect the skidding cycle. These factors control the density of skid tracks to be constructed and log sizes to be skidded.

But these are constant in any given logging block for any given crew. The primary factor is still crew aggressiveness or efficiency that ultimately influences skidding production.

Crews 2A and 2B had a higher production per hour than that of Crew 1, reflecting the difference in crew aggressiveness. It was mentioned earlier that the concept of skidding potential may be used to deduce the production rate. The net production rate is deduced from skidding potential for Crew 1 was 79 ft^3 per hour. The regression equations gave a value of 83 ft^3 per hour, as an average production rate. The results by the two methods are similar for average skid distance and log size. However, the regression equation is more reliable as it portrays the skidding cycle more accurately.

Comparing the production rate of skidding with that of felling, bucking, debarking and loading shows an interesting system balance for Crew 1. Debarking and loading are dependent upon skidding. For these two activities to proceed at a maximum rate, an inventory of loads need to be built up. Taken on a weekly basis, bucking depends on felling. Skidding is, however, not dependent upon bucking as sufficient inventory is already present. Just as in production rate, the skidding component ranked the lowest in terms of person-hour or person-day productivity. On a system basis, however, taking into account the whole logging crew, the productivity is 50 ft^3 per person-day, confirming the general view on peat swamp logging production rate.

VII. LIMITATIONS OF THE STUDY

The limitations of the results obtained in this study must be fully recognized. Firstly, the results pertain to only two logging crews with their particular work habits in two logging blocks with specific stand conditions. Generalization of the results must therefore be treated with caution. In trying to estimate turn times or production rates, interval estimates are better than point estimates, but they only apply to the range of skid distances and log weights studied. The non-linear regression models only suggest the existence of a possible exponential relationship. They remain to be verified. The study of the two-skid team crew was less exhaustive than that of the single skid team crew. Generalizations on the former have to be less restrictive than for the better.

Secondly, the study did not address the psychological factors which could have an important role in controlling the production rate. The 'Hawthorne Effect' is one factor. The crews, recognizing that they were part of the study, could have been actually working at a pace above their normal. This would have probably reduced the effect of skid distance or log weight on skidding time. The two-skid team crew was studied for a week whereas the single skid team crew was studied for a period of three weeks. The 'Hawthorne Effect' is expected to wear off with time. It could have a greater influence on the performance of the two-skid team crew because of the shorter period of study. It could have been less on the single-skid team crew because of the longer study period.

The other psychological factor is related to production and system balance. A crew might pace itself in such a way to achieve a desired production target. Further, they might skid the logs at a rate in order to keep pace with the adjacent components of bucking, debarking and loading components. Depending upon whether they need to feed or keep up with the adjacent components, skidding potential will vary. Within this framework of influence, skid distance and log weight will have less of an effect on cycle and sub-cycle times. This was indeed found to be the case for a certain range of skid distance. However, these psychological factors were not investigated in this study. Hence, all the more caution is necessary in trying to generalize the results.

VIII. SUGGESTIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Should similar studies be conducted in the future, the following recommendations are made:

1. The study should ensure that the independent variables (e.g., skid distance and log weight) cover a wide range of values within the same logging block and crew.
2. It should have replicate data for some given values of an independent variable (e.g., skid distance) so that the linear regression models can be tested for aptness.
3. The study should distinguish between the skidding times on branch skid tracks and main skid tracks. A rating of the skid tracks is even more desirable. The number of curves (tracks) and its effect has to be quantified.
4. It should be informative to determine the value of skid tracks in terms of the number of logs or volume per unit length.
5. It is important to obtain the system balance of a given operation. It would show how each component is linked with one another and their interdependence. Observations on one component alone will not reveal the total picture.
6. It would be interesting to determine the existence of the psychological factors, namely, the 'Hawthorne Effect' and the production oriented effect within a crew. These factors could indeed be the cause of the variability in skidding performance.

Future research should probably look into Methods Improvement of the System.

1. A more efficient means of loading the log on the sled has to be explored.
2. Alternate methods of harvesting should be considered.

IX. CONCLUSION

The production rate of a typical logging operation in the Mixed Peat Swamp Forest is determined by the skidding component. The skidding cycle is comprised of five basic work elements, namely outhaul, load, sling, inhaul and unload. These were found to account for 17-24, 33-39, 3-6, 30 and 8-10 percent of the basic cycle time, respectively. The basic turn time accounted for 60-88 percent of the total cycle time for all the crews. The average total cycle time ranged between 15-22 minutes per cycle for an average skid distance of 500-570 feet and an average log weight of 1560-1950 pounds.

Skid distance and log weight were found to be significant in influencing the skidding elements. In the case of the single-skid team crew, 61 percent of the variation in basic turn time was explained by these two variables. Besides skid distance and log weight, quality of skid tracks, crew's work habits, work organization and experience also influence skidding time. Two-skid team crews have slightly different work organization than one-skid team crews. An efficient or aggressive crew has a high skidding potential. It has fewer delays, relatively shorter skid times and well organized work assignments. The two-skid team crew had a higher skidding potential than the single-skid team crew. The average skidding potential was 7600-8700 kip ft./hr. However, the skidding potential for any one crew was highly variable.

The variability in skidding potential and crew aggressiveness have the tendency to outweigh the effects of skid distance and log weight on skidding time. The load element and high frequency of delays also have the same effect especially if the skid distances are short. The largest proportion of delays occur in the load element, followed by the inhaul for all the crews. The kinds of delays were unique to the work habits and aggressiveness of each crew.

The system balance obtained for the single skid team crew showed that the skidding component has the least productivity as compared to the other components of felling, bucking, debarking and loading. It thus controls the overall productivity of the logging operation. The average productivity of a typical logging operation in the Mixed Peat Swamp Forest was estimated to be 50 ft^3 per person-day.

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APPENDICES

APPENDIX 1

LIST OF SPECIES AND THEIR WET DENSITIES* (lb./ft^3)

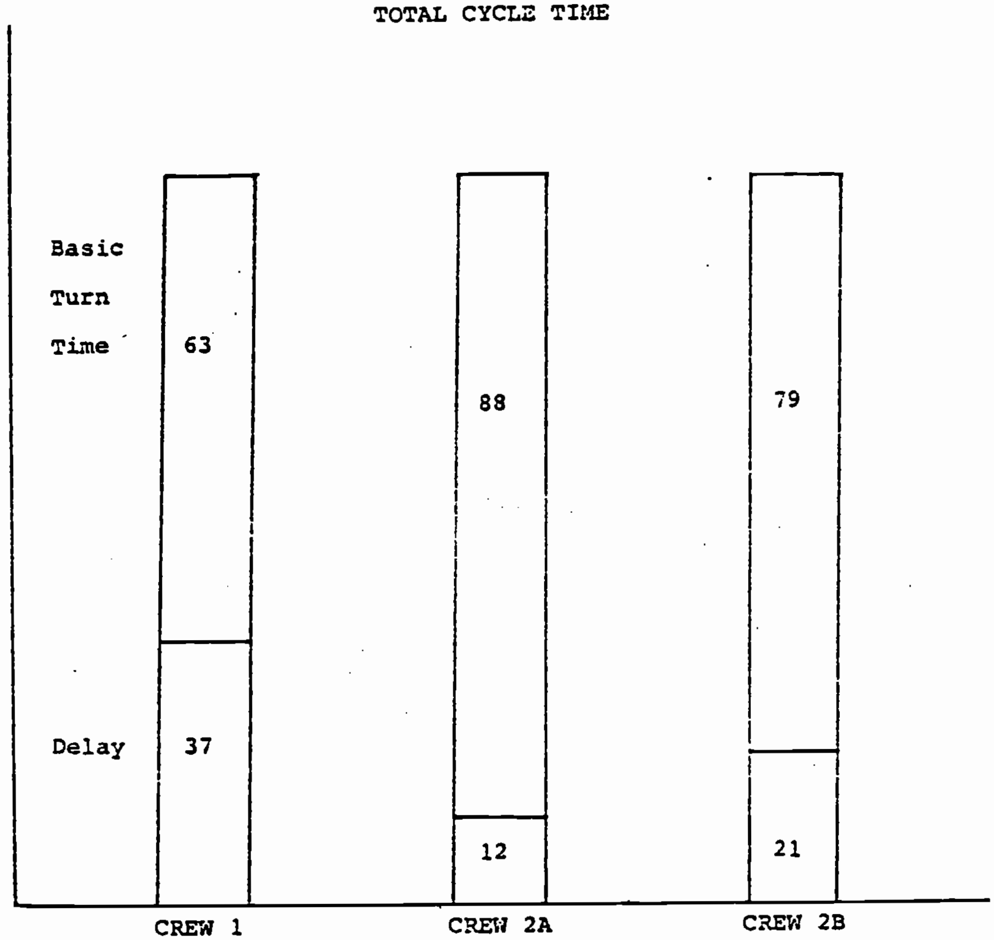
Durian burong *(Durio carinatus)*	64
Geronggang paya *(Cratoxylum arborescens)*	50
Jongkong *(Dactylocladus stenostachys)*	43
Kepayang babi *(Mezzettia leptopoda)*	50
Medang *(Litsea sp.)*	64
Menggiris *(Koompassia malaccensis)*	64
Minggi *(Paratocarpus venenosus)*	44
Nyatoh *(Palaquium sp.)*	60
Ramin *(Gonystylus bancanus)*	61
Sepetir *(Copaifera palustris)*	53

*source: Forest Department Sarawak

APPENDIX 2

BASIC TURN TIME AND DELAY IN PERCENT OF

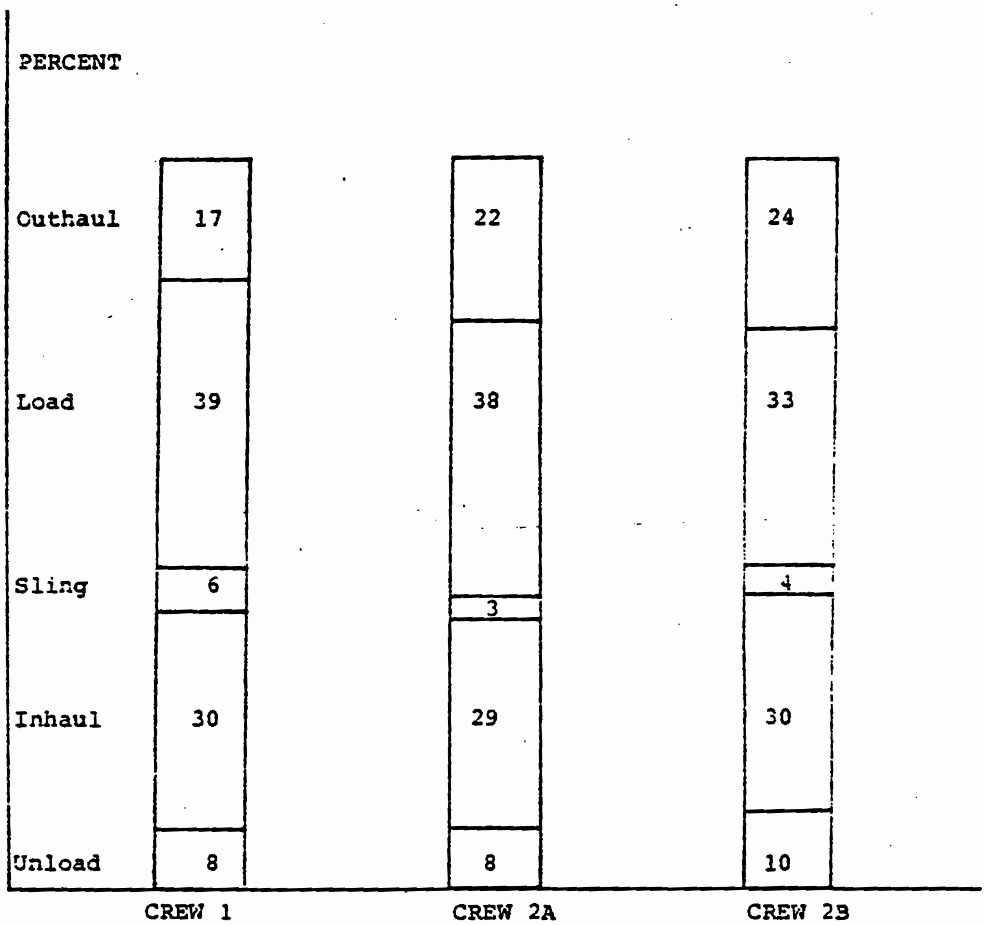
TOTAL CYCLE TIME



APPENDIX 3

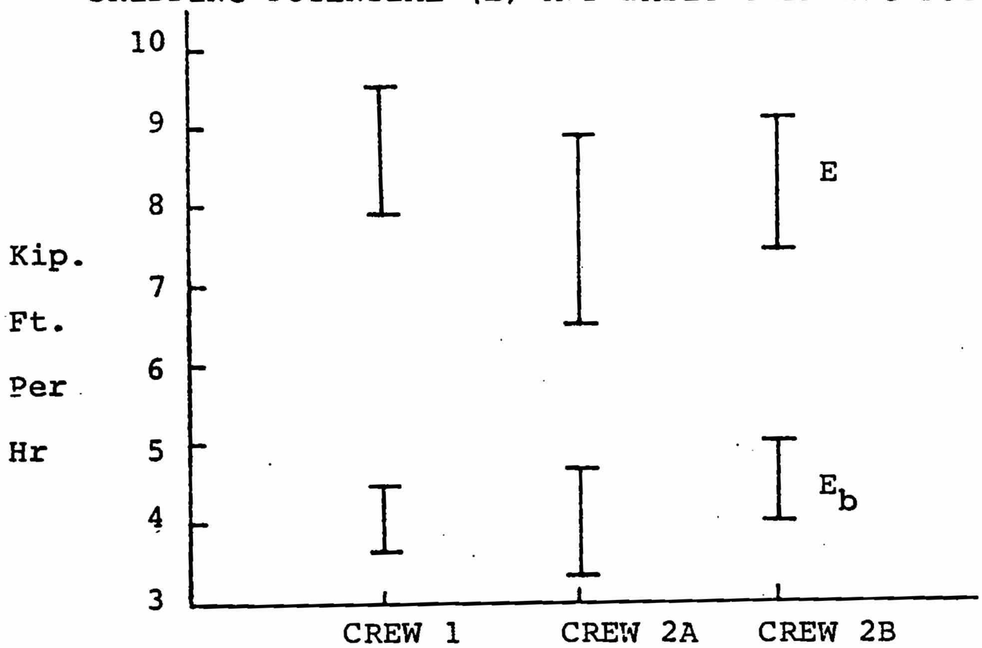
TIME STRUCTURE OF SKIDDING ELEMENTS IN PERCENT OF

BASIC CYCLE TIME

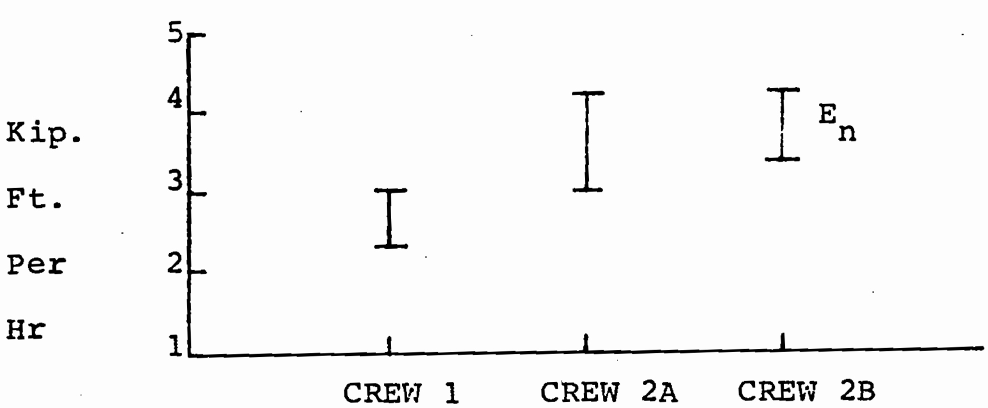


APPENDIX 4

95 PERCENT CONFIDENCE INTERVAL OF AVERAGE SKIDDING POTENTIAL (E) AND BASIC SKIDDING POTENTIAL (E_b)

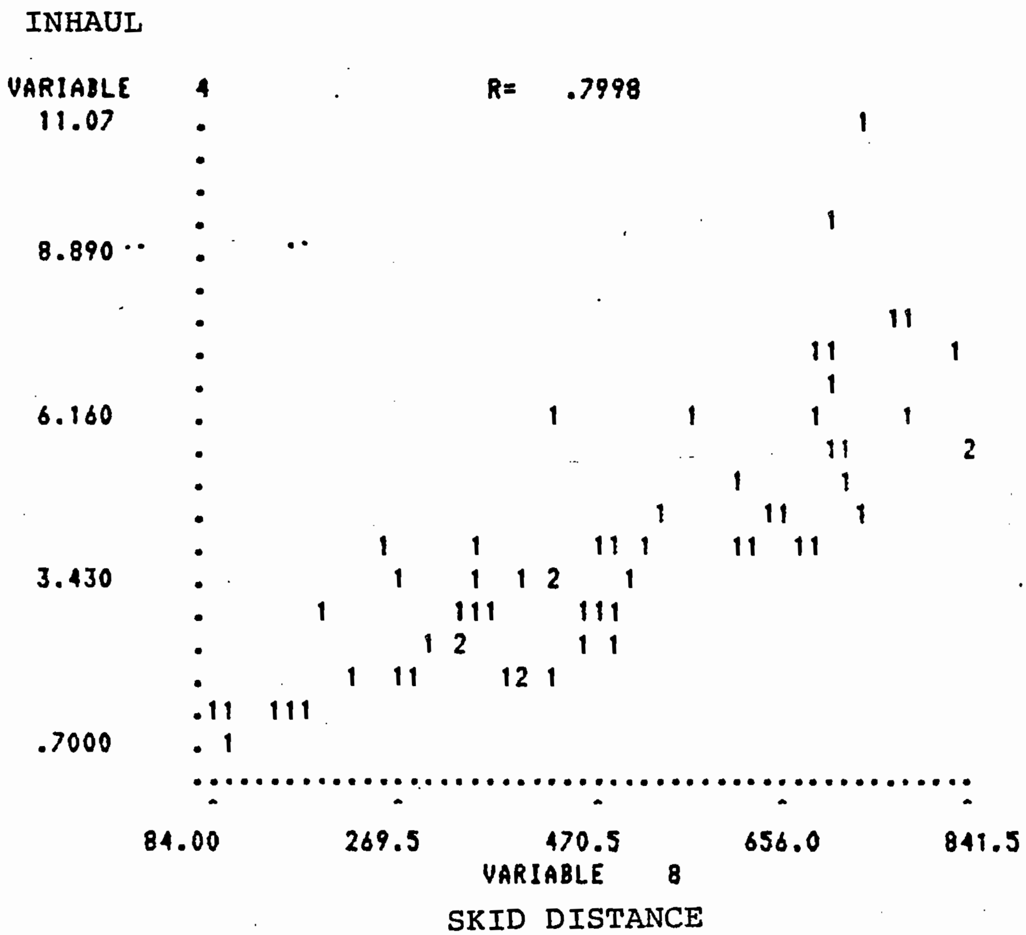


95 PERCENT CONFIDENCE INTERVAL OF AVERAGE NET SKIDDING POTENTIAL (E_n)



APPENDIX 5

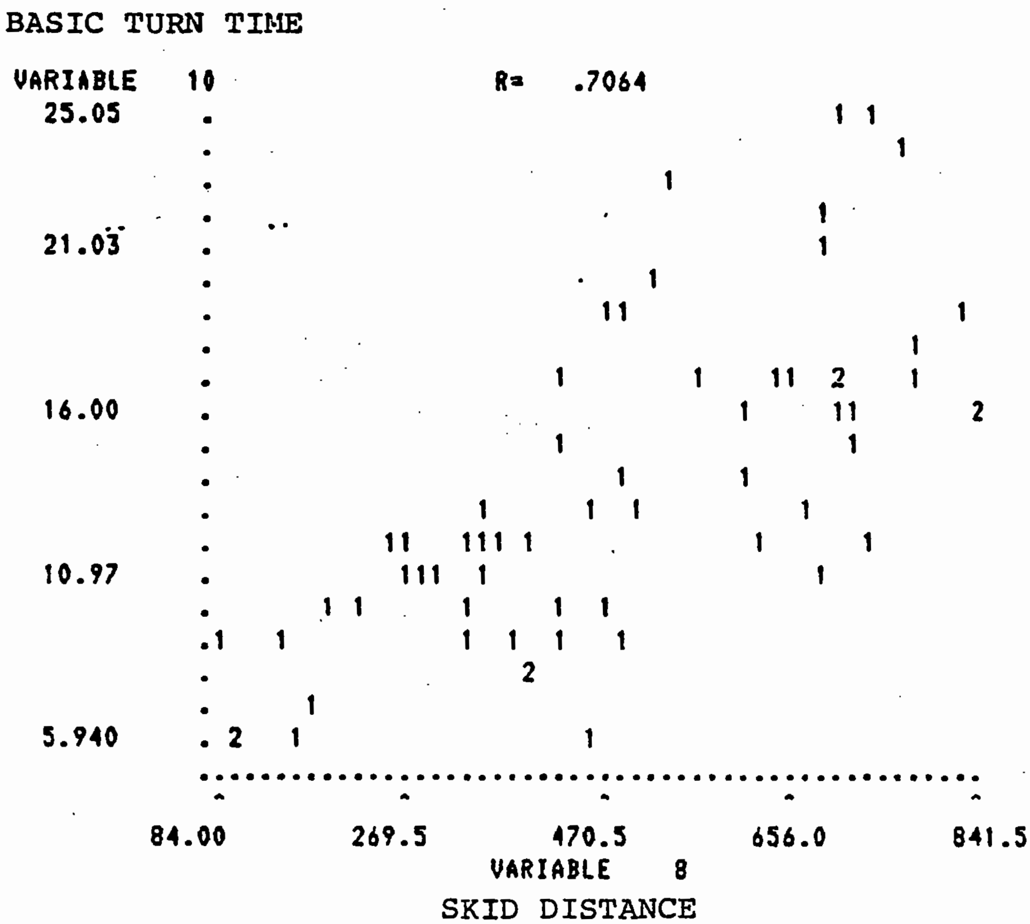
SCATTER-PLOT OF INHAUL AND SKID DISTANCE (CREW 1)



APPENDIX 6

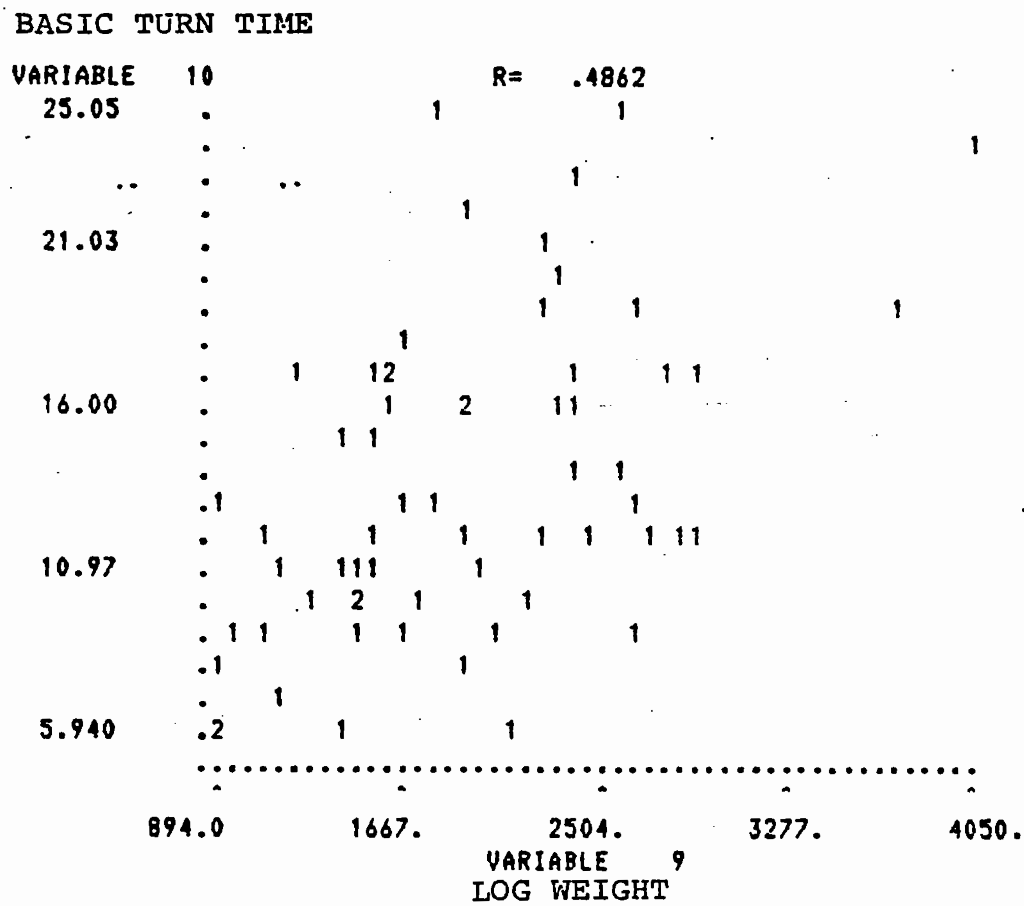
SCATTER-PLOT OF BASIC TURN TIME

AND SKID DISTANCE (CREW 1)



APPENDIX 7

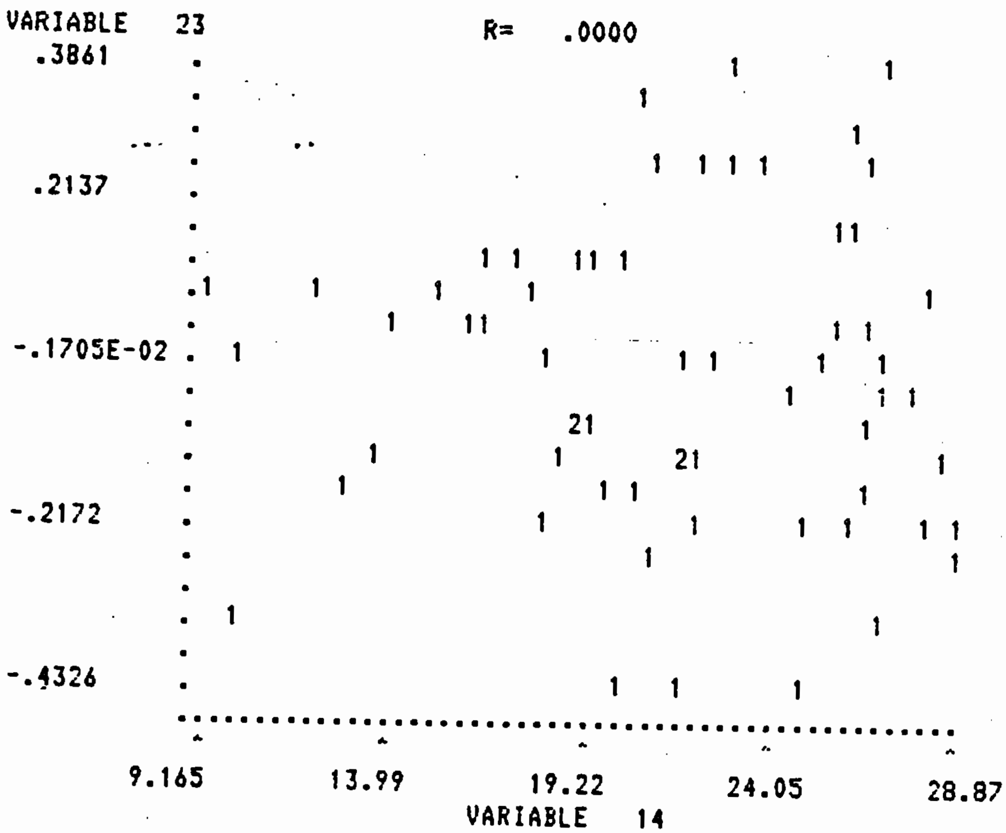
SCATTER-PLOT OF BASIC TURN TIME AND LOG WEIGHT (CREW 1)



APPENDIX 8

SCATTER-PLOT OF THE RESIDUAL AND THE SQUARE ROOT OF SKID DISTANCE (CREW 1)

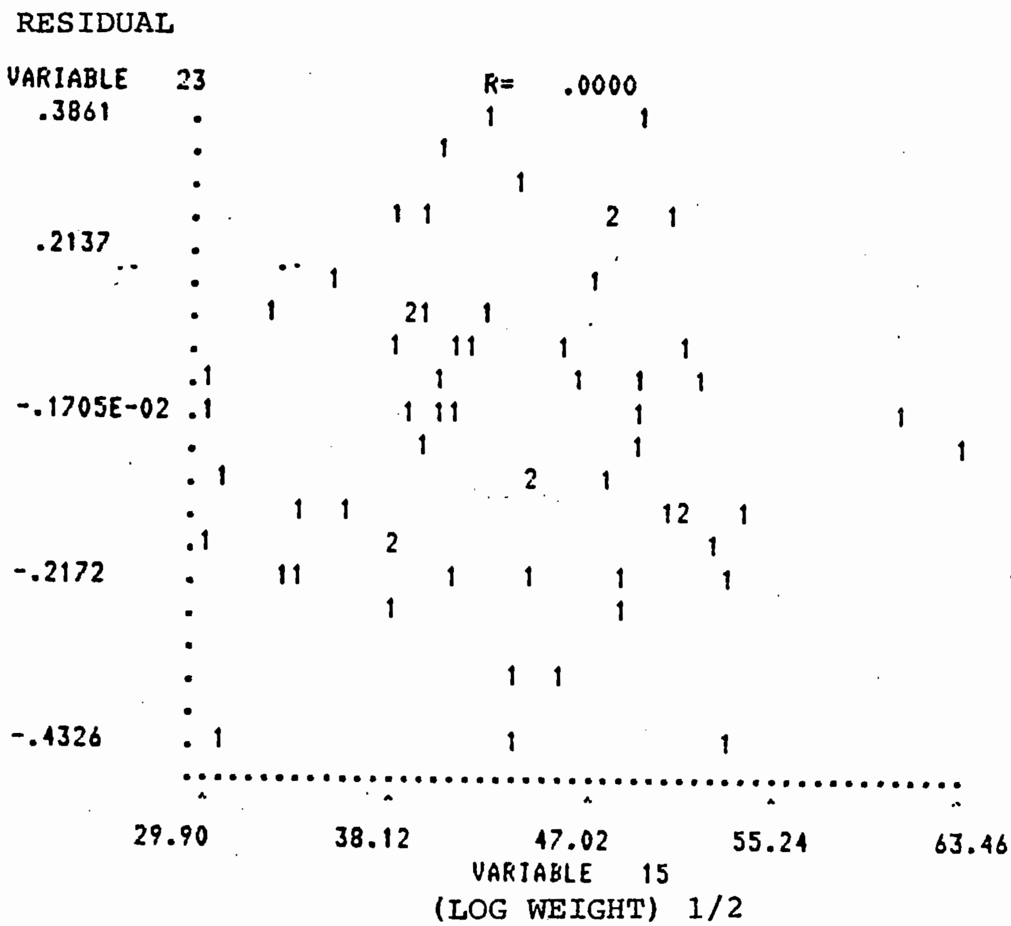
RESIDUAL



(SKID DISTANCE) 1/2

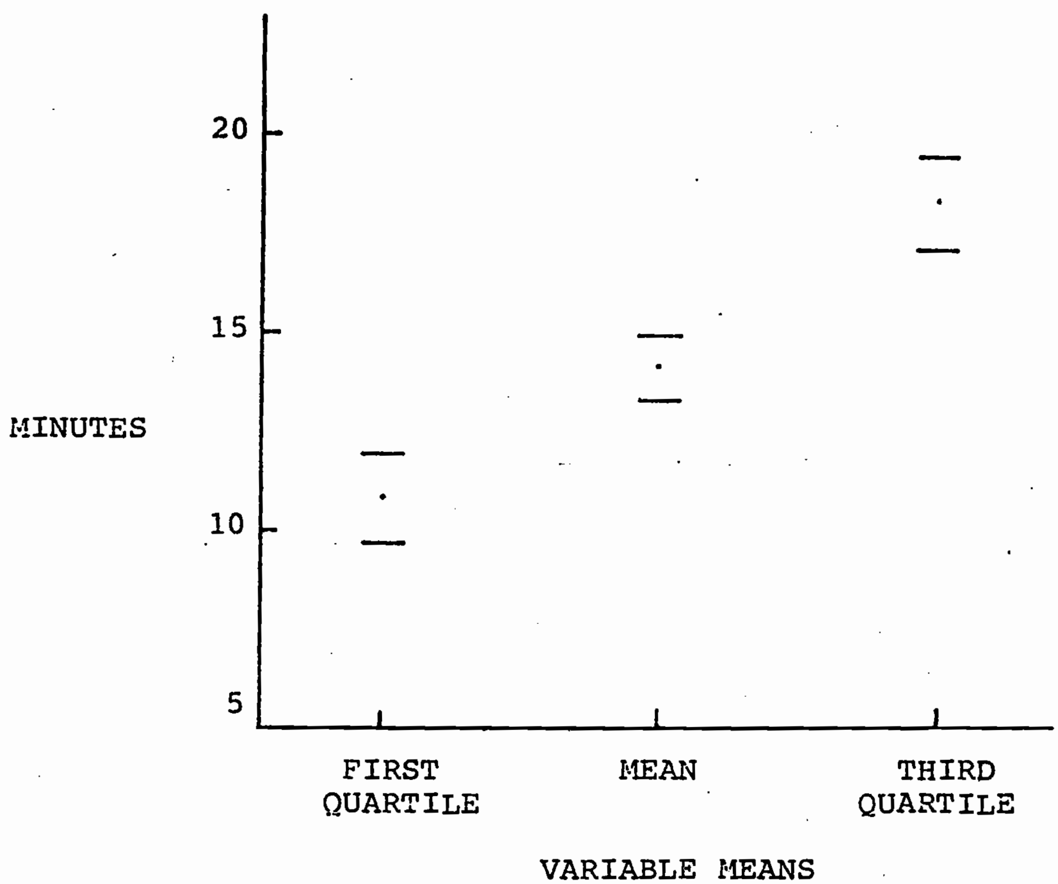
APPENDIX 9

SCATTER-PLOT OF THE RESIDUAL AND THE SQUARE ROOT OF LOG WEIGHT (CREW 1)



APPENDIX 10

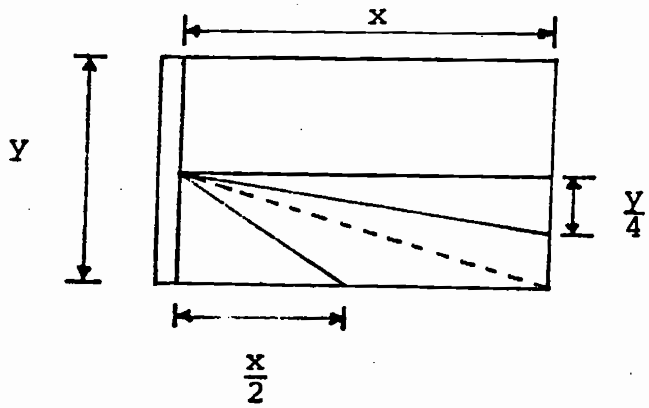
95 PERCENT CONFIDENCE INTERVALS FOR BASIC TURN TIME



APPENDIX 11

AVERAGE SKID DISTANCE

1. One main skid road



x = length of block - length of loading ramp

= 990 - 50 feet

= 940 feet

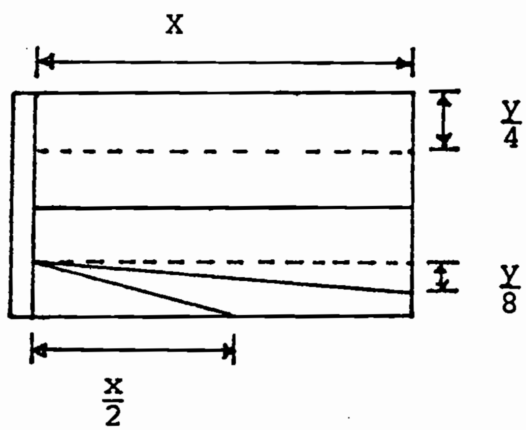
y = width of block

= 660 feet

$$ASD = 1/3\ \left(\left[X(\tfrac{1}{2})^2 + (\tfrac{y}{2})^2 \right]^{\frac{1}{2}} + \left[(X)^2 + (\tfrac{y}{4})^2 \right]^{\frac{1}{2}} \right)$$

= 510 feet

2. Two main skid roads.



$$ASD = 1/3\ \left(\left[\tfrac{x}{2}^2 + (\tfrac{y}{4})^2 \right]^{\frac{1}{2}} + \left[(X)^2 + (\tfrac{y}{8})^2 \right]^{\frac{1}{2}} \right)$$

= 481 feet

APPENDIX 12

DETERMINATION OF WEAVE FACTOR

Actual ASD (feet)	Weave Factor
535	1.05
569	1.12
493	1.00

$$\text{Weave factor} = \frac{\text{Actual average skidding distance}}{\text{Theoretical average skidding distance}}$$

Theoretical average skidding distance = 510 feet

$\therefore$ Average Weave Factor = 1.1

APPENDIX 13

SKIDDING COST PER HOUR

Logging crews are paid on a volume basis. Specifically, they are paid on a volume ton basis. By definition, 1 volume ton = 50 cubic feet. Generally, the word 'volume' is not used and is referred to as just 'ton.'

Rate = M $ 34* per ton (inclusive felling)

= US $ 15 per ton

(M $: Malaysian Ringgit; 1 US $ ≅ M$2.20)

from Table 18:

Skidding production per hour = 82 ft^3

= 1.64 ton

Skidding cost per hour = M$ 35 x 1.64

= M$ 55.76

= US $ 25.35

*1980 cost figure adjusted for 1982

APPENDIX 14

DETAILS OF EXPENSES ON EVERY TON OF LOG (ADJUSTED FOR 1982)

	Type of expenditure	M$	%
1.	Extraction (felling and skidding)	27.00	30
2.	Transportation includes expenses on locomotive operator, rafting and towing expenses by tug boat	8.00	8
3.	Stevedoring	3.50	3
4.	Expenses on rail line	17.00	18
5.	Royalty	13.50	14
6.	Premium and Silviculture cess	17.50	18
7.	Administrative cost	8.00	8
8.	Lubricating oil	2.00	2
	Total expenses	96.50	101*

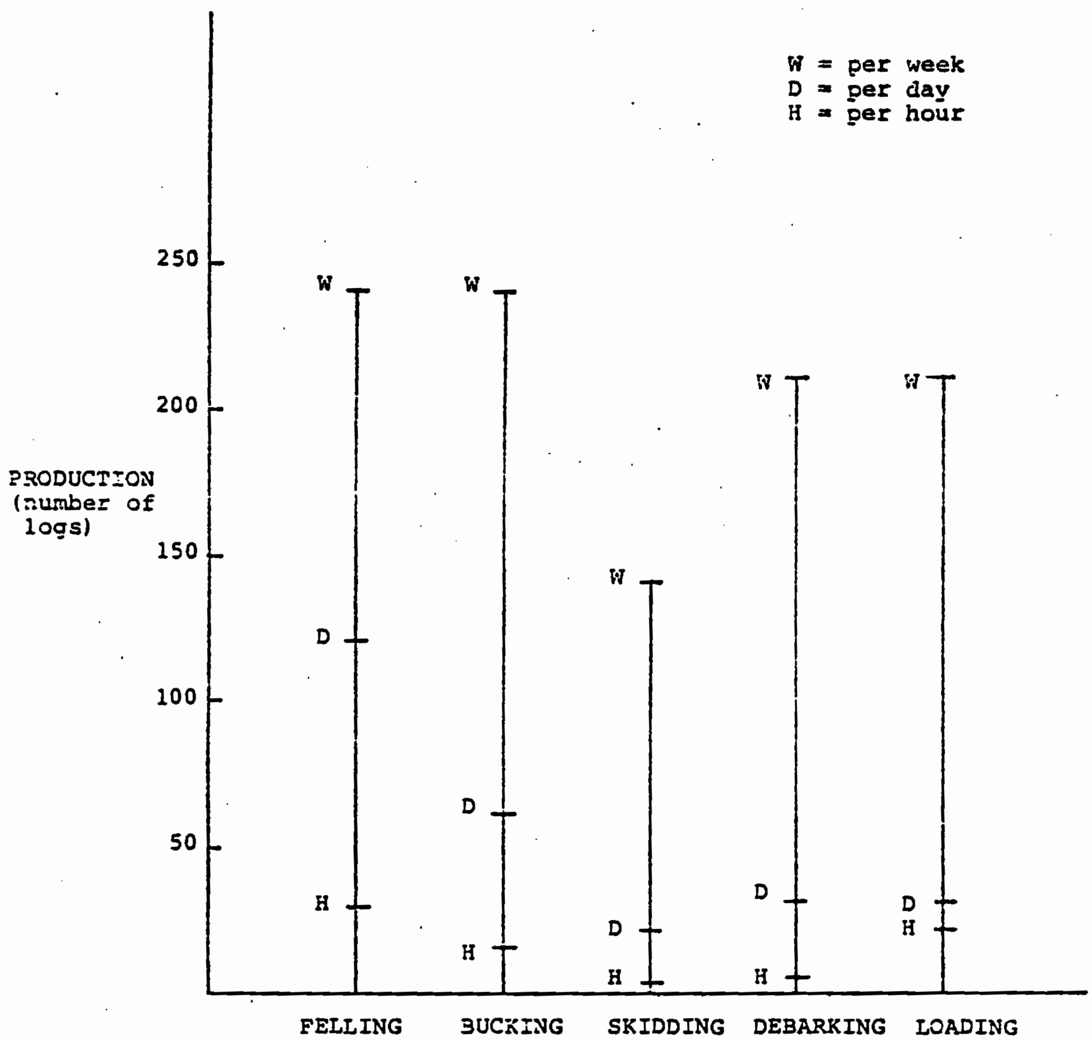
(After, Ahmad, 1979)

*rounding error

M$ 96.50 = US $ 43.86

APPENDIX 15

SYSTEM BALANCE FOR A SINGLE SKID TEAM CREW



APPENDIX 16

PROPORTION OF DELAYS OCCURRING IN THE VARIOUS SKIDDING ELEMENTS IN PERCENT