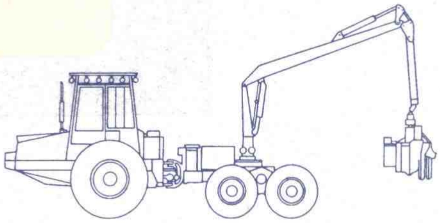
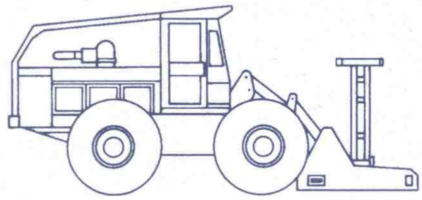
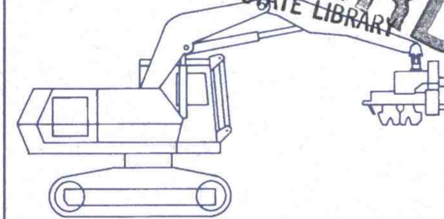

Mechanized Harvesting: A Compendium of Research

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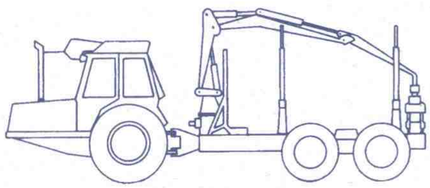
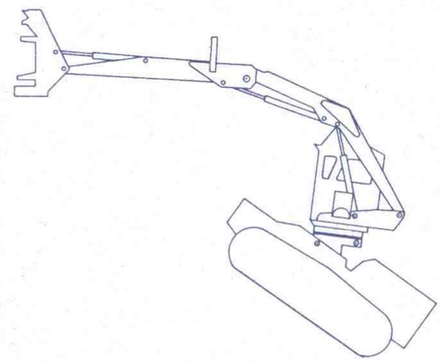
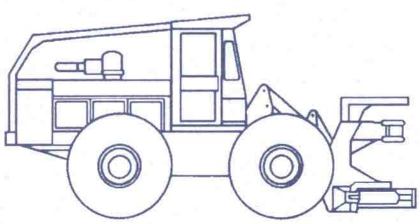
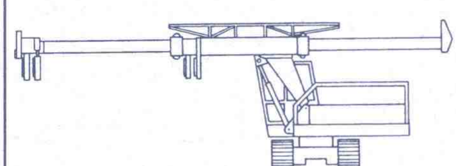
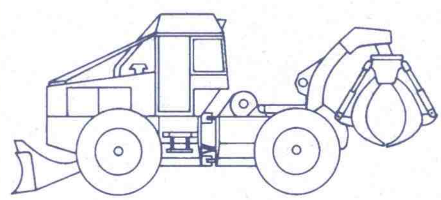

Forest Research Laboratory
College of Forestry
Oregon State University
Corvallis, Oregon
March, 1992

MECHANIZED HARVESTING: A COMPENDIUM OF RESEARCH

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INTRODUCTION

Interest in techniques of mechanized harvesting in the Pacific Northwest region of the United States has increased, because the cost of labor is high and piece sizes are decreasing as second growth harvesting increases. Stands in the 30- to 80-year range of age classes with average diameters of less than 20 inches at breast height are an increasingly important part of the timber supply. This changing stand structure raises the need for research aimed at determining cost-effective and environmentally sound methods for handling small timber.

Greater understanding of the productivity possible with mechanized harvesting equipment under conditions found in the Pacific Northwest will encourage appropriate developments in mechanized harvesting operations. Computer-based analysis of harvesting systems is one method of gaining this understanding. Computer simulation can be a powerful tool for decision making if properly applied, and simulation can expand analysis of field studies to delineate areas where additional information is needed.

The effectiveness of computer simulation, however, is dependent on the quality of the input data. Mechanized harvesting in the Pacific Northwest is relatively new, and many of the conventional aspects of harvesting have not been well documented with studies of production. Krause (1988) evaluated several mechanized harvesting simulation models and found a lack of production data for ground-based harvesting equipment in the Northwest. He attributed this lapse to the short history of mechanized harvesting in the region. No centralized data base, moreover, has yet been compiled for this subject.

Only time and additional field studies can make up for the general lack of information, but the issue of a centralized data base can be addressed with a compendium of studies about the productivity of mechanized harvesting. This centralized and organized data base will indicate areas that require additional information and help harvesting professionals make decisions and run simulations. The purpose of this compendium, therefore, is to supply an organized collection of productivity information about mechanized harvesting, and to identify gaps in the literature that delineate areas where additional research is needed.

FOCUS OF THE COMPENDIUM

This compendium primarily focuses on mechanized harvesting operations that are appropriate to the Pacific Northwest region of the United States. Mechanized harvesting operations, for the purposes of this compendium, are:

> Operations with at least one single or multi-function machine for manufacturing (felling, delimbing, bucking or chipping), or operations where trees or logs are placed in bunches prior to primary transport, or operations where primary transportation is able to handle multiple stems.

This compendium also focuses on productivity, operations analysis, equipment performance, and cost factors. Studies of mechanized harvesting performed in other regions of the United States or in other countries are included in the compendium if the terrain and stand conditions are characteristic of conditions found in the Pacific Northwest.

Typical examples of sites with small timber located on terrain suitable for mechanized harvesting can be found on both the East and West sides of the Cascade Range. A common type of small timber found East of the Cascades would be an 85-year-old stand of lodgepole pine with 1,200 to 1,500 trees per acre and an average diameter of 8 to 9 inches at breast height. Stand conditions for thinning operations on the West side are typified by a 40-year-old stand of Douglas-fir and hemlock with 300 to 400 trees per acre and an average diameter of 11 to 13 inches at breast height. Stand conditions on the West side, where appropriate for clearcut operations, are characterized by a stand of 65-year-old Douglas-fir and hemlock with 100 to 200 trees per acre and an average diameter of 16 to 26 inches at breast height.

A compendium of productivity information about cable yarding is already available (Aubuchon, 1982); therefore, conventional productivity information relating to cable yarding will, for the most part, be excluded from this compendium. Productivity information on grapple-yarding operations and on cable-yarding operations in conjunction with another mechanized process, however, is included in this compendium.

OVERVIEW OF LITERATURE

In the Pacific Northwest, harvesting activities rapidly are shifting from old-growth stands to young-growth stands. In Oregon, the average diameter of trees harvested will decline from about 21 inches in the decade 1991-2000 to 17 inches in the decade 2041-2050 (Sessions, 1991). The decline in average diameter of harvested trees, however, is projected to vary by landowner. Average diameter of trees harvested from National Forest land will decline very little from 1991 to 2020, while average diameter from harvests on BLM land will decline from 25 inches in the decade 1991-2000 to 17 inches in the decade 2021-2030. Average diameter from harvests on State land are projected to decline slowly from 20 inches to between 17 and 18 inches from 1991 to 2090, while average diameter from harvests on private land will slowly decline from 17 to 16 inches during the same period. Harvesting costs per unit-volume on these small-diameter forests will be higher than with old-growth forests.

Ground-based Harvesting

Small trees growing on terrain with slopes of less than 30 percent are harvested in the Pacific Northwest in the same manner as they are harvested in the rest of North America. Typical harvesting systems for these areas consist of feller-bunchers used in conjunction with grapple skidders. Processing at the landing varies with markets in the area, and it may include mechanized delimbing and whole-tree chipping (Johnson, 1981).

Machine studies

Clearcutting -- Table 1 shows that ground-based clearcutting of small- and medium-sized timber on gentle terrain has been extensively studied. Hierarchy I of this compendium (Mechanized Harvesting in Clearcuts) includes 146 machine studies that fall within these categories. These studies include 69 in the felling category, 51 in the processing category, 17 in the primary transport category, 8 in the loading category, and 1 in the bunching category.

Table 1, however, shows that as tree size becomes larger and slopes become steeper, the number of ground-based machine studies rapidly decreases. Only 16 machine studies that cover operations on medium and steep slopes with possible combinations of timber size are included in the compendium. Eight of these 16 studies are concerned with felling operations on medium and steep slopes in small and medium timber. The remaining studies fall within the categories of bunching, primary transport, processing, and loading.

The decrease in the number of studies with larger tree size and steeper slopes was expected, because few ground-based machines have been developed that are capable of harvesting larger timber on steeper slopes. The abundance of information about ground-based harvesting of small and medium timber on gentle slopes and the relative lack of information concerning ground-based harvesting of larger timber on steeper slopes, however, suggests that further research efforts should focus on these areas.

Partial cutting -- Table 2 shows trends for ground-based partial cutting that resemble trends for ground-based clearcutting. Hierarchy II of this compendium (Mechanized Harvesting in Partial Cuts) includes 41 studies of machines for small timber on gentle slopes. These studies include 19 in the felling category, 9 in the primary transport category, 5 in the bunching category, 7 in the processing category, and one in the loading category. Only 5 machine studies in the compendium cover operations on steeper slopes or with larger timber. This lack of information also was expected, because few operations now in use incorporate ground-based thinning of large timber on steep terrain. Stands growing on medium and steep slopes represent a significant proportion of conditions in the Pacific Northwest; however, and partial cutting on these steeper slopes also deserves attention.

System studies

Studies of individual machines do not provide a complete picture of mechanized harvesting. A complete understanding of mechanized harvesting also requires studies of harvesting systems. Mechanized harvesting systems must be carefully balanced for all

Table 1. Studies of ground-based machines used in clearcuts

Logging function	Number of studies in compendium that examine clearcuts on sites with: Small timber on: Gentle slope	Small timber on: Medium slope	Small timber on: Steep slope	Medium timber on: Gentle slope	Medium timber on: Medium slope	Medium timber on: Steep slope	Large timber on: Gentle slope	Large timber on: Medium slope	Large timber on: Steep slope
Felling with a									
Feller-buncher	31	1	4	8	2				
Feller-director				5					
Feller-forwarder	5	1		1					
Multifunction harvester	19								
Bunching with a									
Hydraulic grapple loader									
Winch									
Grapple skidder	1								
Small tractor									
Grapple yarder						1			
Primary transport with a									
Grapple skidder	7			2					
Clambunk skidder	5				1				
Forwarder	2								
Grapple yarder									
Loader	1						1	1	
Processing with a									
Grapple processor	12	2							
Stroke-boom delimber	14	1		4					
Stroke-deck delimber	8								
Chain-flail delimber	6								
Portable chipper	5								
Slasher	1			1					
Loading with a									
Hydraulic grapple loader	3			3		1			
Wire rope crane-type loader				1					
Front-end loader				1					
Total number of studies	120	5	4	26	3	2	1	1	

Table 2. Studies of ground-based machines used in partial cuts

Logging function	Number of studies in compendium that examine partial cuts on sites with: Small timber on			Medium timber on			Large timber on		
	Gentle slope	Medium slope	Steep slope	Gentle slope	Medium slope	Steep slope	Gentle slope	Medium slope	Steep slope
Felling with a									
Feller-buncher	10	1	1						
Feller-director									
Feller-forwarder	5								
Multifunction harvester	4								
Bunching with a									
Hydraulic grapple loader									
Winch	2								
Grapple skidder	2								
Small tractor	1								
Grapple yarder									
Primary transport with a									
Grapple skidder	8								
Clambunk skidder		1							
Forwarder	1	1							
Grapple yarder									
Loader									
Processing with a									
Grapple processor	3								
Stroke-boom delimber	4				1				
Stroke-deck delimber									
Chain-flail delimber									
Portable chipper									
Slasher									
Loading with a									
Hydraulic grapple loader	1								
Wire rope crane-type loader									
Front-end loader									
Total number of studies	41	3	1		1				

classes of timber size and slope to reflect factors that affect cycle time, utilization and productivity. System studies provide information concerning interaction with, utilization of, and productivity of machines, and that information is necessary to attain the proper system balance.

Gaps in studies of harvesting systems are difficult to identify, because almost any combination of machinery is possible. It is apparent, however, that system studies offer more complete information, and future studies should focus on the entire harvesting system rather than a single machine in isolation.

Clearcutting -- Hierarchy I includes 18 studies of ground-based systems. These studies include 14 that examined systems of harvesting for small timber on gentle terrain. Studies of the feller-buncher/grapple skidder system were most common (seven), followed by studies of feller-buncher/grapple skidder/portable chipper systems (two). The remainder of the studies of ground-based systems are in the small timber, medium slope category, including one study of a feller-buncher/stroke-deck delimber/portable chipper system and one study of a feller-buncher/grapple skidder/chain-flail delimber system. As with studies of ground-based, individual machines, the number of studies of ground-based systems decreases as slope and timber size increase.

Partial cutting -- Hierarchy II includes 16 studies of ground-based systems. The most common studies of systems in this section of the compendium involve feller-buncher/grapple skidder/chipper systems and feller-buncher/grapple skidder/hydraulic grapple loader systems (five studies each). Hierarchy II also includes abstracts of studies concerned with each of the following systems: Winch/forwarder, multifunction harvester/forwarder, and small grapple skidder/large grapple skidder systems.

Cable-based Harvesting

Cable systems permit harvesting on slopes too steep for ground-based machinery. As with ground-based harvesting costs, cable-yarding costs are sensitive to tree size, especially with conventional yarding using chokers. Another challenge for harvesters of small timber, therefore, is to establish techniques that achieve optimum payload for skyline systems. Approaches for improving the productivity of cable systems in stands with trees of small diameters include mechanizing the felling and bunching, followed by grapple yarding the bunched trees, or bunching the material with a small winch prior to conventional choker yarding. Felling and bunching or prebunching with a small winch, before cable yarding offer the opportunity of handling the material as an aggregate. These systems, therefore, are less labor intensive than conventional choker systems without bunching. Cable-based systems that include a feller-buncher, a grapple yarder with a mobile tailhold, and a processing machine on the landing result in a fully mechanized stump-to-roadside operation.

Clearcutting -- Felling on steep terrain usually is performed manually. Studies of steep-slope feller-bunchers such as the Menzi-Muck, the Kaiser Spyder, and the Timbco, however, have demonstrated the potential for mechanized felling on such slopes. Hierarchy I includes studies of steep-slope feller-bunchers in cable yarding situations, because these feller-bunchers were not observed as part of a cable-based system. This indicates a large gap in the literature: feller-bunchers have not been studied in operation on steep slopes as part of a cable-based harvesting system. Future studies should focus on steep-slope feller-bunchers operating in a cable-yarding system.

Hierarchy I of the compendium includes nine grapple-yarding studies that range from grapple yarding small timber on medium slopes to grapple yarding large timber on steep slopes (Table 3). Grapple yarding has been studied on most of the timber and slope classifications of the Hierarchy I, but only one study examines grapple yarding as part of a system. The only study of a system that included grapple yarding focused on a feller-buncher/grapple yarder system operating in medium size timber on a steep slope. Further research efforts should be directed toward studies of feller-bunchers on steep slopes and grapple yarders that operate as a system. These research efforts should consider subsequent processing steps in a cable-based system of harvesting in relation to the introduction of processors and delimbers. Operations with delimbers and processors located at the landing must cope with problems of limited space on steep terrain and fully utilizing the landing machinery.

Only two abstracts included in the compendium deal with processors and delimbers in a cable-based operation. One of these two studies concerns a swing yarder/stroke-boom delimber/hydraulic grapple loader system, while the other study is a machine study based on observation of a stroke-boom delimber operating at the landing. The compendium also includes only three studies of loaders operating on small cable-landings. The amount of equipment now being used at landings is increasing; therefore, more system studies and studies of individual machines should be performed.

Partial cutting -- Underloading is common during each turn in a cable thinning operation. One approach for achieving optimum payload is to divide the yarding operation into two stages: prebunch and swing. A small mobile winch prebunches logs in the corridor and a stationary yarder swings the bunches to the landing. Hierarchy II of this compendium includes three studies of prebunch-and-swing systems observed operating on medium slopes with small timber.

Conclusion

This compendium reveals that much of the machinery commonly used for mechanized harvesting has been extensively studied. Hierarchy I, for example, includes 30 studies of feller-bunchers on clearcuts of small timber on gentle terrain. About 70 percent of the studies of individual machines and 80 percent of the system studies included in the compendium, in fact, are in the category of small timber on gentle terrain. This is not surprising, because most commercial operations in small timber take place on gentle terrain.

Interest in techniques of mechanized harvesting in the Pacific Northwest has increased, because labor costs are escalating and tree size is decreasing as harvest of second growth increases. The Pacific Northwest faces special harvesting challenges related to physical landscape, decreasing sizes of wood, and increasing costs of labor. The relative lack of research focused on mechanized harvesting on steep terrain indicates an opportunity for future research. As researchers delve into mechanized harvesting, moreover, they should devote greater energy to system studies rather than studies of individual machines. These studies, in turn, will help advance the use of the mechanized

Table 3. Studies of cable-based machines used in clearcuts

Logging function	Number of studies in compendium that examine clearcuts on sites with: Small timber on			Medium timber on			Large timber on		
	Gentle slope	Medium slope	Steep slope	Gentle slope	Medium slope	Steep slope	Gentle slope	Medium slope	Steep slope
Felling with a									
Feller-buncher									
Feller-director									
Feller-forwarder									
Multifunction harvester									
Bunching with a									
Hydraulic grapple loader									
Winch						1			
Grapple skidder									
Small tractor									
Grapple yarder									
Primary transport with a									
Grapple skidder									
Clambunk skidder									
Forwarder									
Grapple yarder		1	1	1	3	2			1
Loader									
Processing with a									
Grapple processor									
Stroke-boom delimber					1	1			
Stroke-deck delimber									
Chain-flail delimber									
Portable chipper									
Slasher									
Loading with a									
Hydraulic grapple loader									1
Wire rope crane-type loader									
Front-end loader					2				
Total number of studies		1	1	1	6	4			2

harvesting equipment in the Pacific Northwest.

LITERATURE CITED

Aubuchon, R.R. 1982. Compendium of Cable Yarding Production Equations. M.F. Paper, Forest Engineering Department, College of Forestry, Oregon State University.

Johnson, L. 1981. Small Tree Handling Systems in the Intermountain Region. *IN* Proceedings: Harvesting Small Timber: Waste Not, Want Not. Forest Products Research Society. Portland, OR. 28-30 April 1981. P-81-32.

Krause, J.A. 1988. Evaluation of Computer-Based Software for Analyzing Northwest Harvest Systems. M.F. Paper, Forest Engineering Department, College of Forestry, Oregon State University.

Sessions, John (Coordinator). 1991. Timber for Oregon's Tomorrow *The 1989 Update.* Forest Research Laboratory, College of Forestry, Oregon State University. pp. 46-48.

Sources of Harvesting Productivity Information

This compendium was compiled on the basis of a search of existing literature that yielded a body of citations with information about harvesting productivity from the following sources:

Universities

Oregon State University
Louisiana State University
Virginia Polytechnic Institute and State University
State University of New York- ESF
University of California, Davis
University of Idaho
University of Washington
University of Georgia
Auburn University
Swedish University of Agricultural Science

Organizations

Logging Industry Research Association (LIRA)
Forest Engineering Research Institute of Canada (FERIC)
Finnish Forest Research Institute
American Society of Agricultural Engineers (ASAE)
Pulp and Paper Research Institute of Canada (PPRIC)
American Pulpwood Association (APA)
USDA Forest Service

Periodicals

Southern Journal of Applied Forestry
Western Journal of Applied Forestry
Northern Journal of Applied Forestry
Forest Industries
Forest Products Journal
Canadian Forest Industries
Canadian Journal of Forest Research
Pulp and Paper, Canada
Australian Forest Industries Journal and Logger
Australian Forest Research
Australian Forestry

HOW TO USE THIS COMPENDIUM

Organization of the Compendium

The compendium is structured as two separate hierarchies with the intent of leading the user through a series of paths. Each path ends with a reference to studies of harvesting productivity under a certain set of site conditions and with a specific type of machine. A definition and typical illustration of each of the machines listed within the functional categories and systems of each pathway is provided in Appendix A.

The first branch of the compendium leads the user into one of two hierarchies distinguished by the type of silvicultural treatment completed with the harvesting operation. Hierarchy I, which begins on page 15, contains information pertaining to mechanized harvesting in clearcuts. Hierarchy II, which begins on page 285, contains information pertaining to mechanized harvesting in partial cuts and thinnings. Organization within Hierarchies I and II is identical.

The first branch within each hierarchy relates to timber size. Here, the user selects a branch in the pathway defined by timber size: small timber (less than 12 inches dbh), medium timber (greater than 12 but less than 20 inches dbh), and large timber (greater than 20 inches dbh).

Within each timber size, the user then selects a branch in the pathway defined by one of three slope categories: gentle slope (less than 20 percent), medium slope (greater than 20 but less than 40 percent), and steep slope (greater than 40 percent). These categories represent the average terrain conditions of each study site.

Within each slope category, the user chooses either ground-based or cable-based harvesting systems. This choice leads the user to a number that corresponds to a section found later in the hierarchy. These numbered sections of the hierarchy branch into studies of individual machines and systems.

Studies of Individual Machines

Productivity information for studies of individual machines is broken into six function-based categories. Within these function-based categories, the user chooses from among several types of individual machines. These function-based categories, their definitions, and a listing of the machinery found within each category are listed below:

Felling -- This category includes all single, dual and multi-function machinery that replaces hand felling:

- Feller-bunchers
- Feller-directors
- Feller-forwarders
- Multi-function harvesters

Bunching -- This category includes all single-function machines that are not included in the felling category and which are used to pile individual whole trees or logs into bunches prior to primary transport:

- Loaders used to bunch wood prior to primary transport
- Grapple skidders used to bunch wood prior to primary transport
- Small tractors used to bunch wood prior to primary transport
- Small winches used to bunch wood prior to primary transport

Primary Transportation -- This category includes all machines used for grapple skidding, forwarding, cable yarding, and shovel logging, but not machines found in the felling category:

- Grapple skidders (rubber-tired, rigid or flexible tracked)
- Clambunk skidders
- Forwarders (prehaulers)
- Any yarder rigged for grapple yarding, or any yarder in a harvesting system which includes another mechanized process in the yarding operation
- Hydraulic grapple loaders ("shovels") used as primary ground skidding machines to systematically swing logs or tree-length material closer to the landing

Secondary Transportation -- This category includes all transportation machinery not included in the preceding categories. This includes any machinery involved with the transport of materials from the landing or roadside to a central processing deck.

Processing -- This category includes all single, dual and multi-function machines that "manufacture" a raw product, except those included in the felling category:

- Grapple processors
- Stroke-boom delimbers
- Stroke-deck delimbers
- Chain-flail delimbers
- Portable chippers
- Slashers

Loading -- This category includes all loading, stacking and sorting machinery (not integral features of machinery in any of the previous categories) used at the landing (or central site) to load material for final transportation to the mill:

- Front-end loaders
- Hydraulic grapple loaders
- Wire rope crane loaders

Each pathway terminates in a box (for an individual machine) that contains a number (or series of numbers) that corresponds with the number of the abstract in this compendium for the citation where the desired information can be found. Reference numbers in Hierarchy I pertain to information on harvesting productivity in clearcuts. Reference numbers in Hierarchy II pertain to information on harvesting productivity in partial cuts.

System Studies

System studies are those studies where several machines within a harvesting system were studied simultaneously. These studies often provide information concerning machine interaction as well as machine productivity.

Information on harvesting productivity in system studies is arranged around individual systems or groups of machinery. The user identifies the desired harvesting system and obtains a number within the system box. This number refers to the corresponding article abstract in either Hierarchy I (Mechanized Harvesting in Clear Cuts) or Hierarchy II (Mechanized Harvesting in Partial Cuts).

Format for Presentation of Information

Each article is presented in a format standardized for this compendium with a reference number that corresponds with the reference numbers on the pathway chart for the relevant Hierarchy. Each abstract includes the following sections:

CITATION: The author(s), date, title, and source of the publication.

MACHINE SYSTEM: Machine make and model with load-carrying capacity, relative working condition, age and modifications.

OPERATOR RATING: A subjective rating by the author(s) of each research study of the operator's ability and an indication of the operator's experience level.

DESCRIPTION OF SYSTEM: Describes the material flow and type of machinery in the harvesting system.

DESCRIPTION OF OPERATION: Describes the silvicultural system and method of performing work.

DESCRIPTION OF SITE: The location, time of year, and terrain characteristics of the study site.

DESCRIPTION OF STAND: Includes the number of trees per acre, average height, average diameter, volume, and species composition.

MATERIAL SIZE DISTRIBUTION AND LANDING INVENTORY: Includes size distributions and describes merchandizing strategies.

PRODUCTION DATA: Selected statistics such as averages, ranges and standard deviations, regression equations, utilization rates, time distributions, and delay information.

OTHER COMMENTS: Comments concerning the study, operation, or machine(s).

If an article lacks information concerning one of the above sections, that section is left blank. Information included in the compendium is presented in the unit of measure used by the original author(s). To convert the original unit of measure into the desired equivalent, refer to Appendix B for a table of conversion factors and instructions.

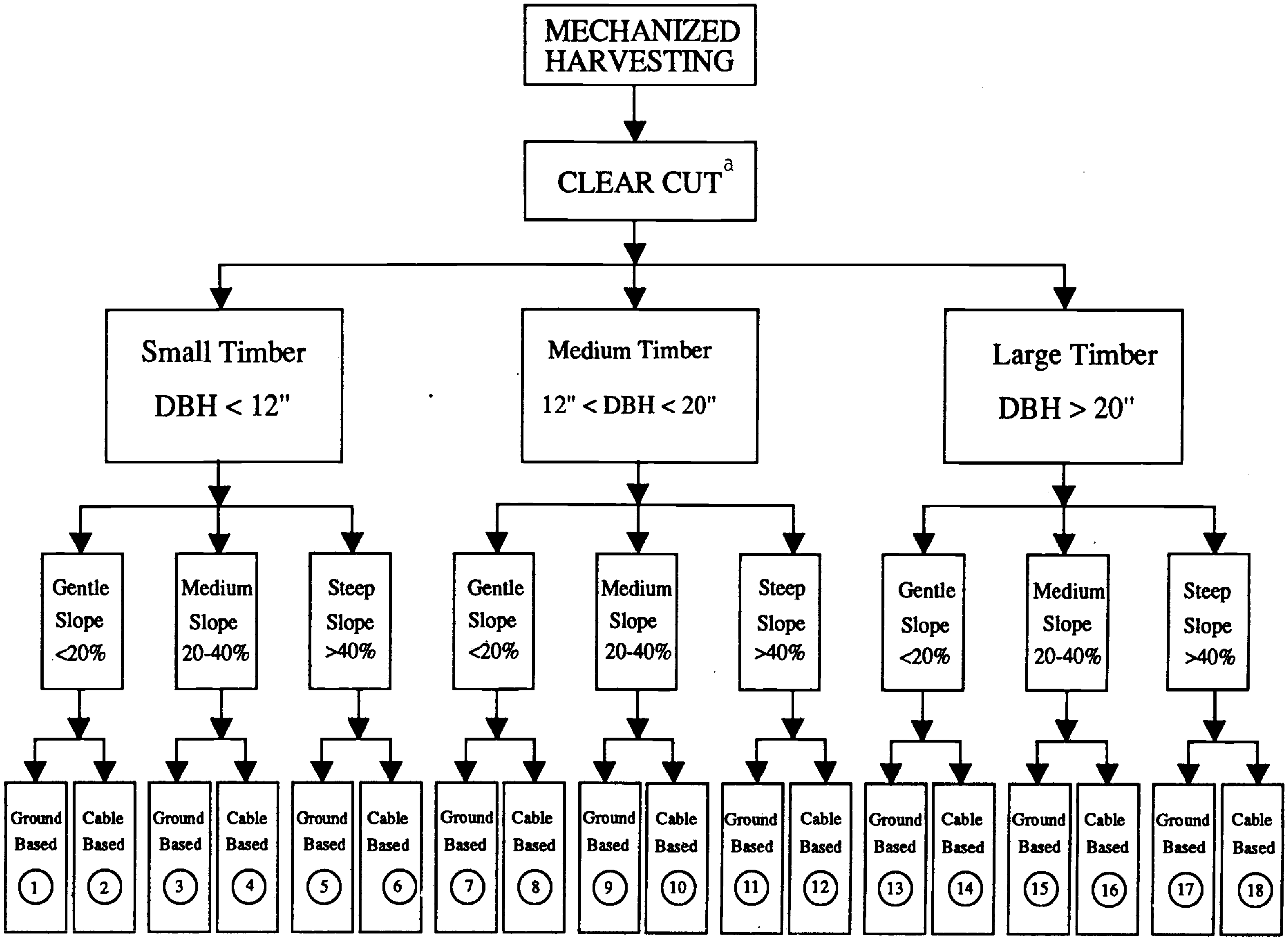
Other Uses of the Compendium

The compendium is flexible, because categories within each Hierarchy can be combined as needed. Suppose, for example, that a user requires information concerning feller-bunchers regardless of silvicultural method, timber size, slope class, type of operation, or type of study. The user could gather this information by noting the numbers within each individual feller-buncher box at the end of the Hierarchy and then locating the corresponding abstracts.

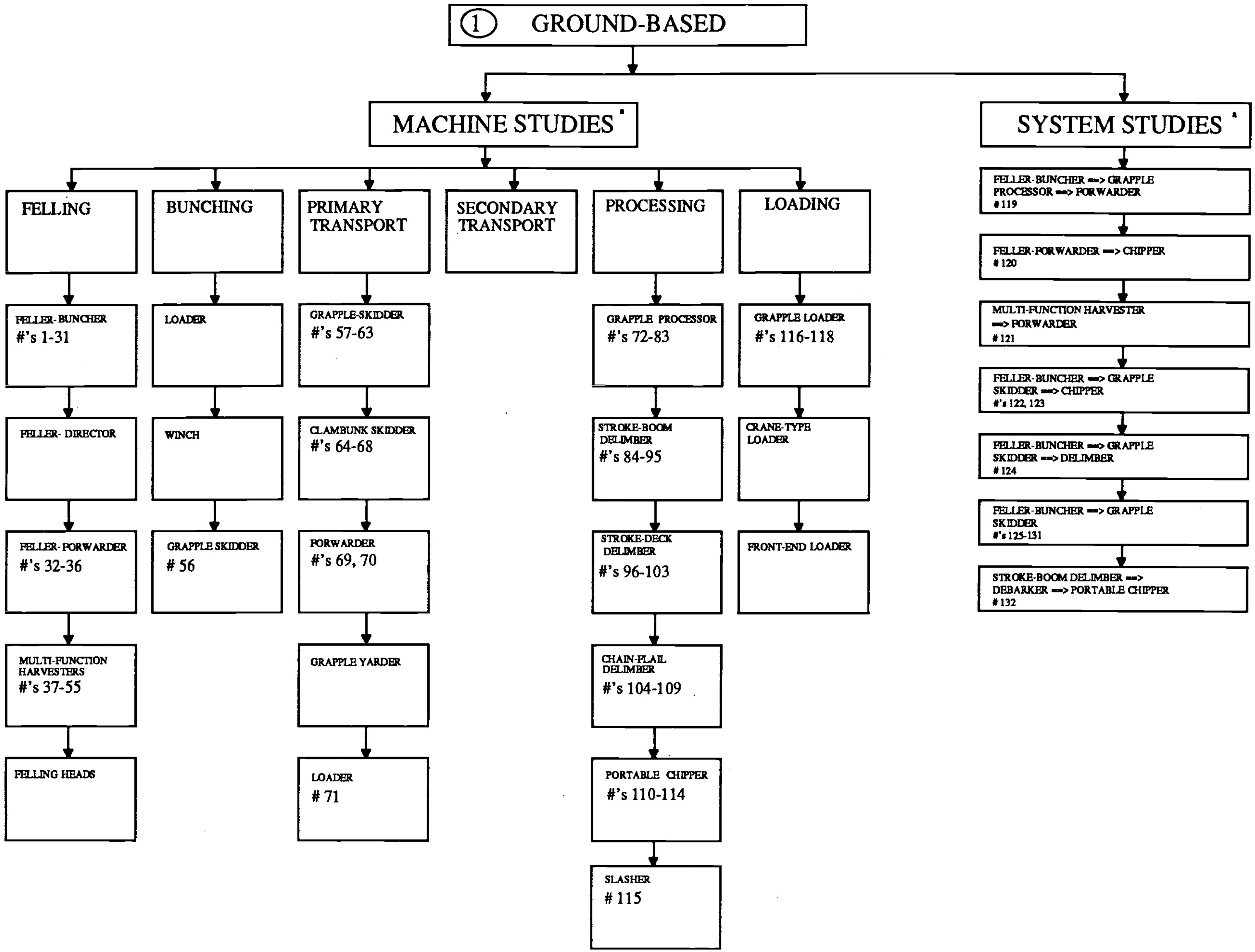
HIERARCHY I: MECHANIZED HARVESTING IN CLEARCUTS

Pathways Chart for Locating Abstract Citations

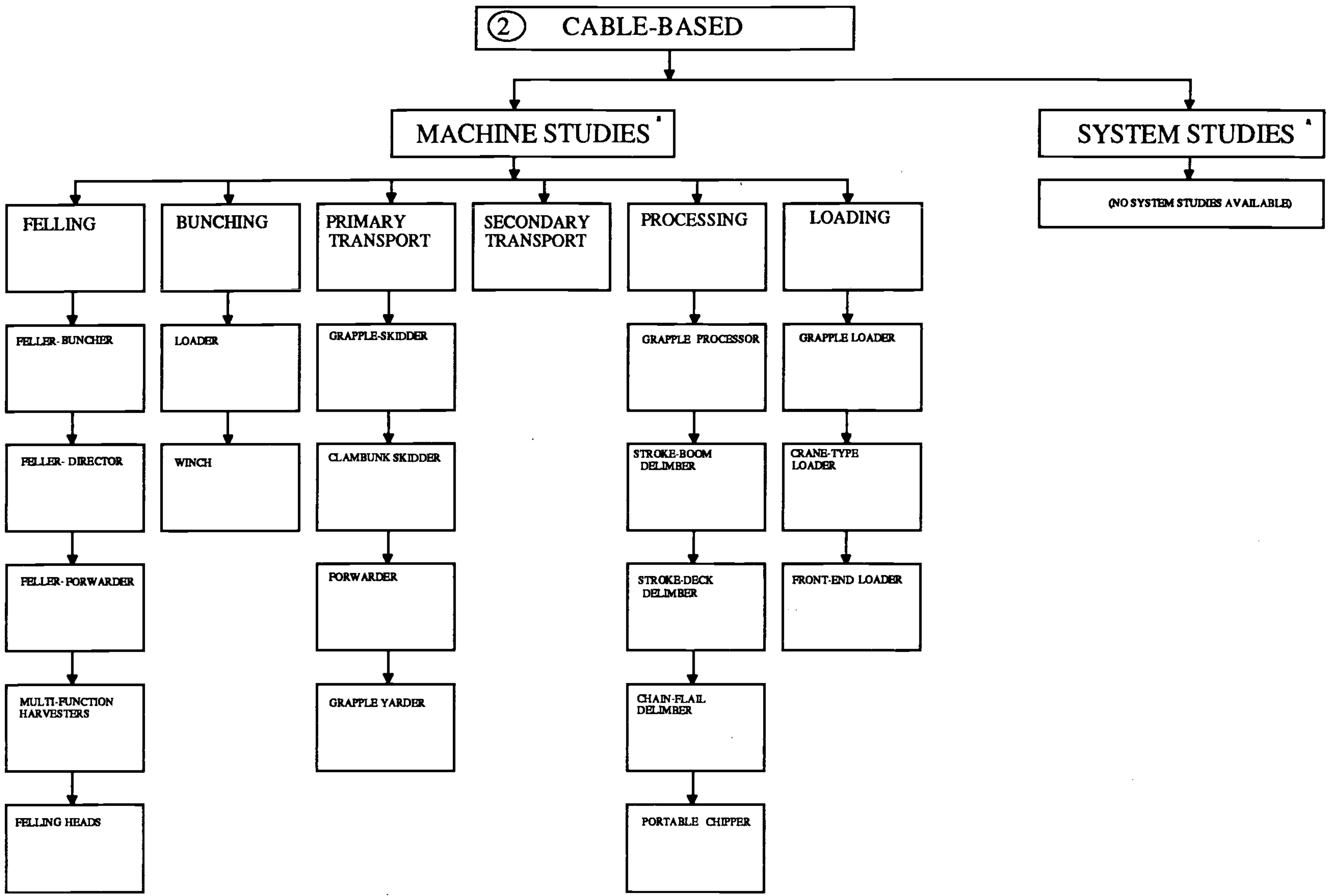
HIERARCHY I: MECHANIZED HARVESTING IN CLEAR CUTS



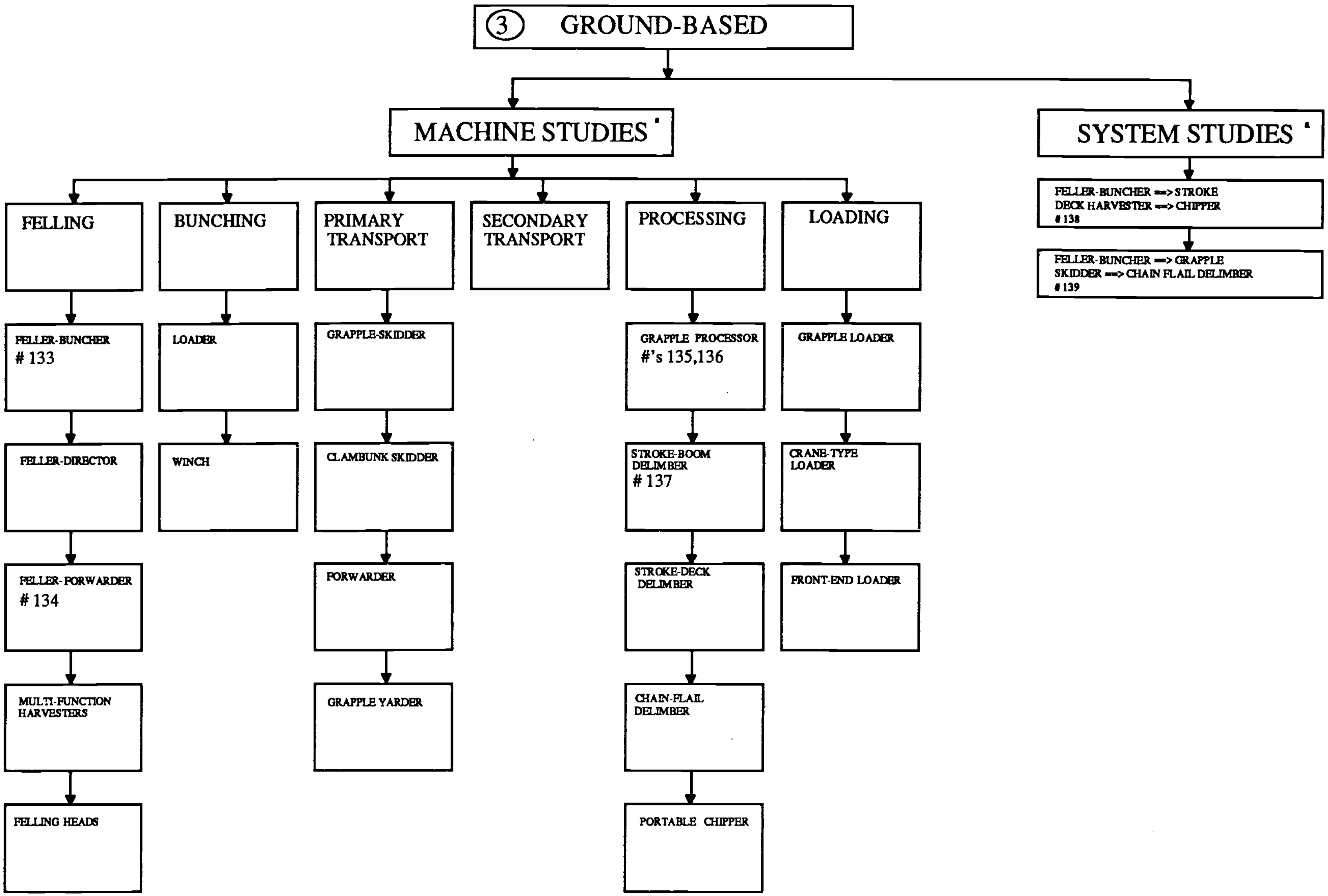
[a] Numbers in circles refer to subsequent pages of the pathways chart for this hierarchy.



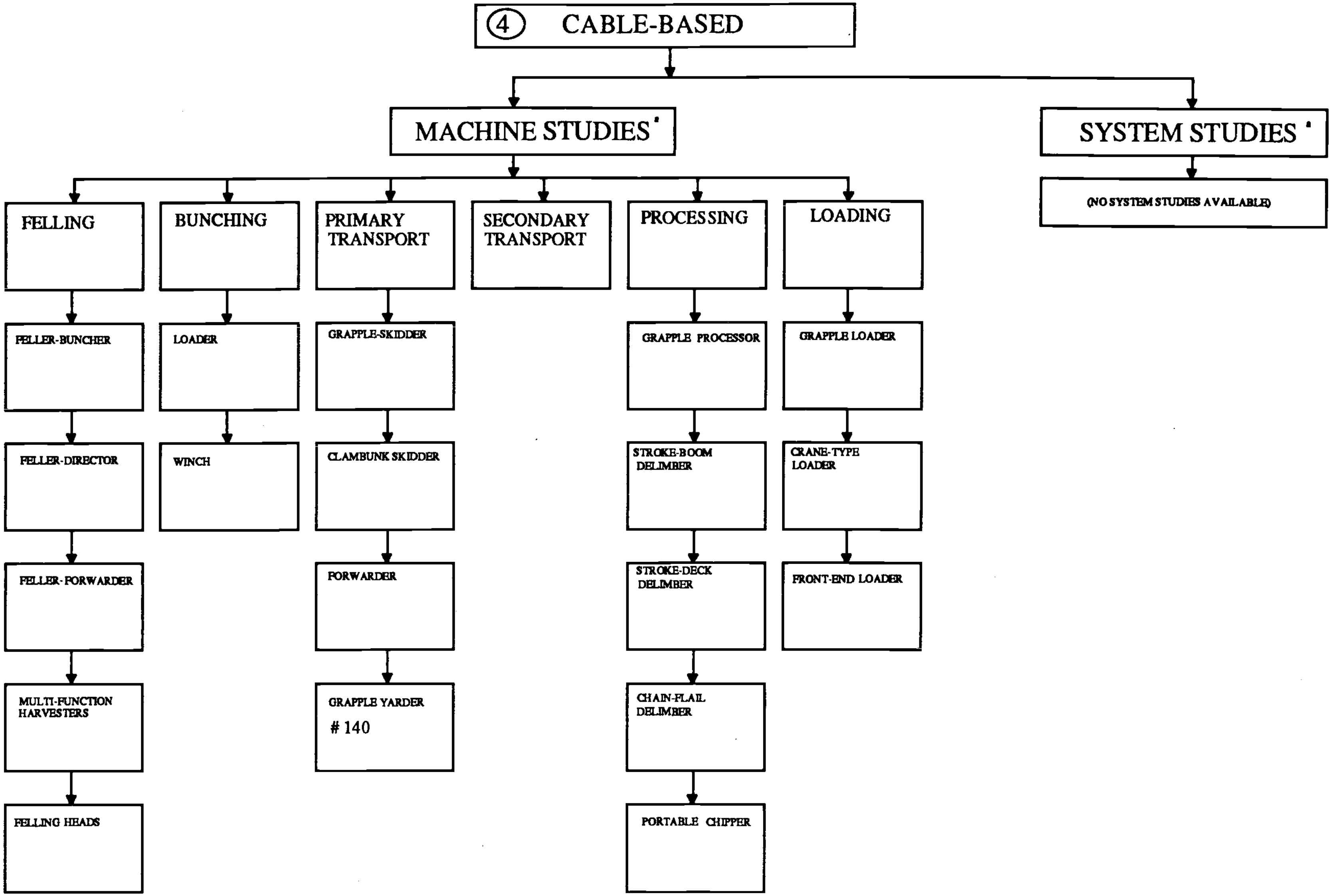
[a] Numbers listed in boxes with the names of individual machines or systems correspond with reference numbers of the citation abstracts listed later in this hierarchy. Boxes with machines or systems listed without a reference number indicate that no studies were located relevant to that pathway category, and suggest areas for future research.



[a] Numbers listed in boxes with the names of individual machines or systems correspond with reference numbers of the citation abstracts listed later in this hierarchy. Boxes with machines or systems listed without a reference number indicate that no studies were located relevant to that pathway category, and suggest areas for future research.



[a] Numbers listed in boxes with the names of individual machines or systems correspond with reference numbers of the citation abstracts listed later in this hierarchy. Boxes with machines or systems listed without a reference number indicate that no studies were located relevant to that pathway category, and suggest areas for future research.



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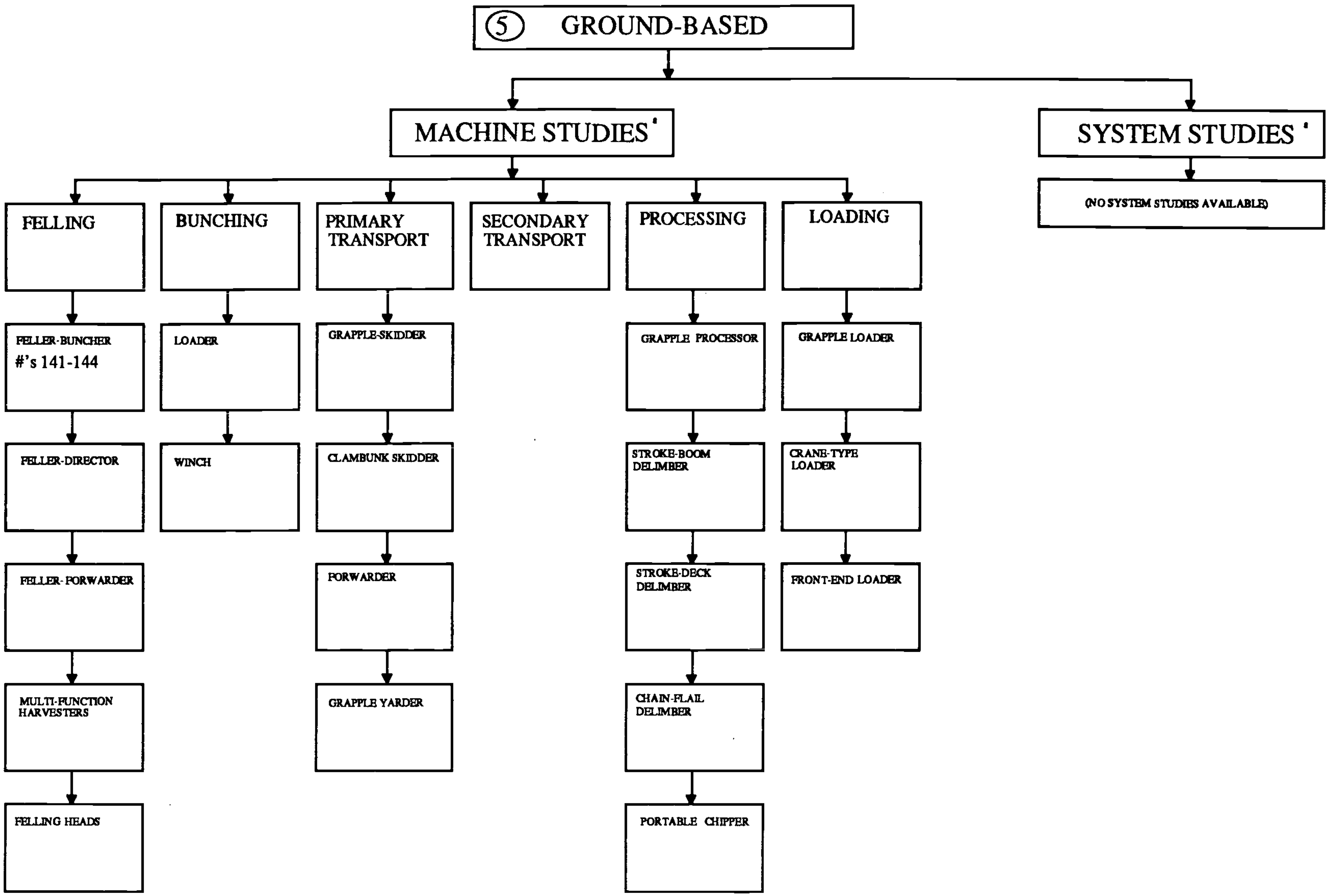

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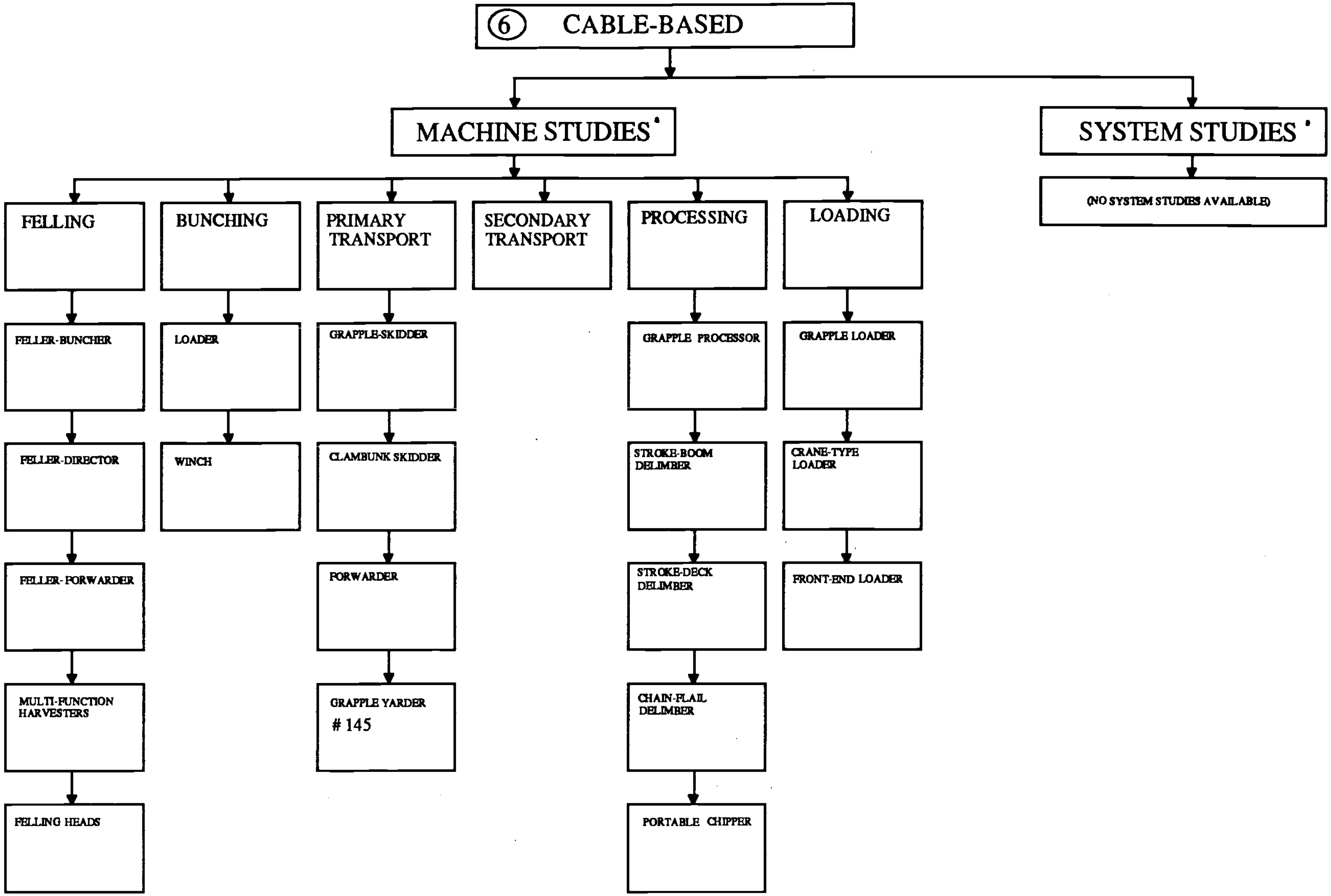

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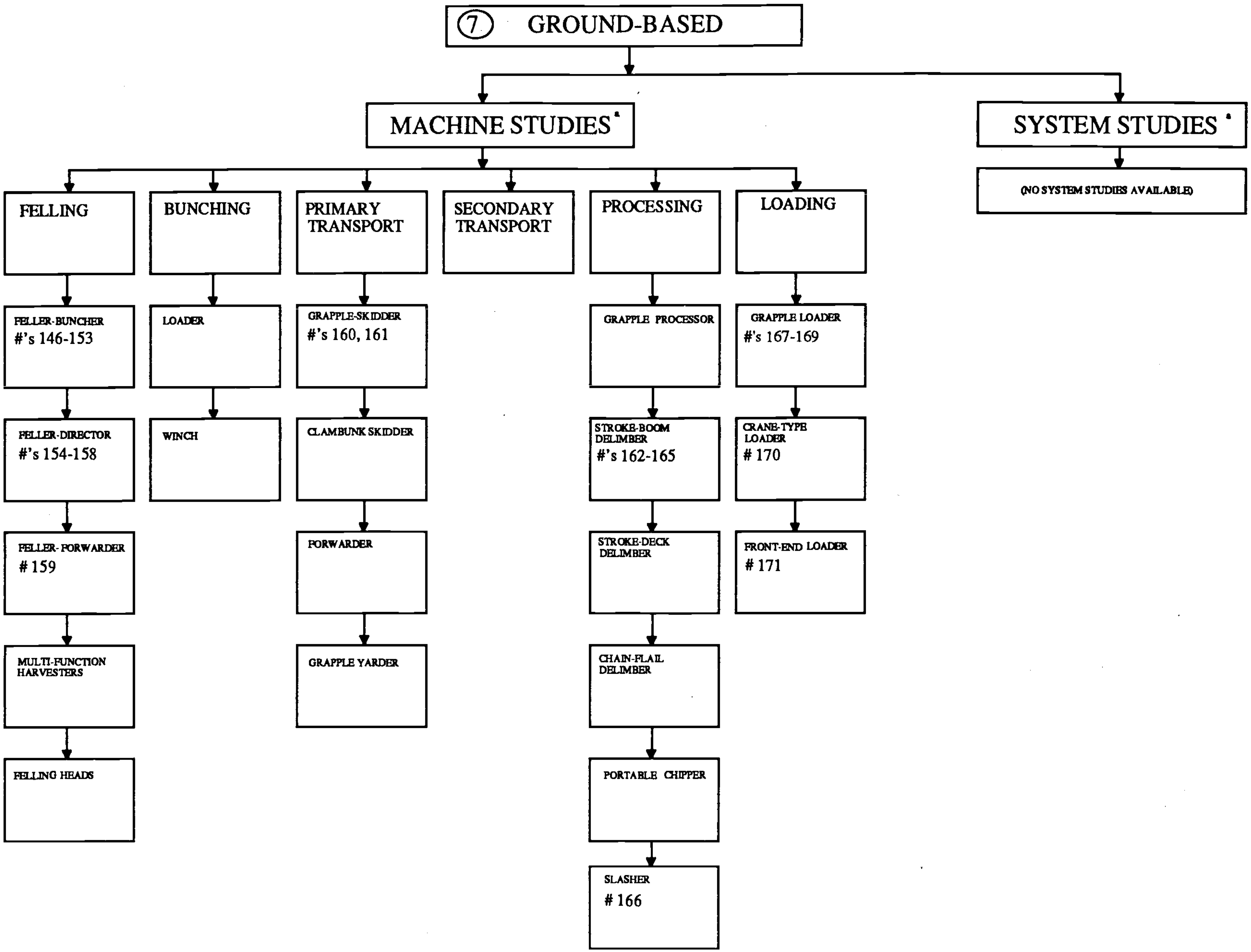

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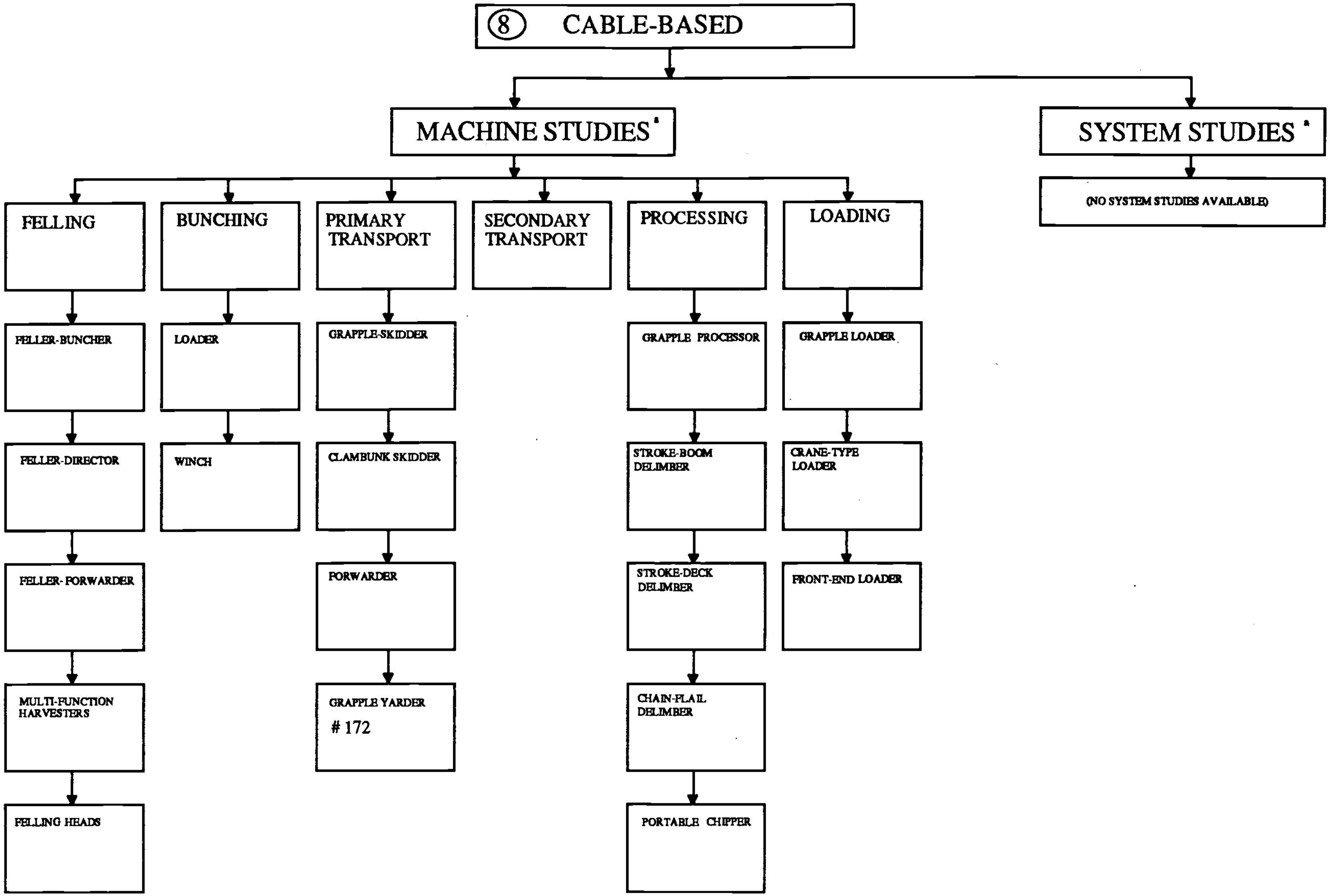

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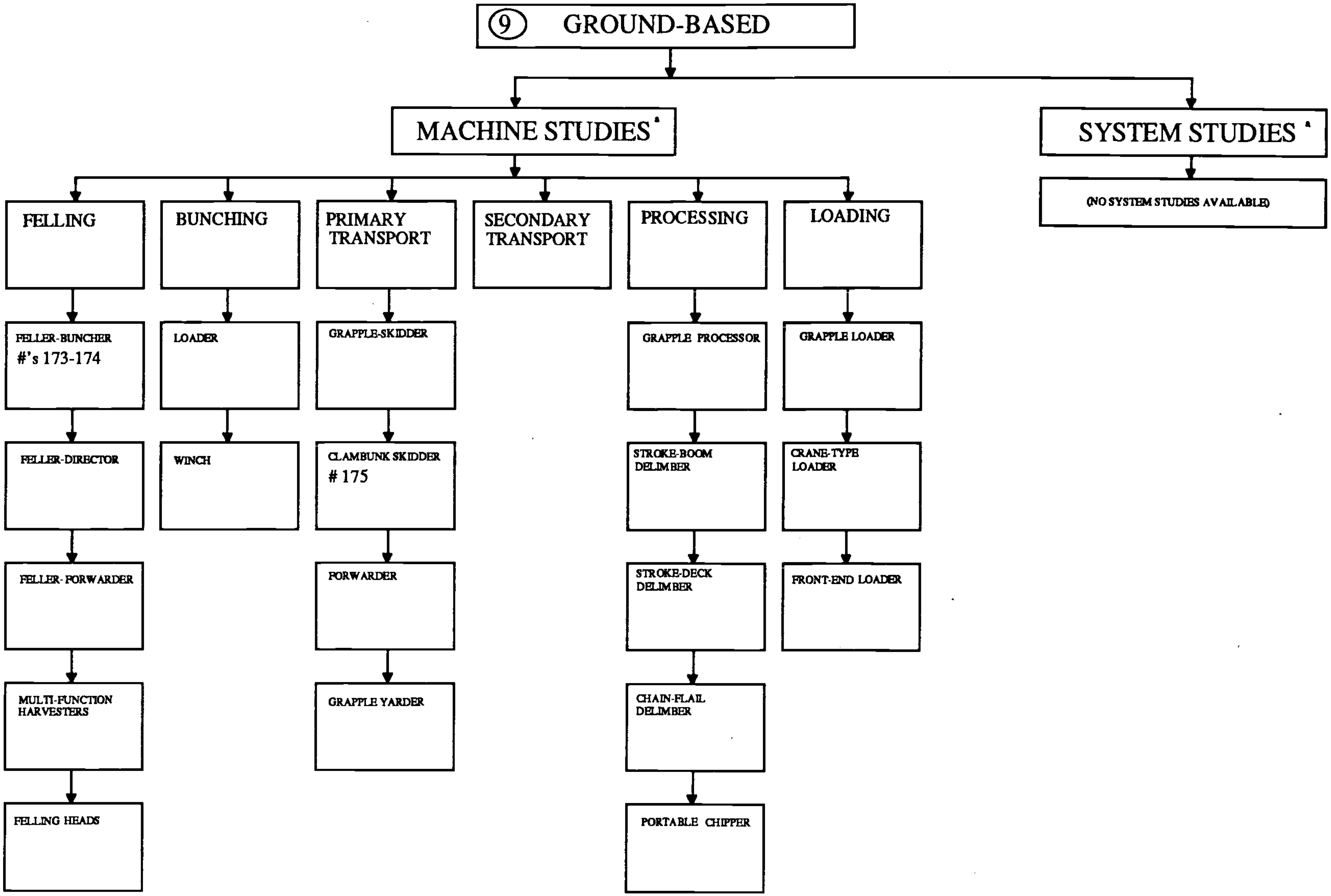

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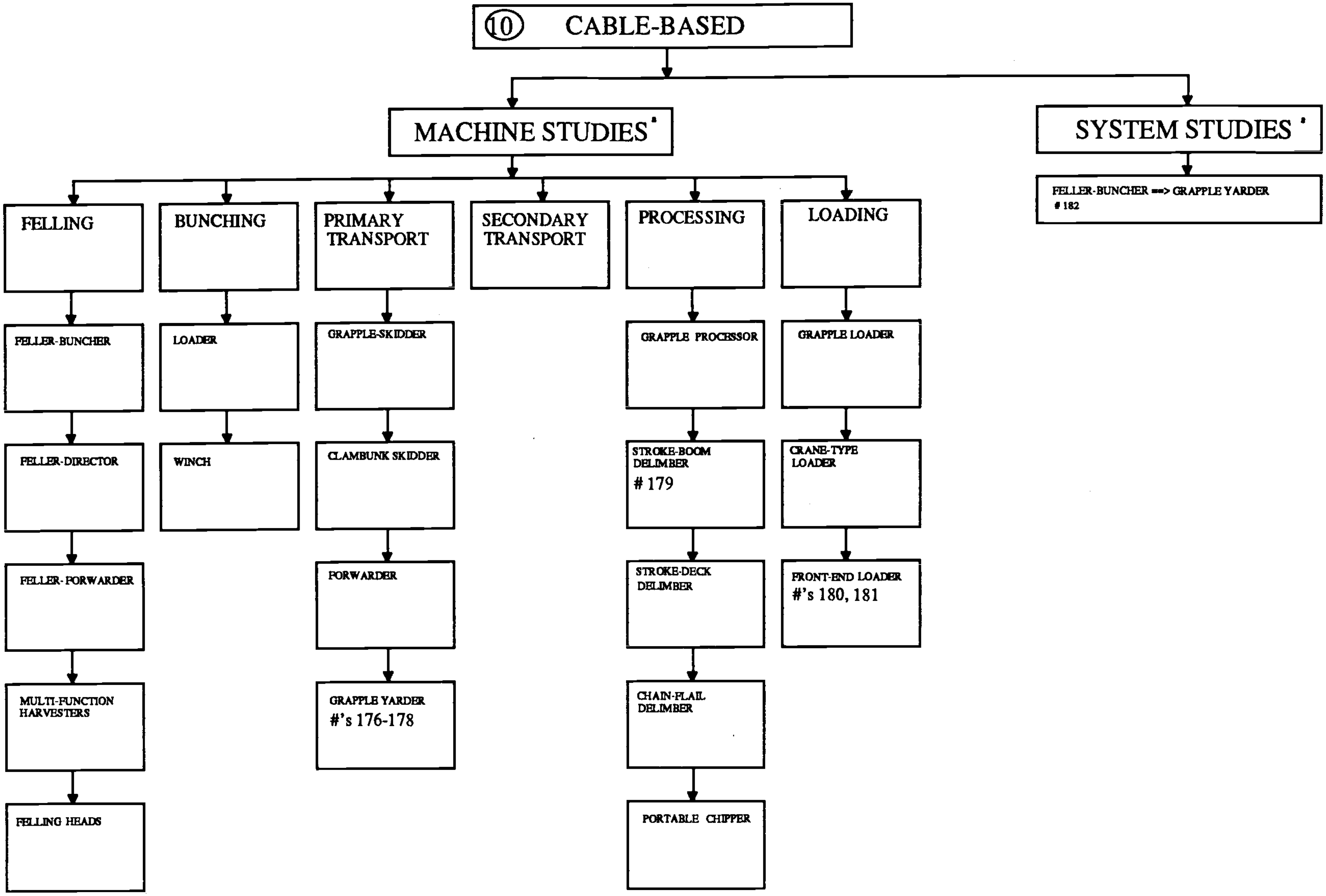

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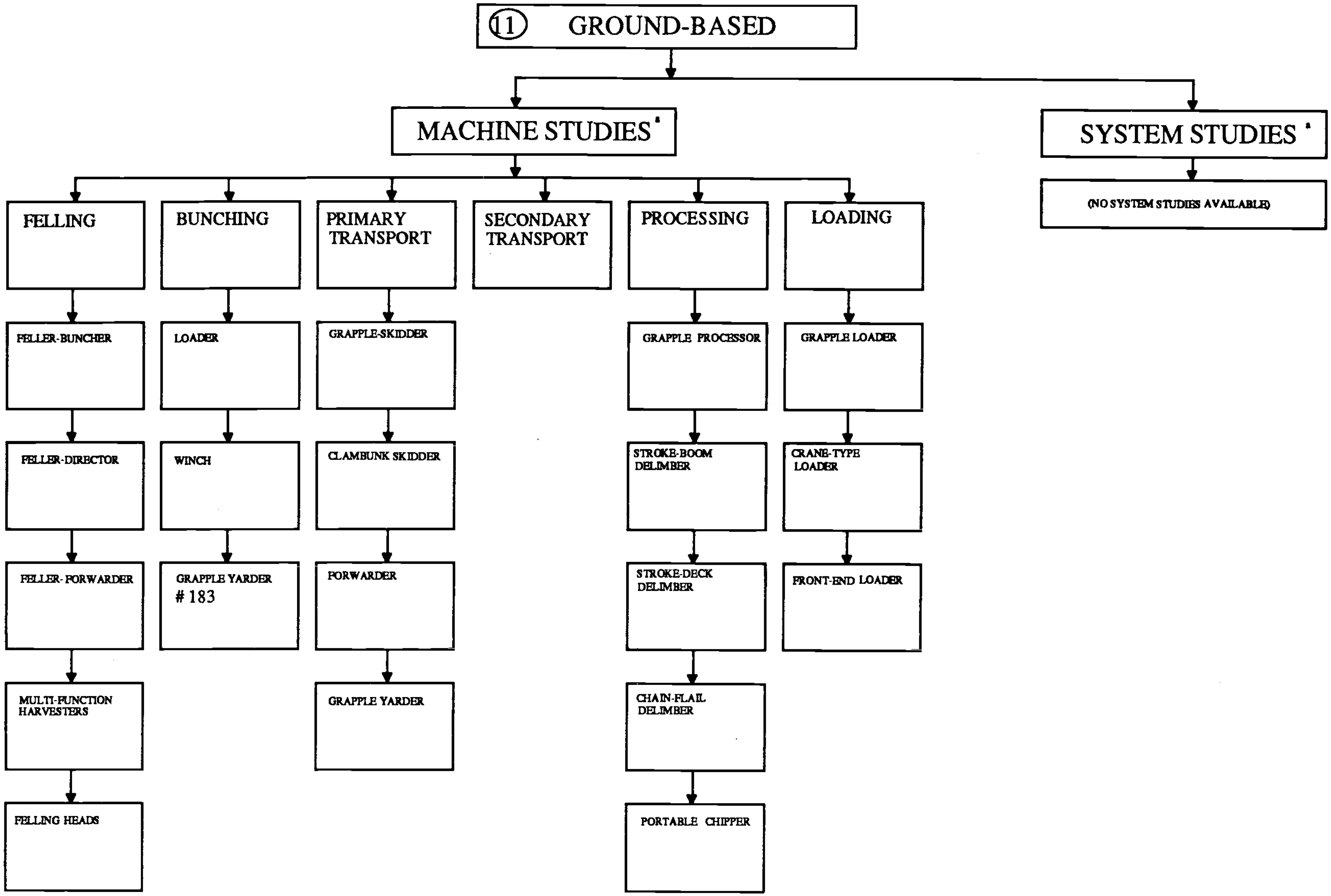

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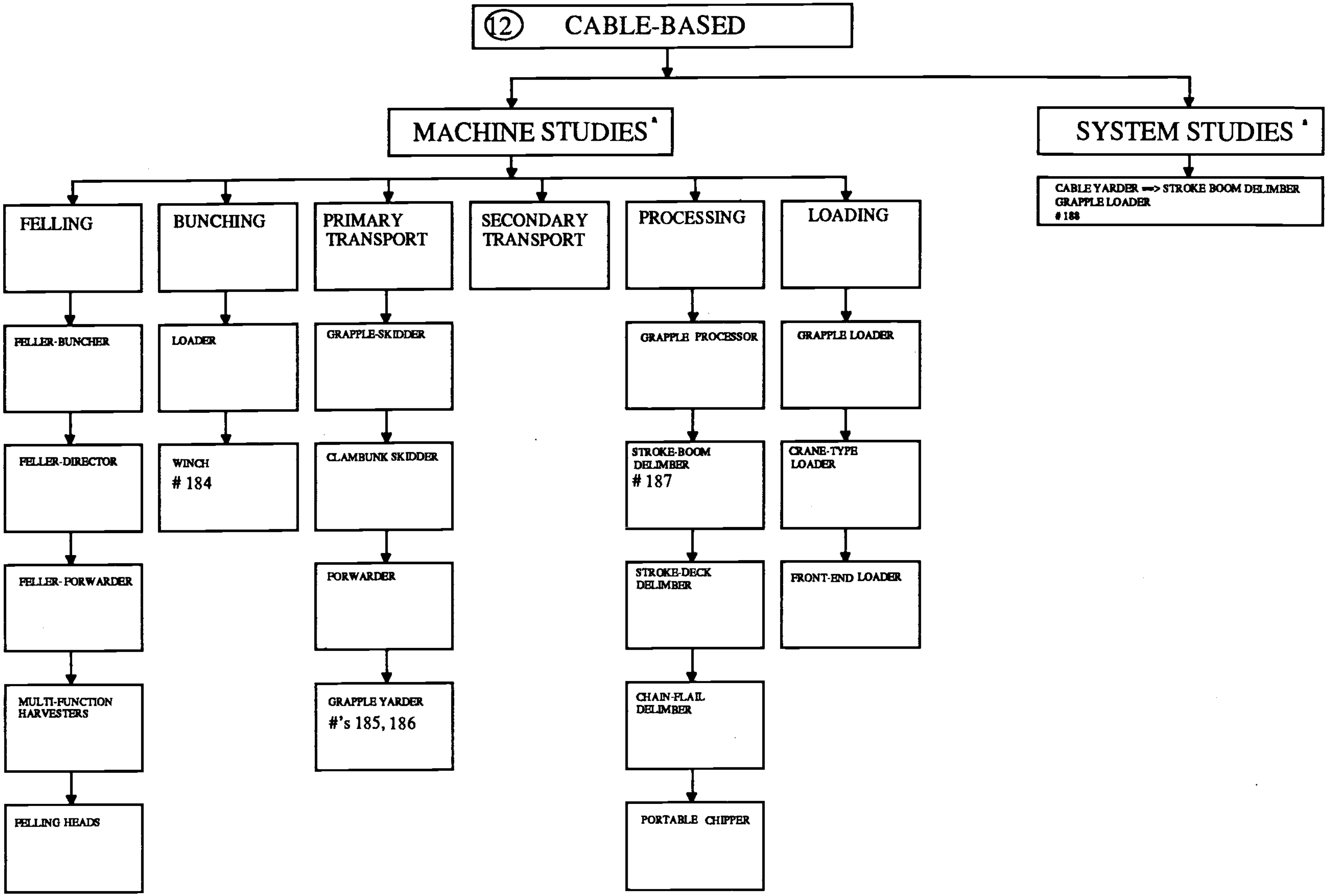

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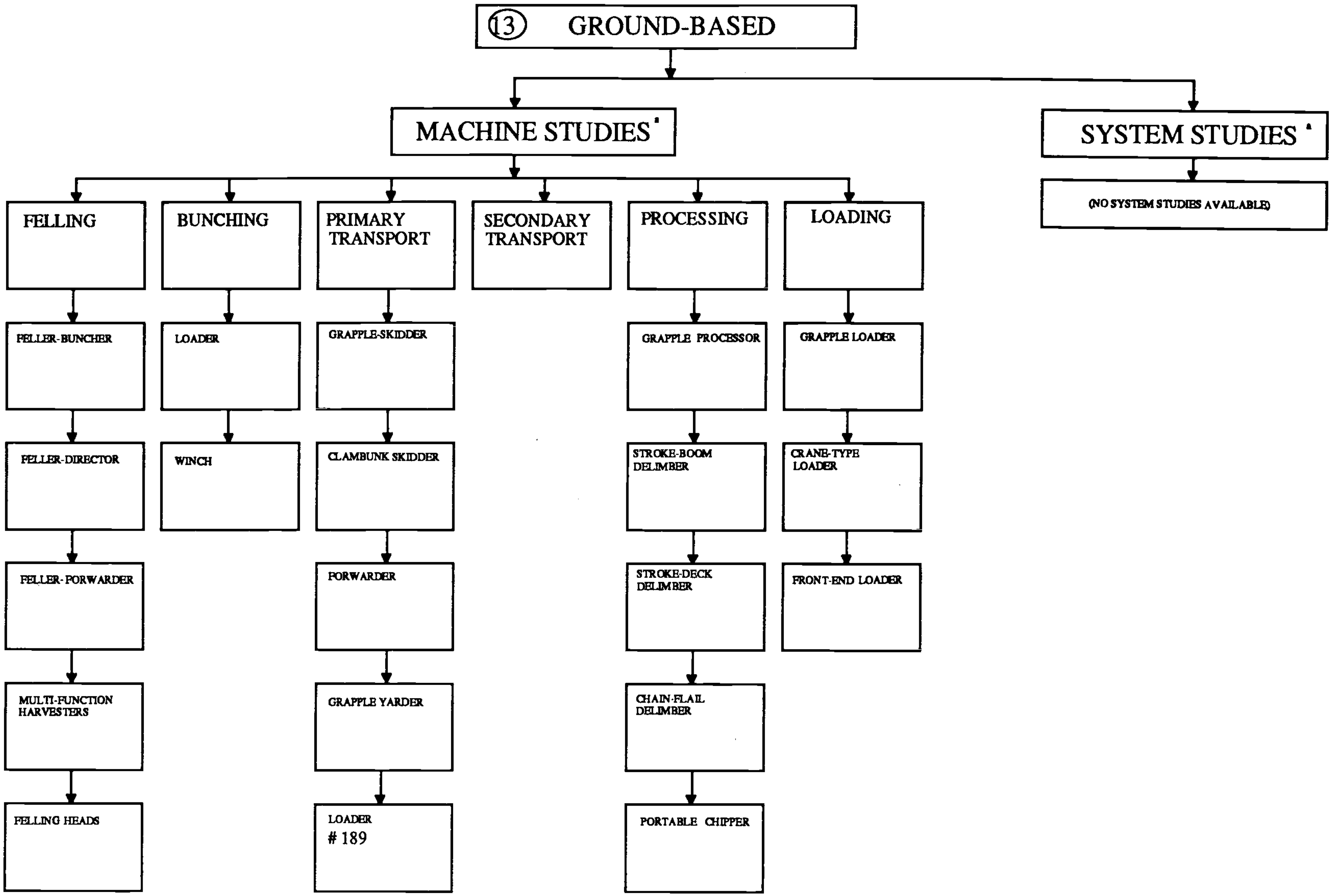

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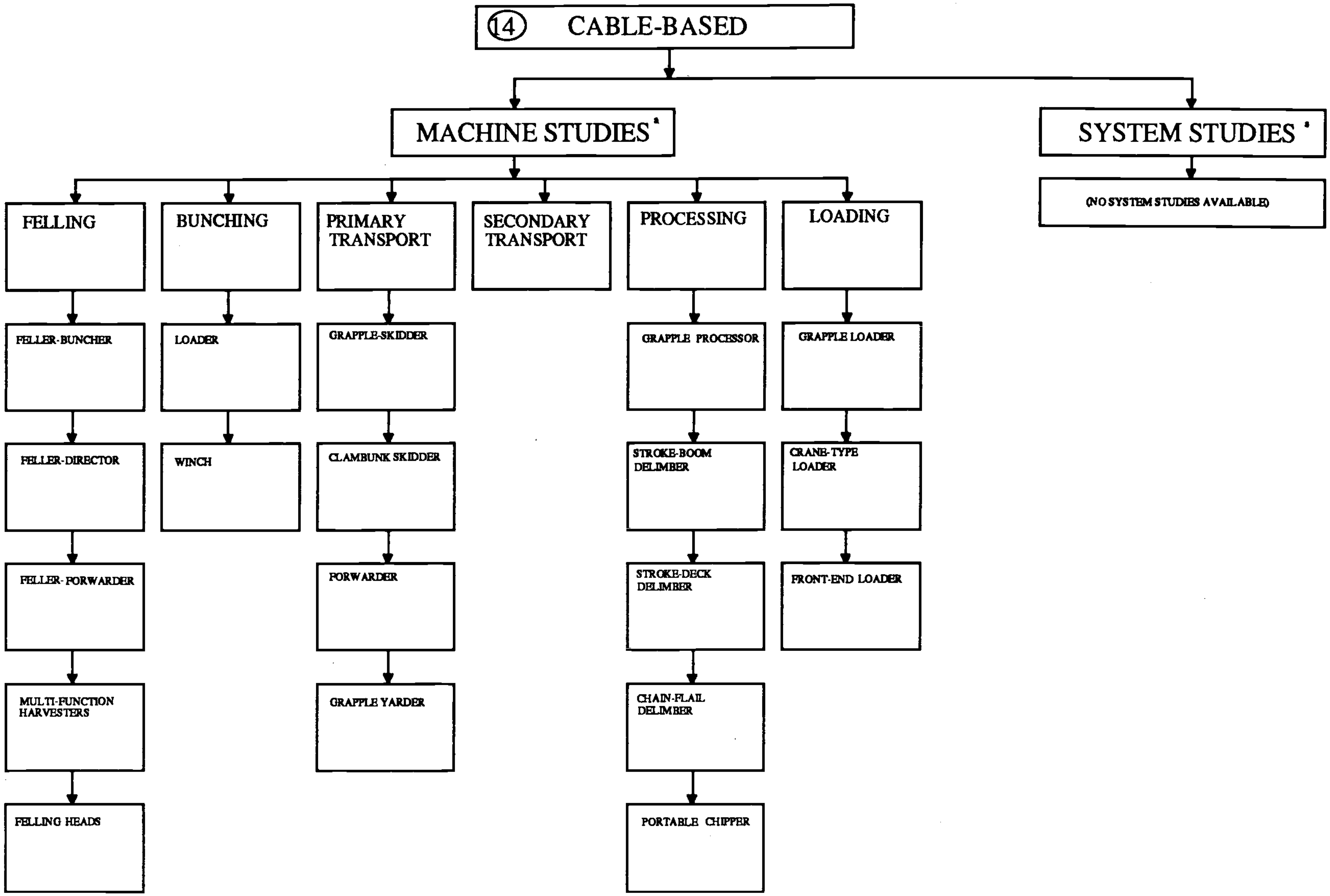

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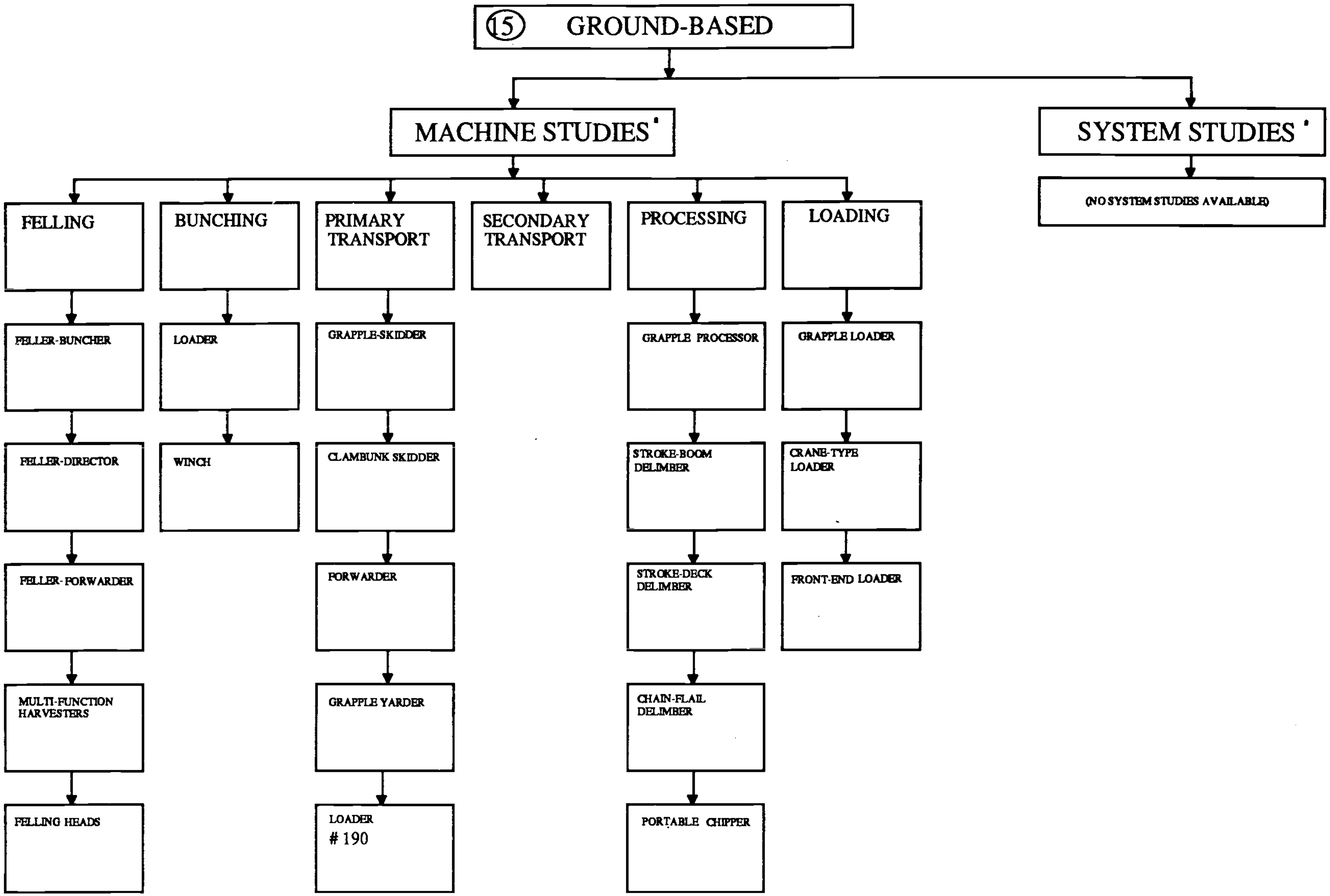

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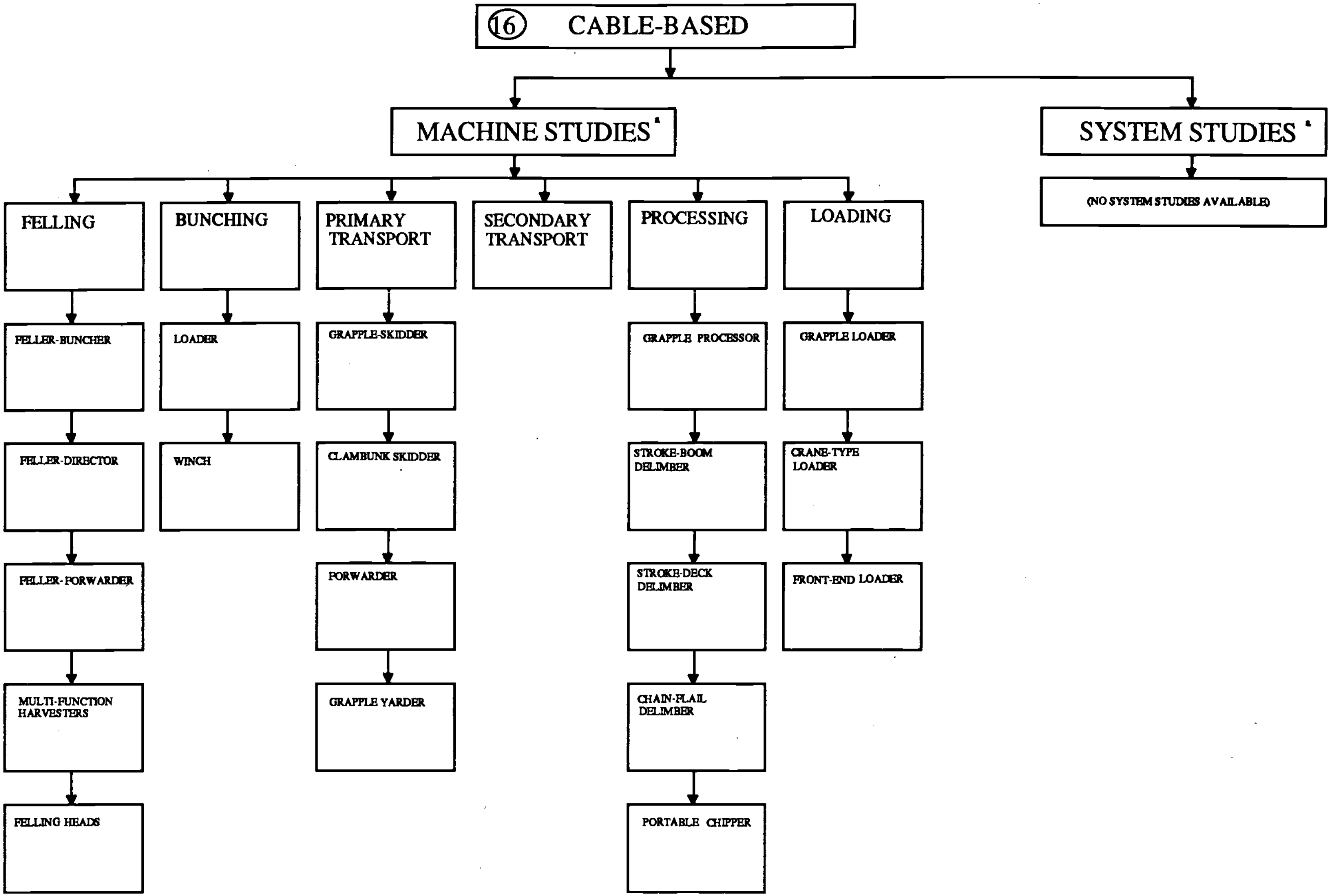

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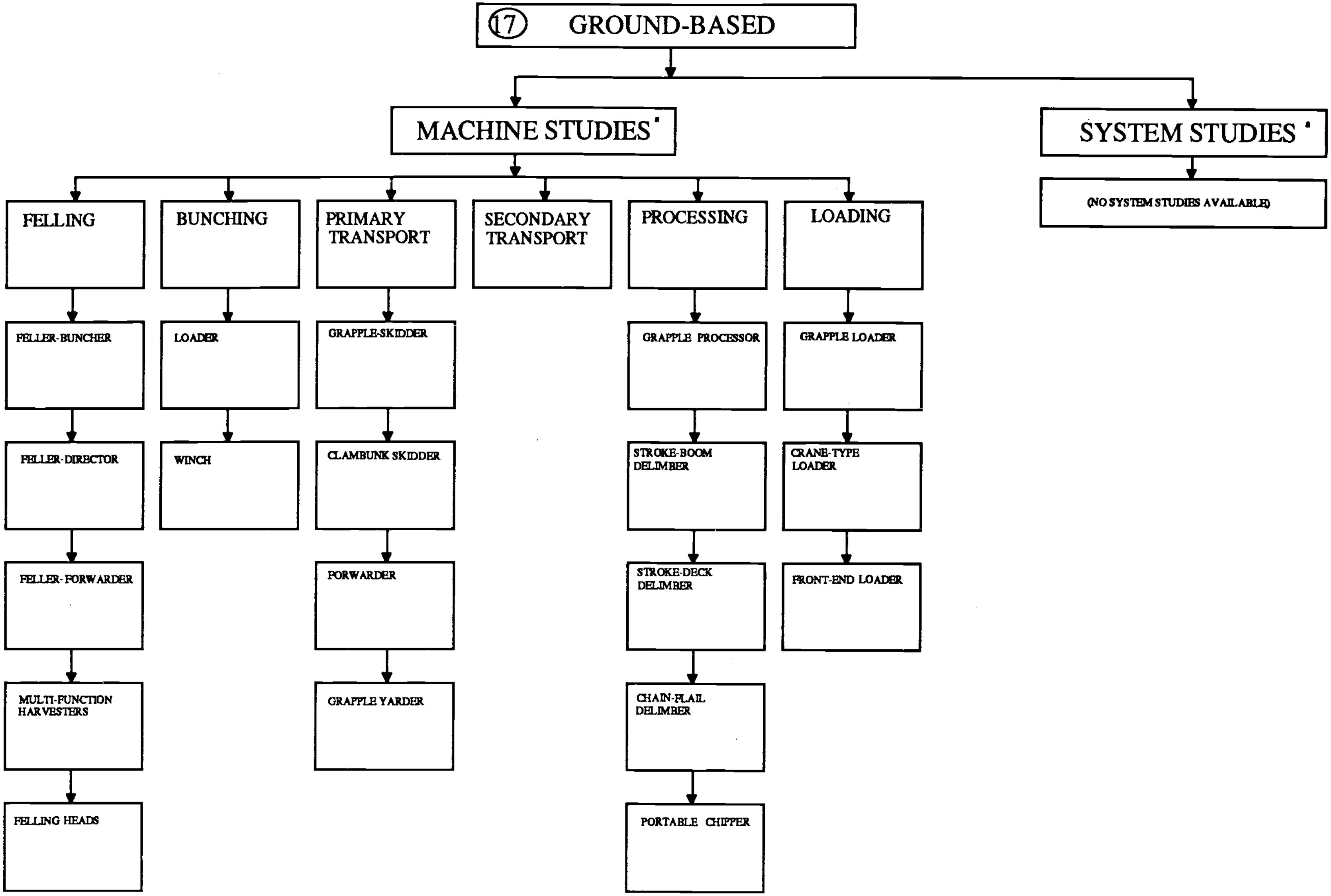

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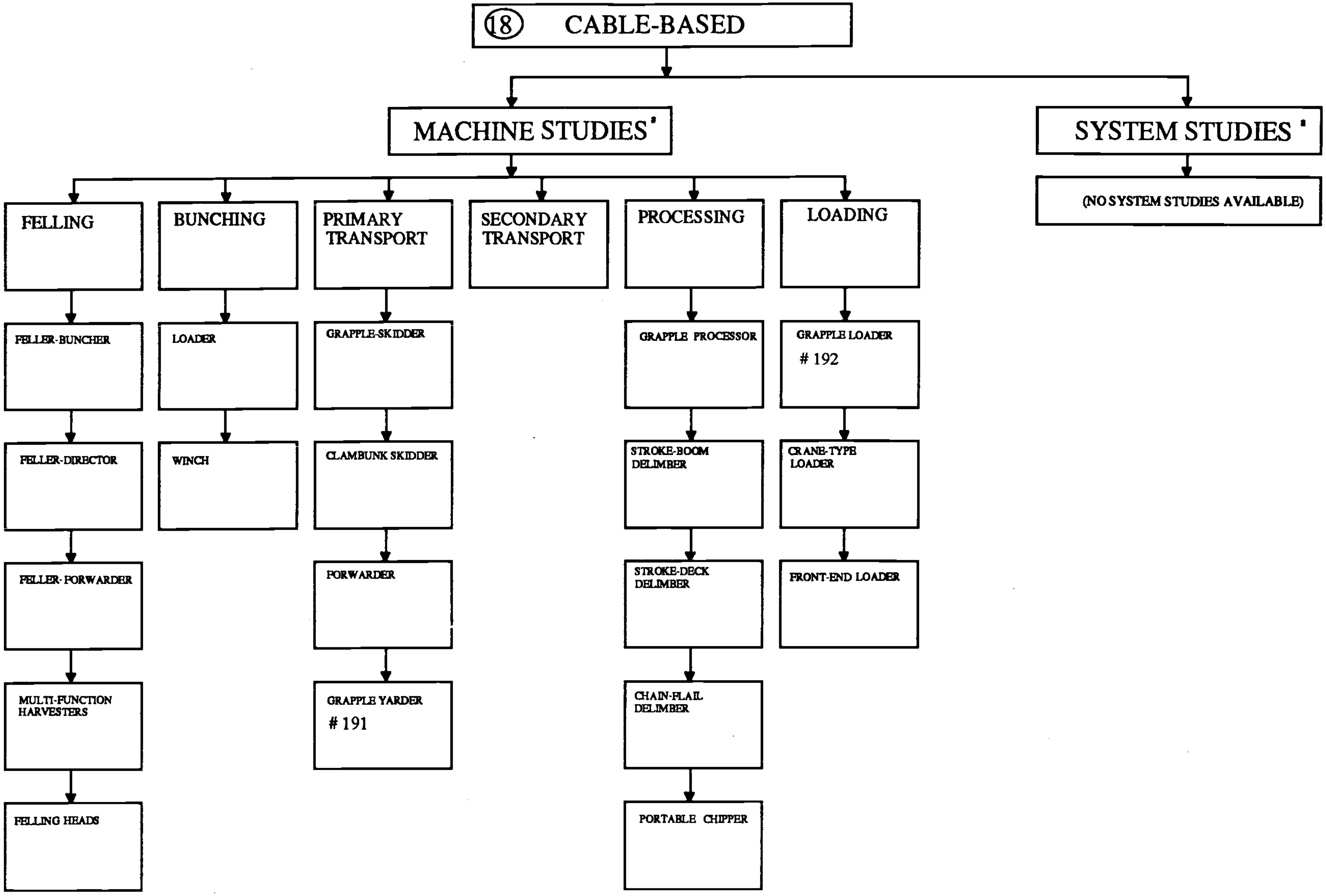

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HIERARCHY I: MECHANIZED HARVESTING IN CLEARCUTS

Citation Abstracts

CITATION: Letkeman, R. 1976. AT DOMTAR, LABOR TURNOVER DOESN'T EXIST. Canadian Forest Industries. 96(10):16-18, 20.

MACHINE SYSTEM: (2) Timberjack RW30 Harvesters (max. butt diameter capacity is 16 in.). (2) Liebherr Harvesters with Timmins Fel-Del heads (modifications: undercarriage and harvester head) (2) Farrano BJ 20 feller-bunchers.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
(2) Timberjack harvesters → (1) JD 740 skidder
(2) Farrano feller-bunchers → (5) Timberjack 230 skidders

DESCRIPTION OF OPERATION: Clearcut, producing tree-length wood.

DESCRIPTION OF SITE: Near Lac St. Jean, Quebec. Described as ideal for mechanized logging.

DESCRIPTION OF STAND: 65% black spruce, 25% balsam fir. 16 cords/acre. Average tree is 45 feet tall, 7 inches in DBH and contains 6 cu. ft. of volume.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Items	Liebherr Harvester	Timberjack RW30 Harvester	Ferrano BJ20s Feller-Buncher
Productivity (cunits/ 8-hour shift)	14	16	30
Productivity (cunits/ productive hour)	3	2.9	---
Mechanical Availability (%)	65	79	76
Net Utilization (%)	58	70	64

OTHER COMMENTS:

CITATION: Folkema, M.P. 1984. CIRCULAR SAW AND CONE SAW FELLING HEADS, AN UPDATE. FERIC. Technical Report No. TR-56.

MACHINE SYSTEM: Koehring Disc saw head "production" unit, a converted shear-type head with side-tilt and a 45° boom adaptor. Was mounted on a Koehring feller-forwarder (model KFF). Saw head capacity = 50 cm.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: The machine felled and bunched trees.

DESCRIPTION OF OPERATION: Clearcut.

DESCRIPTION OF SITE: In two areas about 30 km from Dubreuilville, Ontario. The terrain ranged from flat ground to boulder-strewn slopes and gullies with slopes of 20% or more. The snow depth was 1.2 m or more during FERIC's study.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Study Date: March to June 1982.

<u>Shift Level Study Results:</u> <u>Koehring Disc Saw Head</u>

Total scheduled hours	1,287.5
Productive machine hours	817.5
Mechanical availability (%)	72
Utilization (%)	63
Volume per tree (Ft^3)	7.5
Trees per PMH	60
Productivity (cunits/PMH)	4.5

OTHER COMMENTS: When using the "Scything" principle (swinging the boom sideways), the maximum tree size that could be cut was limited to 20 cm.

CITATION: Folkema, M.P. 1984. CIRCULAR SAW AND CONE SAW FELLING HEADS: AN UPDATE. FERIC. Technical Report No. TR-56.

MACHINE SYSTEM: Harricana circular saw head (which weighed over 2500 kg) was installed on a 4-year old JD 693 excavator. The head was equipped with a side tilt (wrist) cylinder as standard equipment. 50-cm capacity circular saw head. "Standard" unit.

OPERATOR RATING: One operator, age 61. He had 5 years experience on a company-owned Drott 40 shear feller-buncher. A good operator.

DESCRIPTION OF SYSTEM: The machine felled and bunched trees.

DESCRIPTION OF OPERATION: Clearcut.

DESCRIPTION OF SITE: About 60 km southeast of Hearst, Ontario. Terrain: typical clay belt, flat ground.

DESCRIPTION OF STAND: Black spruce stands.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume/tree = 0.138 m^3

PRODUCTION DATA: Study Date: September 1982 to January 1983

Shift Level Study Results: Harricana Circular Saw Head

Total scheduled hours	720.0
Mechanical availability (%)	85
Utilization (%)	68
Volume per tree (Ft^3)	4.9
Trees per PMH	145
Productivity (cunits/PMH)	7.1

OTHER COMMENTS:

CITATION: Folkema, M.P. 1984. CIRCULAR SAW AND CONE SAW FELLING HEADS: AN UPDATE. FERIC. Technical Report No. TR-56.

MACHINE SYSTEM: Koehring disc saw head "production" unit. Re-designed head weight = 2630 kg. The new saw blade design had 18 welded-on teeth (9 above, 9 below). Saw head capacity = 50 cm. Mounted on Koehring's (prototype) K2FF feller-forwarder.

OPERATOR RATING: Both operators were considered experienced and capable: one new operator was trained during FERIC's 9-month study.

DESCRIPTION OF SYSTEM: The machine felled and bunched trees.

DESCRIPTION OF OPERATION: Clearcut.

DESCRIPTION OF SITE: Portage, Maine. The terrain was rolling with long cutting faces and with only a few areas having gradients over 20°. There was 0.8 meters of snow from January to March 1983.

DESCRIPTION OF STAND: Softwood stands that had been selectively cut. Stands consisted of scattered spruce and fir. Merchantable volume per hectare = 40 to 90 m^3. 15 to 50% of the trees were dead (spruce budworm damage).

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: Cull softwoods plus hardwoods comprised about 20 to 30% of the trees in the harvested areas.

PRODUCTION DATA: Study Date: December 1982 to August 1983.

<u>Shift Level Study Results: Koehring Disc Saw Head</u>

Total scheduled hours	2,472.0
Mechanical availability (%)	72
Utilization (%)	62
Volume per tree (m^3)	0.213
Trees per PMH	71
Productivity (cunits/PMH)	15.1

OTHER COMMENTS: Koehring Canada suggests that excavator carriers for the disc head have a minimum weight of 50,000 lbs., and 135 hp net engine power.

CITATION: Folkema, M.P. 1984. CIRCULAR SAW AND CONE SAW FELLING HEADS: AN UPDATE. FERIC. Technical Report No. TR-56.

MACHINE SYSTEM: Harricana circular saw head on a JD 693 carrier. Full joystick controls using monson-tyson values mounted on top of the regular value bank. Hydraulic system: installation of a 2-way, reversible fan having increased pitch, plus a larger oil cooler.

OPERATOR RATING: The operators on both shifts were experienced (shear type) feller-buncher operators who had little problem adjusting to the circu!ar saw.

DESCRIPTION OF SYSTEM: The machine felled and bunched trees.

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: 80 km northeast of Amos, Quebec. Lowland.

DESCRIPTION OF STAND: 100% black spruce. 600 trees/acre. Heavy understory of 3-4 meter high willow and alder.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume per tree = 6.8 Ft^3

PRODUCTION DATA: Study Date: September 8-9, 1982

Production Summary: Harricana Circular Saw Head

Move empty (%)	35
Felling and piling (%)	40
Move between trees (%)	4
Move for piling (%)	16
Delays (%)	5
Total time per tree (cmin)	43.9
Duration of study (hr)	11.16
Cycles/PMH	65
Trees/Cycle	2.11
Tree/PMH	137
Volume/PMH (m^3)	26.5

OTHER COMMENTS: Some difficulty was experienced when cutting large trees (over 35 cm. DBH) because the saw blade had a tendency to "power out" or stall. There was no side-tilt cylinder on the saw.

CITATION: Folkema, M.P. 1984. CIRCULAR SAW AND CONE SAW FELLING HEADS: AN UPDATE. FERIC. Technical Report No. TR-56.

MACHINE SYSTEM: Denis SJ-24 felling head, mounted on a leased Timbco 2518 track carrier with a Cat 235 undercarriage. The Denis head features a sliding twin circular saw.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: The machine felled and bunched trees.

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: About 40 km North of Timmins and later 30 km North of Smooth Rock Falls, Ontario. Terrain: flat with no rocks.

DESCRIPTION OF STAND: Even-age black spruce.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume of merchantable tree = 0.119m^3

PRODUCTION DATA: Study Date: April to September 1983.

Shift Level Study Results: Denis SJ-24 Head

Scheduled days reported	111
Mechanical availability (%)	70
Utilization (%)	60
Volume per tree (Ft^3)	4.2
Trees per PMH	112
Productivity (cunits/PMH)	4.7

OTHER COMMENTS: The main problem with the Denis head was the saw binding and stalling. There was insufficient hydraulic power. The soft ground also contributed to the saw binding problem because of machine sinkage during felling.

CITATION: Folkema, M.P. 1984. CIRCULAR SAW AND CONE SAW FELLING HEADS: AN UPDATE. FERIC. Technical Report No. TR-56.

MACHINE SYSTEM: Boreal DD-20 double-deck saw weighting 1,600 kg. It was mounted on a JD693 tracked carriage. A "pre-production" model.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: The machine felled and bunched trees.

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: 10 km North of Strickland, Ontario. Terrain: lowland.

DESCRIPTION OF STAND: 100% black spruce, 900 trees/hectare.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume per tree = 5.6 Ft^3

PRODUCTION DATA: Study: November 14, 1983.

<u>Production Summary: Boreal DO-20 Saw Head</u>

Move empty (%)	13.4
Felling cycle (%)	74.5
Move between trees (%)	2.0
Brushing (%)	4.8
Delays (%)	5.3
Total time per tree (cmin)	41.8
Duration of study (hours)	2.69
Cycles/PMH	76
Trees/Cycle	1.89
Trees/PMH	143
Volume/PMH (m^3)	22.7

OTHER COMMENTS: Most of the delays resulted from fragments of wood becoming jammed between the insert plate at the lower blade. When this happened the operator would stop felling and remove the wood fragments with a hooked rod.

CITATION: Folkema, M.P. 1984. CIRCULAR SAW AND CONE SAW FELLING HEADS: AN UPDATE. FERIC. Technical Report No. TR-56.

MACHINE SYSTEM: Lokomo L450A cone saw with accumulator arm mounted on a leased Drott 40 (with a Drott 50 undercarriage). The head weighed 1,250 kg including tilt cylinder. Maximum cutting capacity was 45 cm. A "Pre-production" model.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. The machine felled and bunched trees.

DESCRIPTION OF SITE: 30 km North of Smooth Rock Falls, Ontario. Terrain: lowland.

DESCRIPTION OF STAND: 100% black spruce. 850 trees/hectare.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume per tree = 5.4 Ft^3

PRODUCTION DATA: Study Date: October 26-27, 1983

Production Summary: Lokomo L450A Cone Saw

Move empty (%)	5
Felling & piling (%)	82
Move between trees (%)	2
Move for piling (%)	2
Delays (%)	9
Total time per tree (cmin)	39.6
Duration of study (hours)	7.39
Cycles/PMH	81
Trees/Cycle	1.87
Trees/PMH	151
Volume/PMH (m^3)	23.2

OTHER COMMENTS: Its ability to accumulate was limited to two 20-cm trees/cycle. The Lokomo cone saw can also cause butt splitting because the tree must be firmly grabbed prior to severing.

CITATION: Powell, L.H. and Myhrman, D.W. 1977. EVALUATION OF EARLS PARASHEAR FELLER-BUNCHER. FERIC. Technical Report No. TR-17.

MACHINE SYSTEM: The Earls Parashear feller-buncher attachment (prototype) was mounted on the back of a Terex 82-40 crawler tractor. The felling head is mounted on a knuckle-boom in winter conditions. A second cab was mounted above the tractor canopy (2nd prototype). Capacity: 18 in. butt diameter.

OPERATOR RATING: Summer: An experienced crawler tractor operator with eight days of experience on the actual machine. Winter: operator had limited experience with parashear.

DESCRIPTION OF SYSTEM:
Feller-buncher → Grapple skidders

DESCRIPTION OF OPERATION: Clearcut.

DESCRIPTION OF SITE: Summer: Beaverdell, B.C. Slope in direction of travel = 9%. Winter: Okanagan Falls, B.C. The ground was frozen and covered with approximately 1 foot of snow. Slope in direction of travel = +16%.

DESCRIPTION OF STAND: Summer: Spruce-pine stand. Merchantable trees/acre = 570. Unmerchantable trees/acre = 309. Volume/acre = 83.3 cunits. Stump diameter = 10 in. Winter: Merchantable trees/acre = 571. Unmerchantable trees/acre = 53. Stand volume/acre = 65.1 cunits.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Summer: Average volume per tree = 14.7 Ft^3, (SD = 10.8)
Winter: Average volume per tree = 11.4 Ft^3, (SD = 5.5)

PRODUCTION DATA: Summer Study Date: Four days in early June, 1976
Winter Study Date: February 1977

Summary of Times for Merchantable Tree - Summer and Winter Study

	Summer	Winter
Moving in the stand (cmin)	13.7	14.5
Felling cycle (cmin)	49.8	53.8
Brushing time (cmin)	11.6	8.8
Delay time (cmin)	3.8	4.0
Total time (cmin)	78.9	81.3

Productivity - Summer and Winter Study

	Summer	Winter
Trees cut between move	5.3	---
Avg. Time/move (cmin)	69	---
Trees per bunch	7.2	---
Trees/PMH	76	74
Productivity (cunits/PMH)	11.2	8.4

OTHER COMMENTS: Much of the winter shear damage appeared to be the result of faulty positioning of the felling head.

CITATION: Folkema, M.P. 1977. EVALUATION OF KOCKUMS 880 'TREE KING' FELLER BUNCHER. FERIC. Technical Report No. TR-13.

MACHINE SYSTEM: Kockums 880 Tree King wheeled feller-buncher equipped with chainsaw felling head. Maximum cutting capacity = 23 in. Clark choker skidders. Chain-flail delimbers.

OPERATOR RATING: Operator was an employee of Kockums, who proved to be an excellent and highly motivated operator.

DESCRIPTION OF SYSTEM:
Kockums 880 Tree King feller-buncher → Line skidders → Chain-flail delimbing.

DESCRIPTION OF OPERATION: Clearcut. The felled trees were placed into small bunches of 3 to 5 trees for subsequent skidding by choker skidders. Chain-flail delimbing and manual topping were performed at roadside.

DESCRIPTION OF SITE: Beardmore, Ontario. Stand 1: Level, lowland black spruce. Stand 2: Hummocks, maximum sustained slope = ± 15%. Stand 3: Level. Some windfalls, maximum sustained slope = ± 15%.

DESCRIPTION OF STAND: Stand 1: 94% spruce, 6% balsam fir. Average DBH = 6.8 in. Merchantable trees/acre = 395. Stand 2: 56% white spruce, 33% poplar, 6% balsam fir and 5% white birch. Merchantable trees/acre = 149. Average DBH = 8.7 in. Unmerchantable trees/acre = 94. Stand 3: 67% black spruce, 29% jack pine, 4% poplar. Average DBH = 6.8 in. Merchantable trees/acre = 436. Unmerchantable trees/acre = 20.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average vol./tree: Stand 1 = 5.1 Ft^3; Stand 2 = 9.1 Ft^3; Stand 3 = 5.1 Ft^3.

PRODUCTION DATA: Study Period: October 1976 (3-day period)

	Stand 1		Stand 2		Stand 3	
	Avg.	SD	Avg.	SD	Avg.	SD
Move in the stand (cmin)	10	---	17	---	7	---
Brushing (cmin)	1	---	1	---	1	---
Felling cycle (cmin)	26	---	35	---	28	---
Delays (cmin)	2	---	0	---	2	---
Total time per tree (cmin)	39	7.2	53	13.0	38	8.3
Trees per PMH	154	---	113	---	158	---
Productivity (cunits/PMH)	7.8	22.1	10.4	20.4	7.9	22.4

OTHER COMMENTS: Flotation problems with the Kockums 880 were observed when the machine was operating in a lowland black spruce stand. The Kockums 880 had less flotation than the Clark Cable skidders.

CITATION: Folkema, M.P. 1979. THE DROTT ROTARY CUTTER FELLER BUNCHER: LONGER-TERM DATA COLLECTION FROM TWO OPERATIONS. FERIC. Technical Note No. TN-28.

MACHINE SYSTEM: Drott 40 feller-buncher equipped with 24 in. rotary cutter (or auger) head. Machine had major modifications.

OPERATOR RATING: Owner-operator had 14 months of experience on the machine.

DESCRIPTION OF SYSTEM:
Feller-buncher → Grapple skidder (JD 740) → chain-flail delimber → manual power saw delimbing.

DESCRIPTION OF OPERATION: Clearcutting. Operation produced sawlogs, pulpwood and poles, all in tree length at roadside. One partner operated the Drott auger while the other operated a John Deere 740 grapple skidder. Delimbing was performed manually or with a chain-flail delimber.

DESCRIPTION OF SITE: Near Upsala, Ontario. Terrain: sandy outwash plain, flat to very gentle rolling.

DESCRIPTION OF STAND: Mainly jack pine. Merchantable volume = 25 cunits/acre. All softwood over 13 cm DBH was harvested.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree size = 9.8 Ft^3

PRODUCTION DATA: Study Duration: 6 months

Time Distribution % of Total Time	
Productive (PMH)	63.4%
Repair and maintenance	27.5%
Non-productive operating time	2.3%
Delays	6.8%

Productivity Summary	
Trees per PMH	67
Productivity (cunits/PMH)	6.5

Breakdown Information	
Total No. of repairs	32
Mean time to repair (hr)	3.5
Mean time between repairs (based on PMH) (hr)	20.6

OTHER COMMENTS: The main factor which caused fluctuation in the number of trees harvested per PMH was the need for "brushing." The study showed that the Drott auger will not stand up to rough or careless usage.

CITATION: McMorland, B. 1985. PRODUCTION AND PERFORMANCE OF MECHANICAL FELLING EQUIPMENT ON COASTAL B.C.: TIMBCO FELLER BUNCHER WITH ROTOSAW HEAD. FERIC. Technical Note No. TN-85.

MACHINE SYSTEM: Timbco model 2518 Hydrobuncher and Rotosaw felling head. The Rotosaw is a circular-saw type felling head with a 22-inch capacity. Rubber-tired skidders (line and grapple) and a FMC with an Esco grapple. Hahn processor. Barko 250 hydraulic heel-boom loader.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-Buncher → Rubber-tired skidders → FMC 220 → Hahn processor → Barko 250 loader

DESCRIPTION OF OPERATION: Clearcut. Felled trees were skidded to roadside by the rubber-tired skidders and the FMC 220. At roadside, a Hahn processor delimbed, bucked and topped them. Then, the material was sorted by the loader and loaded.

DESCRIPTION OF SITE: Buckley Bay, Vancouver Island, B.C. 50% of the area between 0-10% slopes, 50% of area between 10-20% slopes.

DESCRIPTION OF STAND: 61% Douglas fir, 20% western red cedar, 19% western hemlock. Average DBH = 30.0 cm. Merchantable volume/ha = 520.0 m^3. Merchantable stems/ha = 898.5.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Products: Export. Hemlock and fir sawlogs: cedar; fir pulp; and hemlock pulp. Pulp sorts accounted for about 40% of total volume. Average volume/tree = 0.58 m^3.

PRODUCTION DATA: Study period: June to September 1984.

	Day Shift	Afternoon Shift	Both
Productive time ratio (productive/scheduled) (%)	64.2	68.8	65.8
Availability (%)	68.3	74.6	70.5
Volume per PMH (m^3)	35.8	34.7	35.4
Trees per PMH	61.7	59.9	61.0
Volume per shift worked (m^3)	215.9	188.7	205.3
Tree count per shift worked	372	325	354
Production per 8-hour shift: m^3	183.7	191.0	186.6
Tree count	317	329	322

OTHER COMMENTS: FERIC believes that there are at least three factors which influenced mechanical downtime in this trial: ground conditions; tree height; and stick-boom length. FERIC has been involved with other Timbco machines which have been in use longer than this, and no downtime levels of this order were encountered in a 2-month period.

CITATION: Levesque, R. 1983. SHORT-TERM EVALUATION OF THE TIMBCO 2518 FELLER-BUNCHER IN EASTERN CANADA. FERIC. Technical Note No. TN-72.

MACHINE SYSTEM: Timbco 2518 feller-buncher. Standard 56-cm wide tracks; side tilting cab; Detroit Diesel 4-tin (113 kW) engine; reinforced protective frame and a Harricana accumulator head with the accumulator arm removed.

OPERATOR RATING: Very good.

DESCRIPTION OF SYSTEM:
Feller-buncher → conventional skidders → sliding-boom delimbers

DESCRIPTION OF OPERATION: Clearcutting. Cut 15 meter wide strips at right angles with the roadside. Bunched and then piled on an axis parallel with the road.

DESCRIPTION OF SITE: 60 km North of Lebel-sur-Quevillon, Quebec. Moderately compacted snow, one meter deep, on slopes of less than 10%.

DESCRIPTION OF STAND: 72% spruce, 28% balsam fir and some white birch. Mean merchantable volume: spruce = 183.8 m^3/ha; balsam fir = 36.7 m^3/ha. Mean DBH of merchantable trees = 19.2 cm.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Mean volume per tree = 0.16 m^3

PRODUCTION DATA: Study Date: April 13 to 16, 1982.

Short-Term Study of Timbco 2518 Feller-Buncher
<u>Summary of Productivity</u>

Mean time per cycle (cmin)	70.0
Trees per cycle	2.1
Trees per PMH	180.9
Volume per PMH (m^3)	27.9

	% of Total PMH
Travel empty (%)	28
Cutting (%)	34
Travel loaded (%)	13
Piling (%)	8
Brushing (%)	6
Delays (%)	12

OTHER COMMENTS: Even without the accumulator arm, the operator was able to maintain some accumulation by holding the cut trees on the felling head while cutting new stems.

CITATION: McMorland, B. 1984. PRODUCTION AND PERFORMANCE OF MECHANICAL FELLING EQUIPMENT IN INTERIOR B.C.: HARRICANA CIRCULAR SAW. FERIC. Technical Note No. TN-74.

MACHINE SYSTEM: Harricana circular saw feller-buncher equipped with accumulator arm. Pre-production model. Modifications: grab-arm system and blade designs.

OPERATOR RATING: The operator has no previous experience with non-shear heads.

DESCRIPTION OF SYSTEM: Felling and bunching blocks of 93-151 hectares.

DESCRIPTION OF OPERATION: Clearcut. Contractor-owned operation.

DESCRIPTION OF SITE: Interior B.C. Slopes = <15%, moist soil.

DESCRIPTION OF STAND: 56% pine, 31% spruce, 8% balsam fir. Merchantable volume/ha = 282-336 m^3. Merchantable stems/ha = 686-864. Average DBH = 23.6-29.1 cm.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

	Area 1	Area 2	Area 3	Area 4	All
Average tree size (m^3)	0.46	0.52	0.40	0.38	0.44

PRODUCTION DATA: Study Duration: July 27 to December 23, 1982.

<u>Time and Production Summary for Shifts Worked</u>

	Area 1	Area 2	Area 3	Area 4	All
Productive time ratio (%)	69.2	71.5	74.7	68.9	71.2
Availability (%)	75.0	76.3	83.4	72.7	77.4
Volume per PMH (m^3)	39.4	56.1	45.0	45.7	44.7
Trees per PMH	85.7	107.8	112.5	120.3	101.7
Volume per shift worked (m^3)	252.6	365.3	282.1	256.5	280.9
Tree count per shift worked	549	703	705	675	639
Production per 8-hour shift: m^3	217.3	321.1	268.7	253.3	255.4
Trees	472	618	671	667	581

OTHER COMMENTS: Repair time heavily influenced by unexpected turntable and engine repairs.

CITATION: Giguere, P. 1982. SHORT-TERM EVALUATION OF THE "A-HEAD" FELLING HEAD WITH ACCUMULATOR. FERIC. Technical Note No. TN-59.

MACHINE SYSTEM: "A-Head" shear felling head with accumulator mounted on a front-end loader (Hydro - Axe 411) carrier. It is equipped with accumulators designed for use in small-tree stands. Machine had been on trial for 5 months.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: The felling head is front-mounted. The entire machine must move to each tree to position the head for shearing. By replacing the felling head with a flail delimbing head, the same carrier was used for both felling and delimbing operation.

DESCRIPTION OF OPERATION: Clearcutting. The machine cut each swath by means of a series of narrow adjoining strips. Each was oriented perpendicular to the direction of the swath. Delimbing was done when a sufficient number of trees had been felled.

DESCRIPTION OF SITE: Limits of Bowater, Newfoundland. Temperature = 5°C.

DESCRIPTION OF STAND: Trees harvested were mostly small black spruce.

	Trees/Hectare	Butt Diameter (cm)
Stand 1	1700	15.2
Stand 2	2600	14.7
Stand 3	3200	12.5

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

	Volume/Tree (m^3)
Stand 1	0.103
Stand 2	0.094
Stand 3	0.061

PRODUCTION DATA: Two-day study on Oct. 29 & 30, 1980.

	Stand 1	Stand 2	Stand 3	Combined
Productive Time per cycle				
Moving empty & shearing (cmin)	68	79	91	85
Moving within stand (cmin)	53	67	102	87
Moving for piling and piling (cmin)	52	50	62	54
Delays (cmin)	2	4	4	4
Total time (cmin)	176	199	258	230
Productivity				
Total number of trees	57	295	783	1135
Total number of cycles	12	47	87	146
Trees per cycle	4.7	6.3	9.0	7.8
Trees per PMH	161	189	209	203
Volume per PMH (m^3)	16.7	17.8	12.7	14.5

Regression Equations

$$\text{Trees/PMH} = 52.5 + \frac{2037}{MBD} \qquad r^2 = 0.35$$

where MBD = mean butt diameter, cm

$$\text{Volume/PMH}(m^3) = 87.5 - \frac{1590}{MBD} + \frac{3882}{(MBD)^2} \qquad r^2 = 0.76$$

where MBD = mean butt diameter, cm

OTHER COMMENTS: The percentage gain in productivity, attributed to the use of an accumulator, drops with increasing tree size. The felling head impedes operator visibility, especially if the head contained several trees with branches all the way down to the butt.

CITATION: Forrester, P. 1980. EVALUATION OF THE BRODY-EVERETT CLIPPER. FERIC. Technical Note No. TN-37.

MACHINE SYSTEM: 20-inch Brody-Everett clipper, a two-knife shear head for felling or felling/bunching, mounted on a Drott 50 excavator.

OPERATOR RATING: Operator had operated the clipper head for 3 weeks when the detailed timing was done. Operated the Drott for 6 months with a different head.

DESCRIPTION OF SYSTEM:
Feller-buncher → skidders.

DESCRIPTION OF OPERATION: Clearcutting. 11 hour shift.

DESCRIPTION OF SITE: Mackenzie, B.C. Daytime temperatures -18°C. About 16 inches of crusted snow lay on the ground. Slopes: +7% to -9%.

DESCRIPTION OF STAND: Predominantly spruce. Average DBH = 9.7 in. Merchantable stems/acre = 319. Unmerchantable stems/acre = 102. Volume = 56 cunits/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average volume/tree = 18 Ft^3

PRODUCTION DATA: Evaluations were conducted in February and March 1980.

Productivity of Brody-Everett Clipper

Felling cycle (min)	0.39
Brushing & delays (min)	0.08
Total time/tree (min)	0.47
Average Trees/bunch	6.7
Trees/PMH	104.64
Volume/PMH (cunits)	18.1
Repair & service hours/100 PMH	12.6

OTHER COMMENTS:

CITATION: McMorland, B. 1980. NON-SHEARING FELLING HEADS. FERIC. Technical Note No. TN-34.

MACHINE SYSTEM: Drott auger-buncher equipped with accumulator arms. The auger head was mounted on a Drott 40LC (wide gauge) logger. 24 inch capacity. 5 months old.

OPERATOR RATING: The operator was experienced with shear-bunchers and had worked with the auger from the time of its arrival.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. Only winter data is available.

DESCRIPTION OF SITE: Crankbrook, B.C. Terrain was flat. Good weather. Temperature = 0°C. Snow = 6 inches.

DESCRIPTION OF STAND: 60% pine, with the balance composed of larch, spruce and balsam fir. Average DBH = 8.8 in. Merchantable stems/acre = 365. Unmerchantable stems/acre = 30. Cunits/acre = 56.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume/tree = 15 Ft^3

PRODUCTION DATA:

Detailed Time Study Results and Productivity

	Winter
Felling cycle (%)	92
Brushing (%)	6
Delays (%)	2
Felling cycle (minutes)	0.48
Average trees/bunch	5.0
Trees/PMH	125.0
Volume/PMH (cunits)	18.1

Shift-Level Study Results
Production, Productivity and Mechanical Downtime

	Winter
Average volume/tree (Ft^3)	19.7
Trees/PMH	82.0
Volume/PMH (cunits)	16.2
Average PMH/Shift worked (hours)	6.4
Trees/shift worked	521
Volume/shift worked (cunits)	102.6
Repair and Service hours/100 PMH	32.7

OTHER COMMENTS: The accumulator arms on the Cranbrook auger were useful under the conditions observed although no more than two trees were accumulated. It appeared to be difficult to gather a third tree without one falling out.

CITATION: Folkema, M.P. 1984. CIRCULAR SAW AND CONE SAW FELLING HEADS: AN UPDATE. FERIC. Technical Report No. TR-56.

MACHINE SYSTEM: Harricana circular saw mounted on a leased Timbco 2518 tracked carrier. Head weighted 2500 kg. 50-cm capacity. Side tilt (wrist) cylinder. "Standard" version. Production unit. Timbco stick boom was shortened by 0.58 m.

OPERATOR RATING: There were 6 or 7 different operators.

DESCRIPTION OF SYSTEM: Felled and bunched trees.

DESCRIPTION OF OPERATION: Clearcut.

DESCRIPTION OF SITE: About 40 km North of Timmins, Ontario. Terrain: typical clay belt; flat ground with no rocks.

DESCRIPTION OF STAND: Stands: even-age black spruce.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree volume = 0.150 m^3

PRODUCTION DATA: Study Period: August 1982 to February 1983.

Shift Level Study Results: Harricana Circular Saw Head

Total scheduled hours	2,248.3
Mechanical availability (%)	69
Utilization (%)	59
Volume per tree (Ft^3)	53
Trees per PMH	102
Productivity (cunits/PMH)	5.4

OTHER COMMENTS: The lift capacity of the Timbco was inadequate with the Harricana circular saw head (2,500 kg). There were major structural failures in the boom, turntable and frame.

CITATION: McMorland, B. 1980. NON-SHEARING FELLING HEADS. FERIC. Technical Note No. TN-34.

MACHINE SYSTEM: Drott auger-buncher without accumulator arms. The auger head was mounted on a Drott 40LC (wide gauge) logger. 24 inch capacity.

OPERATOR RATING: Summer: Operator was experienced with a shear-equipped Drott 50LC, but had run the auger for only 8 weeks.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: Vanderhoof, B.C.
Summer: Slopes = -10 to +7%. Good weather with only slight amounts of rain.
Winter: Slopes = -8 to +7%. Excellent weather conditions. Temperature ranged from 0°C to -25°C. Powder snow to a depth of 2 feet.

DESCRIPTION OF STAND: Summer: Stand consisted of Lodgepole pine with small amounts of spruce and balsam fir. Avg. DBH = 11.2 in. Merchantable stems/acre = 175; unmerchantable stems/acre = 15; cunits/acre = 40. Winter: Mature spruce and pine, balsam fir understory. Avg. DBH = 9.5 in. Merchantable trees/acre = 436; unmerchantable trees/acre = 31; cunits/acre = 85.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Summer: Volume/tree = 23 Ft^3
Winter: Volume/tree = 20 Ft^3

PRODUCTION DATA:

Detailed Time Study Results and Productivity

	Summer	Winter
Felling cycle (%)	95	88
Brushing (%)	4	9
Delays (%)	1	3
Felling cycle (minutes)	0.80	0.93
Average trees/bunch	3.0	6.6
Trees/PMH	75.0	64.5
Volume/PMH (cunits)	17.3	12.9

Shift-Level Study Results Production, Productivity and Mechanical Downtime

	Summer	Winter
Average volume/tree (Ft^3)	21.1	17.9
Trees/PMH	69.9	39.8
Volume/PMH (cunits)	14.7	7.1
Average PMH/shift worked (hours)	4.7	6.6
Trees/shift worked	332	263
Volume/shift worked (cunits)	69.9	47.0
Repair and service hours/100 PMH	63.7	39.2

OTHER COMMENTS: The head has no capability for lateral rotation (wrist, or sideways motion). Upper gripper-arms do not grip small trees, but only contain them.

CITATION: McMorland, B. 1980. NON-SHEARING FELLING HEADS. FERIC. Technical Note No. TN-34.

MACHINE SYSTEM: Albright Buncher Mark III, 24 inch. Mounted on a Caterpillar 225 equipped with a Cat 235 undercarriage. The head was modified by the manufacturer from time to time during the study.

OPERATOR RATING: Summer: The operator had 3 weeks' experience on the machine. Winter: A new operator who had been with the machine for 8 weeks.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: Houston, B.C.
Summer: Slopes = -6 to +6%. Minor swamps existed but did not impede machine movement. Winter: Slopes = +10 to +16%. Weather conditions were good. Average temperature = -7°C. Loose snow = 2 to 3 feet. Wood was frozen to about a 3-in. depth.

DESCRIPTION OF STAND: Summer: Timber species consisted of spruce and pine. Merchantable stems/acre = 526; unmerchantable stems/acre = 108; cunits/acre = 80; average DBH = 9 in. Winter: Pine and spruce, some small balsam fir. Average DBH = 9.9 in.; merchantable stems/acre = 283; unmerchantable stems/acre = 20; cunits/acre = 68.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Summer: Average volume/tree = 15 Ft^3
Winter: Average volume/tree = 24 Ft^3

PRODUCTION DATA:

Detailed Time Study Results and Productivity

	Summer	Winter
Felling cycle (%)	67	85
Brushing and Delays (%)	33	15
Total time/tree (minutes)	1.50	0.89
Average trees/bunch	4.6	6.0
Trees/PMH	40.0	67.4
Volume/PMH (cunits)	6.0	16.2

Shift-Level Study Results Production, Productivity and Mechanical Downtime

	Summer	Winter
Average volume/tree (Ft^3)	19.1	21.9
Trees/PMH	60.5	52.6
Volume/PMH (cunits)	11.6	11.5
Average PMH/shift worked hours	3.1	4.1
Trees/shift worked	187	215
Volume/shift worked (cunits)	35.7	47.1
Repair and service hours/100 PMH	78.6	104.4

OTHER COMMENTS:

CITATION: Johnson, L.R. 1988. SUMMARY OF PRODUCTION AND TIME STUDIES OF MECHANIZED HARVESTING EQUIPMENT IN THE INTERMOUNTAIN WEST. Forest Products Department, University of Idaho (Unpublished).

MACHINE SYSTEM: Caterpillar Model 227 with 20 inch rotosaw.

OPERATOR RATING: Experienced.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. End product was chunkwood for energy.

DESCRIPTION OF SITE: Slopes ranged from 0 to 30%, averaging 12%.

DESCRIPTION OF STAND: Stagnant lodgepole pine stand consisting of 5,028 trees per acre. The average tree was 4.7 inches in diameter and 44 feet tall.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Diam. (in.)	Freq.	Diam. (in.)	Freq.	Diam. (in.)	Freq.
3	25	7	572	11	47
4	213	8	303	12	35
5	565	9	112	13	13
6	833	10	89	14	3

PRODUCTION DATA:

Time Distribution	
Swing and move	33.8%
Saw and bunch	49.2%
Extra moves	5.8%
Delays	11.2%
	100%
Utilization (%)	88.8

Production Statistics	Avg.	SD
Pieces/turn	1.38	0.51
Minutes/delay	1.33	---
Average diameter (in.)	6.485	1.737
Distance moved (ft.)	12.551	8.034
Pieces/turn	1.38	0.51
Pieces/cycle	7.597	4.365
Trees/productive hour	158.8	
Trees/scheduled hour	141.0	

Regression Equation: Trees/PMH = 179.7 - 8.96 (move distance) + 0.183 (move distance)^2 + 86.65 LN (pieces/turn) [$R^2 = 0.27$]

OTHER COMMENTS:
Cycle = all felling and bunching activity at a single location.
Turn = all felling and bunching activity.

CITATION: Lanford, B.L. and Sirois, D.L. 1983. DRIVE-TO-TREE, RUBBER-TIRED FELLER BUNCHER PRODUCTION STUDIES. USDA Forest Service. Southern Forest Experiment Station. General Technical Report SO-45.

MACHINE SYSTEM:
1) **Franklin 170 XLN with Morbark 15 inch shear**
2) **John Deere 544 with Morbark 15 inch shear**
3) **John Deere 544 with Rome 20 inch shear**
4) **Hydro Ax 511 with Morbark 20 inch shear**

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Study focused on drive-to-tree, rubber-tired, feller-bunchers.

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: Coastal plain and lower piedmont sites in Georgia, Florida and Mississippi.

DESCRIPTION OF STAND: Southern Yellow Pine

Machine	1	2	3	4
Trees/acre	565	515	384	336
Cunits/acre	11	25	31	24

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Machine	1	2	3	4
DBH (in.)	5.9	6.8	8.2	7.9
Trees/accumulation	3.1	2.0	2.0	1.7
Volume/accumulation	9.4	12.1	17.8	13.5

PRODUCTION DATA:

Machine	1	2	3	4
Productive minutes/tree				
Average	.55	.28	.41	.29
Range	.22-1.77	.12-1.02	.13-1.34	.11-.72
Average trees/PMH	109	214	146	207
Average cunits/PMH	3.3	13.0	13.0	16.4
Number of trees	86	93	220	275

OTHER COMMENTS:

CITATION: Selby, J.S. and J.D. Jolley. 1986. RECENT RESEARCH AND DEVELOPMENT WORK WITH FELLING AND DELIMBING IN THE WEYERHAEUSER COMPANY USA. Non-Published Paper Presented at the IUFRO World Congress, Yugoslavia. September 1986.

MACHINE SYSTEM: Koehring K4FB Feller-Buncher with Weyerhaeuser circular saw felling head.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
(1) Koehring K4FB feller-buncher → (4) John Deere 740 (or Cat 528) grapple skidders → Koehring 620 slide-boom delimber.

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: Oklahoma. Hard rocky soils with slopes <30%.

DESCRIPTION OF STAND: Natural mixed species; 76 m^3/ha of pine; 14 m^3/ha of hardwoods. Average pine DBH = 25 cm; Average pine height = 15 m.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree = 0.24 m^3

PRODUCTION DATA:

Mechanical availability (%)	85
Utilization (%)	85
Productivity (m^3/PMH)	50
(Trees/PMH)	208

OTHER COMMENTS:

CITATION: Ward, R.E., et al. 1984. FIELD STUDIES AND ANALYSIS OF A FELLER-BUNCHER OPERATION. *IN* Proceedings, Mountain Logging Symposium, West Virginia University. June 5-7, 1984. pp. 229-242.

MACHINE SYSTEM: National Hydro-Ax Series 511 prime mover with a Morbark 20 inch feller-buncher attachment.

OPERATOR RATING: 4 years with machine.

DESCRIPTION OF SYSTEM:
(1) Feller-buncher → (4) Cable skidders → (1) Grapple skidder → (1) Bulldozer → (1) Chipper

DESCRIPTION OF OPERATION: Clearcutting. Feller-buncher operator would arrive one week early and begin operating. The rest of the crew would arrive later, and cable skidders would skid material to within 40 yards of the chipper.

DESCRIPTION OF SITE: Ohio.

DESCRIPTION OF STAND: Mixed hardwood consisting of hickory, sassafras and oak. The average DBH was 8 inches, and ranged from 4.5 to more than 16 inches. Tree height averaged 57 feet, and ranged from 21 to 80 feet.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: Pulpwood was the only product.

PRODUCTION DATA:

Regression Equation:
Cycle Time/Tree (cmin) = .3658 + .2765 (No. trees cut per cycle) [$R^2 = 0.23$]

Cycle Time Study	Avg.	N	SD	Min	Max
Cycle time	0.7902	675	0.4364	0.06	2.8
Trees/cycle	1.5689	675	0.7719	1.0	6.0

Average Productivity: 86 tons/PMH

OTHER COMMENTS: Low production was blamed on adjacent property which could not sustain any damage.

CITATION: Anon. 1976. DROTT 40 LC FELLER BUNCHER, MACHINERY EVALUATION. Logging Industry Research Association, New Zealand. Vol. 1., No. 4, pp. 1-4.

MACHINE SYSTEM: Basic carrier is Drott track-type excavating machine, with 150 HP engine, twin shear felling head with 61 cm opening, and an accumulator attachment.

OPERATOR RATING: Unexperienced.

DESCRIPTION OF SYSTEM: Following the feller-buncher, delimbing was done by a Vulcan chain-flail on the Clark Ranger 666 carrier. The Clark Ranger 667 grapple skidder forwarded the tree lengths to the landings.

DESCRIPTION OF OPERATION: Clearfelling, with the feller-buncher progressing around the stand felling a five-row width strip, and then bunching the trees with tops spread to facilitate delimbing.

DESCRIPTION OF SITE: Generally flat.

DESCRIPTION OF STAND: Ponderosa pine, planted 1934. Light vegetation.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Stocking was 1,245 stems/ha, ranging from 840 to 1,581. Merchantable volume/ha (to 7 cm top) was 208 m^3. Mean height was 15.3 m, mean DBH was 19 cm, and mean stem volume was 0.20 m^3.

PRODUCTION DATA:

Trees Accumulated	Avg. Volume/Tree (m^3)	Cycle time/tree (min)
1	0.25	0.38
2	0.12	0.40
3	0.11	0.39

Productivity: 110 trees/PMH

OTHER COMMENTS: This machine must always be used as a part of a highly mechanized system in which subsequent phases of harvesting benefit from precise directional felling and bunching.

CITATION: Sarna, R.P. 1976. CATERPILLAR 225 WITH FELLER-BUNCHER IN MAINE. American Pulpwood Association. 76-R-40.

MACHINE SYSTEM: Caterpillar 225 hydraulic excavator with a Harricana shear head attached. Maximum shear butt diameter = 20" (softwood). Modifications included a "heel boom" device for more support while swinging.

OPERATOR RATING: After the operator had 8.02 hours of experience, production went from 99.81 to 188.31 trees/machine hour.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcut. Method 1: Cut and dropped trees in front of the machine at a 10-20° angle to the right of center. Method 2: Cut and dropped trees behind the machine 160° to 170° left of center.

DESCRIPTION OF SITE: Near Ashland, Maine. Consisted largely of swamp and rock intermingled.

DESCRIPTION OF STAND: Spruce/fir stand. No. of merchantable softwoods stems/acre = 277.90. No. of merchantable hardwood stems/acre = 28.33. Unmerchantable stems/acre = 68.00. Average volume = 36 cords/acre. Merchantable volume = 28 cords/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
No. of stems/cord = 10.35

PRODUCTION DATA:

Summary of the Six Days of Operation

Total No. of scheduled hours	42.45	Production of
Availability (%)	88	Method 1: 194 stems/hr
Avg. No. of merchantable softwood/hour	129.13	Method 2: 120 stems/hr
Avg. No. of merchantable hardwood/hour	13.16	
Avg. No. of unmerchantable stems/hour	31.60	
Total No. of trees per hour	173.89	

OTHER COMMENTS: The wood was not bunched during these tests.

CITATION: Sarna, R.P. 1976. KOCKUMS 880 ON TRIAL AT GREAT NOTHERN IN MAINE. American Pulpwood Association. 76-R-22.

MACHINE SYSTEM: Kockums 880 Tree King feller-buncher with a boom mounted 50 cm shear.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Method 1: Strip cutting leaving the trees with their tops toward the road. Method 2: Strip cut with the butts toward the road.

DESCRIPTION OF OPERATION: Clearcut.
Method 1: Strip cutting leaving the trees with their tops toward the road.
Method 2: Strip cutting with the butts placed toward the road.

DESCRIPTION OF SITE: Millinocket, Maine. A solid bottom consisting of clay, rock, or firm sand was 1.5 to 2.5 feet under the surface.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Study Period: November 21 - December 11, 1975.

Productivity of Kockums 880 F-B		
Operational hours (%)	63.3	
Non mechanical delays (%)	6.3	
Moving (between settings) (%)	3.6	
Repairs (%)	13.2	
Service (%)	10.3	
Wait for parts and mechanic (%)	3.3	
Productivity (trees/hour)		
Method 1 (tops toward road)	183	(smaller tree size)
Method 2 (butts toward road)	206	(larger tree size)

OTHER COMMENTS: The production in terms of trees cut per hour was lower for the site with the smaller average tree size. This was apparently due to the operator having to make more decisions about which trees to cut.

CITATION: Powell, L.H. 1974. EVALUATION OF NEW LOGGING MACHINES: CATERPILLAR 950 TREE-LENGTH HARVESTER. Pulp and Paper Research Institute of Canada. Logging Research Reports LRR/54.

MACHINE SYSTEM: Caterpillar 950 tree-length harvester.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-Buncher → Grapple Skidder

DESCRIPTION OF OPERATION: Clearcutting. Tree length operation with the Cat 950 and two Beloit H-14 harvesters felling and limbing trees. Bunched tree lengths skidded to roadside by a Volvo SM-868 and Lokomo grapple skidders.

DESCRIPTION OF SITE: Northern Quebec. Terrain was flat to slightly rolling with clay soils. Slopes averaged 4%. Snow depth was 24 inches.

DESCRIPTION OF STAND: Major species were black spruce and jack pine.

	Avg.	SD	Range
Cu. Ft. Vol/tree	6.0	4.6	0.1-25.1
Merch. trees/acre	692	251	400-1234
Unmerch. trees/acre	53	63	0-290

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: N = 325 Trees.

Regression Equation:

Harvest time per tree = $31 + 0.71\ S^2 + 22\ NT + 0.23\ D + 2.3\ V$ $[R^2 = .44]$

Where: S = Slope in direction of travel, %
D = Distance from stump to bunch, Ft.
NT = Number of trees harvested at one time
V = Volume per tree, cu. ft.

Time Distribution	
Move empty (%)	23
Position & shear (%)	14
Move & process (%)	58
Brush & delay (%)	5

	Avg.	SD	Range
Time per tree	86 cmin	21 cmin	80-180 cmin

Average Productivity = 4.2 cunits/PMH

Sample size = 700 trees

OTHER COMMENTS:

CITATION: Powell, L.H. 1975. FORANO BJ-20 FELLER-BUNCHER. Pulp and Paper Research Institute of Canada. Logging Research Reports LRR/62.

MACHINE SYSTEM: (2) Forano BJ-20 feller-buncher with 20 inch shear, mounted on a felling boom.

OPERATOR RATING: One was fast and one was slow. The results were combined.

DESCRIPTION OF SYSTEM:
(2) Forano BJ-20 feller-bunchers → Kockums 875-78 ATK Processor → Kockums 875-66 forwarder.

DESCRIPTION OF OPERATION: Clearcut. Full trees were felled and bunched at the stump by the Forano BJ-20. The full trees were then limbed and bucked to 8 foot lengths by a Kockums 875-78 ATK processor. The piles of pulpwood were then forwarded to the roadside with a Kockums 875-66 forwarder.

DESCRIPTION OF SITE: December in Nova Scotia. The study area was rolling and the soil was dry and unfrozen. Slopes ranged from 0-15% and averaged 5%.

DESCRIPTION OF STAND: Major Species: black spruce, balsam fir.

	Average	SD	Range
Volume (Ft^3)	3.7	4.3	0.8-28.4
Merch. Trees per acre	644	233	243-1133

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: 8 ft. pulp bolts.

PRODUCTION DATA:

<u>Time Distribution</u>

Moving in stand (%)	12
Felling cycle (%)	72
Delay (%)	7
Brushing (%)	9

<u>Productivity (Average)</u>

5.16 cunits/PMH

<u>Harvesting Time per Tree</u>

Time (cm) = 32 + 15 S + 0.6 VT¹ [$R^2 = 0.21$]
where: S = 1 for slow operator, 0 for fast operator
VT¹ = Volume per tree, Ft^3

Mean = 43 cmin SD = 16.5 cmin Range = 11-120 cmin

OTHER COMMENTS:

CITATION: McCormack, B. 1976. 'BOBCAT' FELLER BUNCHER. CSIRO Harvesting Research Group, Australia. Machine Evaluation No. 5.

MACHINE SYSTEM: Clark-Melroe Bobcat, powered by a John Deere four-cylinder diesel engine (61 kW or 82 hp). Equipped with a Morbark felling head, with a lift capacity of 1,800 kg.

OPERATOR RATING: The operator had only a few hours of experience.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: Gippsland, Victoria, Australia. Average slopes were 5° or less.

DESCRIPTION OF STAND: *Eucalyptus regnans* & *E. sieberi* (silvertop ash). Average stem volume = 0.22 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:
Average trees felled per hour = 73

OTHER COMMENTS: A test on mixed species (predominantly silvertop ash) produced similar results. The machine was working on slopes up to 14°, but would work more comfortably on slopes less than that.

CITATION: MacDonald, A.J. 1990. A CASE STUDY OF ROADSIDE LOGGING IN NORTHERN INTERIOR OF BRITISH COLUMBIA. FERIC. Technical Report No. TR-97.

MACHINE SYSTEM: Two Cat FB 227 feller-bunchers.
FB 227 #1 (1986): Levelling cab and a Koehring 51 cm diameter circular saw felling head.
FB 227 #2 (1981): Non-levelling cab and a 51 cm diameter home-made rim-driven felling head.

OPERATOR RATING: Both fully experienced.

DESCRIPTION OF SYSTEM:
Cat FB 227 feller-buncher → (3) Cat 528 grapple skidders → (1) Lim-mit processor → Cat LL229 loader

DESCRIPTION OF OPERATION: Feller-bunchers clearcut the trees, which were then grapple skidded to the roadside for limbing and topping. The trees were then loaded tree-length on off-highway trucks.

DESCRIPTION OF SITE: 75 km South of Houston, B.C. Terrain rolling with occasional guillies or steeper ground. Average slope 8%. Road density 58 m/ha.

DESCRIPTION OF STAND:

	Large wood area	Smallwood area
Average tree size (m^3)	0.86	0.24
Stems/ha merch.	388	976
unmerch.	77	13
Average tree diameter (cm)	35.8	10.7
Species distribution (%) Pine	32	97
Spruce	47	2
Balsam fir	21	1

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Butt diameter class (cm)	% Distribution by class	Tree volume (m^3)
10	4	0.08
20	56	0.21
30	30	0.52
40	9	1.07
50	1	2.04
ALL	100	0.41

PRODUCTION DATA:

	FB 227 #1	FB 227 #2
Production (m^3)	21,270	14,569
Production (stems)	40,607	27,813
Production shifts	48	43
PMH (hr)	395.5	346.2
m^3/PMH	53.8	42.1
Stems/PMH	103	80
SMH (hr)	500.6	473.9
Utilisation (%)	79	73
Production/8 hr shift (m^3)	340	246

OTHER COMMENTS: When harvesting the smallwood area, the feller-bunchers were unable to provide sufficient inventory for the rest of the system to operate at full capacity. FB 227 #1 had poor mechanical availability and its performance is not representative of its productive potential.

CITATION: Levesque, R. 1985. EVALUATION OF THE KOEHRING K2FF FELLER FORWARDER. FERIC. Technical Note No. TN-80.

MACHINE SYSTEM: Prototype Koehring K2FF feller-forwarder with a 510 mm circular saw accumulator head (prototype). Can handle trees 18 meters in length and 16,000 kg in weight. Firestone 29.5" x 35" tires, also 29.5" x 35" tires. All were equipped with traction chains. Koehring K266 delimbers, boom similar to Logma 310.

OPERATOR RATING: A new operator on the K2FF managed to adapt within a month and bring productivity back to its normal level.

DESCRIPTION OF SYSTEM:
(1) Feller-forwarder → (2) Koehring K266 delimbers.

DESCRIPTION OF OPERATION: Clearcutting. Machine felled and forwarded full trees. Machine was driven empty to the end of the forwarding distance, and then cut a 10-meter strip back toward the road.

DESCRIPTION OF SITE: Near Portage in Northern Maine. Terrain: mostly rolling with slopes rarely steeper than 25%.

DESCRIPTION OF STAND: 30% red spruce, 70% balsam fir. Merchantable volume of softwoods per hectare varied from 16 to 175 m^3/ha.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Merchantable volume per tree = 0.206 m^3.
Product was tree length pulpwood.

PRODUCTION DATA:

Time Distribution	
Productive machine hours	59.4%
Repair & maintenance	34.0%
Non-productive	2.2%
Delays	4.4%

Operational Summary	
Average maximum forwarding distance (m)	400
Trees per hour	71
Productivity (m^3/PMH)	14.6
Mechanical availability (%)	70
Utilization (%)	59
Utilization of total time (%)	59

Details on Repairs	
Productive machine hours (PMH)	2,128
Total number of repairs	208
Mean time between repairs (hr)	10.2
Average repair time per occurrance (hr)	2.1

OTHER COMMENTS: The most critical areas for repairs were the hydraulic and electrical systems and the felling head.

CITATION: Levesque, R. 1985. EVALUATION OF THE KOEHRING K2FF FELLER-FORWARDER. FERIC. Technical Note No. TN-80.

MACHINE SYSTEM: Prototype Koehring K2FF feller-forwarder with a 510 mm circular saw and an accumulator head (prototype), an 8.8 meter wheelbase. It can take trees up to 18 meters in length. 39.5" x 35" goodyear tires and traction chains. A Caterpillar 3208 engine (150 kW). 16,000 kg capacity.

OPERATOR RATING: Experienced operator.

DESCRIPTION OF SYSTEM: Block 1: cut a strip about 10 metres wide next to the stand and move at right angles with the roadside where the operator would finally unload.

DESCRIPTION OF OPERATION: Clearcutting. Block 1. Operator would drive the unloaded machine over a predetermined forwarding distance. He would then begin to cut a strip 10 meters wide next to the stand and move at right angles to the roadside where he would later unload. Block 2. The strip was cut by entering the stand from roadside. To unload, the operator had to back up loaded, turn towards the roadside, and then position the machine.

DESCRIPTION OF SITE: Northern Maine, USA.
Block 1: A regular and flat area, sandy loam, drainage varied from average to poor.
Block 2: A sandy area, drainage was good. 12% slope. Block 2 (roadside): Flat.

DESCRIPTION OF STAND: Red spruce, white spruce, balsam fir, dead softwood and hardwood (except block 1). Block 1: Stems/ha = 2304; m^3/ha = 247.3; mean DBH of softwood = 17 cm (alive), 12 cm (dead). Block 2: Stems/ha = 813; m^3/ha = 128.2; mean DBH of softwood = 18 cm (alive), 11 cm (dead).

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
All pulpwood

PRODUCTION DATA: Study period: June 13 - June 17, 1983

		Block 2	
	Block 1	Roadside	Long-Distance
Maximum forwarding distance, (m)			
- Empty	369	10	412
- Loaded	319	79	405
Forwarding distance (m)	344	45	408
Travel speed (km/hr)	2.8	2.0	2.0
DBH per harvested tree (cm)	15	15	16
Volume per harvested tree (m^3)	0.11	0.14	0.16
Trees per load	95	70	62
Volume per load (m^3)	9.8	9.9	10.0
Productivity (m^3/PMH)	10.9	14.2	8.6

OTHER COMMENTS: Using the circular saw felling head led FERIC to conclude that the softwood cutting time was basically the same whatever the diameter (8-42 cm) and that the variation observed had nothing to do with the diameter of the trees.

CITATION: Heidersdorf, E. 1978. THE KOEHRING FELLER-FORWARDER LONG-TERM DATA COLLECTION FROM TWO HARDWOOD OPERATIONS. FERIC. Technical Note No. TN-20.

MACHINE SYSTEM: Koehring feller-forwarder, Morbark model 22 Chiparvestor.

OPERATOR RATING: Both of the operators had 8 months of experience on the KFF at the start of the study.

DESCRIPTION OF SYSTEM: KFF felled, forwarded, and dumped hardwood at roadside for later chipping with a Morbark Chiparvester.

DESCRIPTION OF OPERATION: Clearcutting. Producing whole tree chips. A large pocket of pure softwood was left for conventional cutting.

DESCRIPTION OF SITE: Northern Quebec. The terrain was gently rolling with occasional lowland areas.

DESCRIPTION OF STAND: Species cut were predominantly white birch and poplar along with about 15% softwood.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Avg. volume/tree = 4.0 Ft^3

PRODUCTION DATA: Study Period: July - November 1977.

Time Distribution: Percent of Total Time		Productivity Summary - KFF	
Productive (PMH)	68.7%	Tree size (Ft^3)	4.0
Repair & maintenance	16.9%	Trees per PMH	142
Non-productive	2.4%	Productivity (cunits) per PMH	5.7
Delays	12.0%		
Availability (%)	83		
Utilization (%)	69		

OTHER COMMENTS: Major mechanical problems with the machine resulted from the failure in hydraulic system, overheating of the engine and drive system.

CITATION: Heidersdorf, E. 1978. THE KOEHRING FELLER-FORWARDER: LONG-TERM DATA COLLECTION FROM TWO HARDWOOD OPERATIONS. FERIC. Technical Note No. TN-20.

MACHINE SYSTEM: Koehring feller-forwarder. Morbark model 22 Chiparvestor.

OPERATOR RATING: Both operators had only 1 month experience at the start of the study.

DESCRIPTION OF SYSTEM: KFF felled, forwarded and dumped at landings for immediate chipping with a model 22 Morbark chipper.

DESCRIPTION OF OPERATION: Clearcutting. Operation produced whole tree chips (hardwood and softwood) and sawlogs.

DESCRIPTION OF SITE: Central New Brunswick. Terrain: flat to rolling (up to 30% slope), with some wet areas.

DESCRIPTION OF STAND: Area 1: mixed stand of hard maple, beech, yellow birch and some softwoods. Area 2: primarily hard maple and white birch, with about 20% softwood content (mostly balsam fir). Merchantable stems = 400/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree volume = 7.2 Ft^3

PRODUCTION DATA: Study Duration: 6 months

Time Distribution: Percent of Total Time		Productivity Summary - KFF	
Productive (PMH)	70.2%	Tree size (Ft^3)	7.2
Repair & maintenance	24.3%	Trees per PMH	93
Non-productive	2.2%	Productivity (cunits)	
Delays	3.3%	per PMH	6.7

Availability (%)	79
Utilization (%)	73

OTHER COMMENTS: Mechanical downtime on the machine was largely associated with the modification campaign.

CITATION: Sarna, R.P. 1976. KOEHRING FELLER-FORWARDER - MODEL KFF. American Pulpwood Association. 76-R-28.

MACHINE SYSTEM: Koehring model KFF feller-forwarder with multiple tree accumulating shear and an integral dumping bunk. Payload capacity = 50,000 lbs. Pre-production model.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcut. Whole tree system, trees were felled, accumulated and forwarded to the roadside.

DESCRIPTION OF SITE: Maine.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Summary of Timing and Productivity of KFF

	Trial 1	Trial 2	Trial 3	Average
Total travel distance (ft)	1458	1806	1044	1436
Total travel time (min.)	10:18	11:56	6:04	9:26
Loading time (min.)	50:02	34:53	43:53	42:56
Maneuver and unloading (min.)	4:00	3:54	4:56	4:16
Total time per load (min.)	64:20	50:43	54:53	56:38
Trees per cord	16	11	11	12.67
Trees per load	130	83	107	107
Cords per load	8.12	7.54	9.73	8.46
Cords per hour	7.57	8.92	10.64	8.96

OTHER COMMENTS: Can carry its loads up grades to 40%.

CITATION: Sterle, J.R. 1973. CAT 950 TREE HARVESTER. American Pulpwood Association. 73-R-13.

MACHINE SYSTEM: Cat 950 tree harvester. Attachment: single blade - 18" (maximum) shear. A segmented chain moves the tree through the limbing knife arrangement. The tree shears are used to buck the tree.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Harvester → Franklin 132 XL grapple skidder → Husky 141 loader.

DESCRIPTION OF OPERATION: Clearcut. Company operation. 7-man crew.

DESCRIPTION OF SITE: Near Jesup, Georgia. Flat, moderate underbrush with some flotation problems.

DESCRIPTION OF STAND: Natural slash pine with mixture of longleaf. Average DBH = 9 in. Volume = 10-15 cords/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: Produced tree length pulpwood.

PRODUCTION DATA: Study Period: August 22 - December 29, 1972

Cat 950 Tree Harvester Performance	
Machine availability (%)	72
Utilization (%)	75.6
Production per operating hour (cds/hr)	8.53

OTHER COMMENTS: Most of the trees had very few limbs except at the very top, thus the tree harvester was primarily used as a feller-buncher.

CITATION: Upton, R.W. 1972. KOEHRING HARVESTERS AT WORK ON CAPE BRETON HIGHLAND PLATEAU. Pulp and Paper Canada. 73(12):111, 113.

MACHINE SYSTEM: (2) Koehring Waterous harvesters.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. Harvester shears, limbs, tops, and bucks the material into 8 foot bolts. When a 7 cord load is obtained, the harvester forwards the wood to a predetermined area and piles the wood for later truck loading.

DESCRIPTION OF SITE: Cape Breton Highland Plateau. Severe climate.

DESCRIPTION OF STAND: Short, limby fir trees.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Performance Data

Start-up	Utilization*	Scheduled Hours	Trees/cord	Cords/PMH
Machine 1	50%	10,309	14.7	2.48
Machine 2	56%	7,281	15.0	2.60
Later				
Machine 1	65%	2,178	13.8	3.24
Machine 2	67%	2,186	13.1	3.30

$$\text{Utilization*} = \frac{\text{Productive}}{\text{Scheduled}}$$

OTHER COMMENTS:

CITATION: Folkema, M.P. and R. Legault. 1976. EVALUATION OF THE LOGGING DEVELOPMENT CORPORATION PROCESSING HEAD, MODEL 421. FERIC. Technical Report No. TR-2.

MACHINE SYSTEM: Two L.D.C. 421 Processing heads, mounted on Forano BJ-20 articulated wheeled carriers. Shear capacity = 18 in. diameter (Max.). Processor head can be mounted on standard knuckle-boom carrier.

OPERATOR RATING: Both operators had 10 months experience with the processing heads.

DESCRIPTION OF SYSTEM: Sheared, delimbed and bunched tree-length wood which was placed in windrows beside the machine.

DESCRIPTION OF OPERATION: Clearcutting. The operation produced tree-length wood. The machine sheared, delimbed and then bunched the tree-length wood in windrows.

DESCRIPTION OF SITE: On the timber limits of Rexfor, Chute-Aux-Ontardes, Quebec. Slope was negligible.

DESCRIPTION OF STAND: Black spruce stands. Mean DBH = 7 in.
Merchantable stand volume = 38.6 cunits/acre.
No. of merchantable trees/acre = 1,052.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume per tree = 4.6 Ft^3

PRODUCTION DATA: Study Date: November 1975

Productivity of L.D.C. 421 Processor Head	
Avg. harvesting time/tree (min.)	0.81
Avg. production (trees/PMH)	74
Avg. vol. per tree (Ft^3)	4.6
Avg. productivity (cunits/PMH)	3.4

Time Distribution	
Moving in Stand (%)	11
Brushing (%)	3
Felling (%)	52
Processing (%)	28
Delays (%)	6

Production Equations

Felling cycle (cmin),
FCY = 31 + 1.6 VT + 8 OP [R^2=0.23]

Processing cycle (cmin),
PCY = 13 + 2.0 VT [R^2=0.31]

Total time (cmin),
TT = 59 + 3.6 VT + 13 OP [R^2=0.45]

Where VT = Volume per tree, Ft^3
OP = 1 for slow operator = 0 otherwise

Based on 307 observations

OTHER COMMENTS: The L.D.C. 421 lacks a topping shear, and the positioning of the trees into neat bunches is rather difficult.

CITATION: Folkema, M.P. and W.P. Novak. 1976. EVALUATION OF TIMMINS "FEL-DEL" HARVESTER. FERIC. Technical Report No. TR-5.

MACHINE SYSTEM: A Timmins "Fel-Del" harvester head mounted on a Drott 40 LC tracked carrier.

OPERATOR RATING: Operator experience = 1 week.

DESCRIPTION OF SYSTEM:
Harvester → skidders

DESCRIPTION OF OPERATION: Clearcutting. The operation produced tree length wood which was later sorted into pulpwood or sawlogs. The harvester sheared, delimbed, topped and bunched tree length material in a continuous, decreasing spiral pattern.

DESCRIPTION OF SITE: Northeastern New Brunswick. Average temperature = 32°C. Slope was negligible.

DESCRIPTION OF STAND: 59% spruce, 31% balsam fir and 10% eastern white cedar. Mean DBH = 6.7 inches. Merchantable volume = 23 cunits/acre. Number of merchantable trees per acre = 760.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average volume per tree = 4.6 Ft^3 (SD = 4.7)

PRODUCTION DATA: Study: July 1975

Summary of Production Data

	Avg	SD
Total time per tree (cmin)	94	17
Trees per productive machine hour	63	--
Productivity (cunits/PMH)	2.9	--
Brushing and moving expressed as % of total time per tree	28	--

Production Equations

Felling cycle,
FCY = 36 + 1.0 VT [R^2=0.11]

Processing cycle,
PCY = 17 + 0.39 VT + 15 F [R^2=0.32]

Total time,
TT = 54 + 1.7 VT + 24100/TA [R^2=0.33]

(based on 201 observations)

Time per tree (cmin)	Avg	
Felling cycle	41	VT = Volume per tree, Ft^3
Processing cycle	20	F = 1 if trees has large branches, 0 otherwise
Brushing	17	TA = Number of merchantable trees per acre
Delays	7	
Total Time	94	R^2 = Coefficient of multiple determination

OTHER COMMENTS: The skidder operators had problems due to the improper orientation of many of the tree butts. Seventy-five percent of the downtime was attributed to the Timmins head and the remaining 25% to the carrier.

CITATION: Folkema, M.P. and W.P. Novak. 1976. EVALUATION OF TIMMINS "FEL-DEL" HARVESTER HEAD. FERIC. Technical Report No. TR-5.

MACHINE SYSTEM: Two 1-year-old Timmins "Fel-Del" harvester heads mounted on Liebherr carriers.

OPERATOR RATING: Operator experience = 2-3 months.

DESCRIPTION OF SYSTEM:
Harvester → choker skidders. Harvested sheared, delimbed and topped trees.

DESCRIPTION OF OPERATION: Clearcutting. Operation producing tree-length pulpwood. The harvesters cut strips of varying length at right angles to the road, and piled the small tree lengths in scattered windrows.

DESCRIPTION OF SITE: Temiscaming, Quebec. Slope was negligible. Average temperature = -20°C.

DESCRIPTION OF STAND: Second growth: 58% black spruce, 42% balsam fir. Mean DBH = 6.6 in. Merchantable volume = 14.6 cunits/acre. Number of merchantable trees per acre = 486.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average volume per tree = 3.7 Ft^3 (SD = 3.7)

PRODUCTION DATA: Study Date: December 1975

Summary of Production Data

	Avg	SD
Total time per tree (cmin)	73	19
Trees per productive machine hour	83	--
Productivity (cunits/PMH)	3.0	--
Brushing and moving expressed as % of total time per tree	18	--

Production Equations

Felling cycle,
FCY = 31 + 1.7 VT [R^2=0.19]

Processing cycle,
PCY = 11 + 1.1 VT + 15 F [R^2=0.25]

Total time,
TT = 62 + 2.8 VT [R^2=0.29]

(based on 268 observations)

Time per tree (cmin)	Avg
Moving in stand	6
Felling cycle	38
Processing cycle	15
Brushing	7
Delays	7
Total Time	73

where:
VT = Volume per tree, Ft^3
R^2 = Coefficient of determination

Brushing & delays regarded as constants in the Regression Equations

OTHER COMMENTS: Availability (based on company records) = 55 to 60%. The harvester cut strips of varying length at right angles to the road. On completing a strip, these machines made time-consuming trips back to the road in order to begin another strip.

CITATION: Folkema, M.P. and W.P. Novak. 1976. EVALUATION OF TIMMINS "FEL-DEL" HARVESTER HEAD. FERIC. Technical Report No. TR-5.

MACHINE SYSTEM: Timmins "Fel-Del" harvester head. This head, one of the first built by Timmins Manufacturing Ltd., had been recently rebuilt (after 2 years of service) to the specifications of the latest model and was equipped with a single blade topping shear mounted on a Drott 40 LC tracked carrier.

OPERATOR RATING: Operator experience = 2 years.

DESCRIPTION OF SYSTEM:
Harvester → choker skidders.
Harvester sheared, delimbed and topped trees.

DESCRIPTION OF OPERATION: Clearcutting. Operation produced tree-length sawlogs. The harvesters cut strips of varying length at right angles to the road and piled the tree lengths in scattered windrows.

DESCRIPTION OF SITE: Chapleau, Ontario. Slope was negligible. Average temperature = -30°C.

DESCRIPTION OF STAND: 37% black spruce, 47% eastern white cedar, 16% balsam fir. Merchantable volume = 14.0 cunits/acre. Number of merchantable trees per acre = 242.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average volume per tree = 11 Ft^3 (SD = 6.2)
Average DBH = 9.4 inches (SD = 2.2)

PRODUCTION DATA:

Summary of Production Data

	Avg	SD
Total time per tree (cmin)	121	17
Trees per productive machine hour	49	--
Productivity (cunits/PMH)	5.4	--
Brushing and moving expressed as % of total time per tree	55	--

Production Equations

Felling cycle, FCY = 28 + 0.90 VT	[R^2=0.17]
Processing cycle, PCY = 10 + 0.51 VT	[R^2=0.20]
Total time, TT = 105 + 1.4 VT	[R^2=0.27]

Time per tree (cmin)	Avg
Moving in stand	43
Felling cycle	38
Processing cycle	15
Brushing	24
Delays	1
Total Time	121

where:
VT = Volume per tree, Ft^3
R^2 = Coefficient of determination

Brushing & delays regarded as constants in the Regression Equations

OTHER COMMENTS: Availability (based on company records) = 80%. Stump heights of 8 to 10 inches sometimes impeded the movement of the tracked carrier.

CITATION: Heidersdorf, E. 1976. EVALUATION OF LAJOIE "FIBRE-FLOW" HARVESTER HEAD. FERIC. Technical Report No. TR-3.

MACHINE SYSTEM: Lajoie "Fibre-Flow" harvester head was mounted on a Drott 40-LC tracked carrier. The head can produce both tree-length and 8-foot wood. Machine in trial demonstration.

OPERATOR RATING: Both operators were employees of the manufacturer.

DESCRIPTION OF SYSTEM: Sheared, delimbed, topped (tree-length) or bucked (8-foot bolts) and bunched.

DESCRIPTION OF OPERATION: Clearcutting. The machine normally harvests a swath about 18 to 25 ft. wide along the cutting face. During the study, the machine sheared, delimbed and topped and then bunched tree-length wood.

DESCRIPTION OF SITE: Edmundston, New Brunswick. 8% side slope. Snow Depth = 3 in.

DESCRIPTION OF STAND: 85% fir and 15% spruce. Mean DBH = 7.5 inches. Merchantable stand volume = 31 cunits/acre. Number of merchantable trees per acre = 750.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average volume per tree = 5.7 Ft^3 (SD = 4.1)

PRODUCTION DATA: Study Date: November 1975

Productivity of LaJoie Harvester	
Average harvesting time/tree (min.)	1.04
Production (trees/PMH)	58
Productivity (cunits/PMH)	3.3

Production Equation	
Processing cycle, $17 + 3.0\ VT - 4\ S$	$[R^2=0.49]$
Total time, $75 + 3.4\ VT + 15\ S$	$[R^2=0.50]$

where
VT = Volume per tree, Ft^3
S = 1 for slower operator = 0 otherwise
R^2 = Coefficient of multiple determination based on 207 observations

OTHER COMMENTS: The LaJoie's major weaknesses would appear to be its large size and weight (5,200 lb.) which preclude the use of small, lower-priced carrier units and contribute to the incidence of high stumps.

CITATION: Folkema, M.P. 1977. THE TIMMINS "FEL-DEL" HARVESTER HEAD. FERIC. Technical Note No. TN-14.

MACHINE SYSTEM: Three Timmins heads "Fel-Del" harvester heads mounted on Drott 40 tracked carriers. The heads were the 1975-1976 models.

OPERATOR RATING: The operators had 1 year of experience prior to the 6-month study.

DESCRIPTION OF SYSTEM: Hydraulic shear was used to sever the bolt.
Feller-delimber → Wheel forwarder

DESCRIPTION OF OPERATION: Clearcutting. Shortwood operation. Shortwood was produced by advancing the tree through the Timmins head until the butt stuck the steel plate, then the hydraulic shear was used to sever the bolt.

DESCRIPTION OF SITE: Central Newfoundland. Upland flats and undulating terrain.

DESCRIPTION OF STAND: 425 merchantable trees/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
4.0 Ft^3 (0.11 m^3)/tree.

PRODUCTION DATA: Study Period: August 1976 - June 1977.

Time Distribution % of Total Time		Breakdown Information	
Productive (PMH) (%)	70.8	Mean time to repair (hr)	2.3
Repair & Maint. (%)	21.1	Mean time between repairs (based on PMH) (hr)	15.0
Non-Productive (%)	1.2	No. of Repairs	273
Delays (%)	6.6		

	SHORTWOOD		
	Machine No. 3	Machine No. 4	Machine No. 5
Machine & Operations			
Mechanical availability (%)	77	87	86
Utilization (%)	60	77	76
Production			
Tree/CT (m^3)	25 (8.8)	25 (8.8)	25 (8.8)
Trees/PMH	45	37	36
Productivity CT/PMH (m^3/PMH)	1.8 (5.1)	1.5 (4.2)	1.5 (4.2)

OTHER COMMENTS:

CITATION: Folkema, M.P. 1977. THE TIMMINS "FEL-DEL" HARVESTER HEAD. FERIC. Technical Note No. TN-14.

MACHINE SYSTEM: Two Timmins "Fel-Del" harvester heads mounted on Liebherr 925 tracked carriers. Heads were the 1975-1976 model.

OPERATOR RATING: The operators had 1 year of experience prior to the 6-month study.

DESCRIPTION OF SYSTEM: Topping was done by using the butt shear.
Feller-delimber → Cable skidder.

DESCRIPTION OF OPERATION: Clearcut. Tree length operation topping was done by using the butt shears. The tree lengths were moved to roadside by cable skidders.

DESCRIPTION OF SITE: Lac St. Jean, Quebec. The terrain was flat to slightly rolling with a few swampy areas.

DESCRIPTION OF STAND: 375 merchantable trees/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree volume = 4.3 Ft^3

PRODUCTION DATA: Study Period: June - December 1976.

Time Distribution % of Total Time		Breakdown Information	
Productive (PMH) (%)	52.5	Mean time to repair (hr)	2.6
Repair & Maint. (%)	35.2	Mean time between repairs (base on PMH) (hr)	5.5
Non-Productive (%)	5.9	No. of Repairs	188
Delays (%)	6.5		

	SHORTWOOD Machine No. 1	SHORTWOOD Machine No. 2
Machine & Operations		
Mechanical availability (%)	65	59
Utilization (%)	57	53
Production		
Tree/CT (m^3)	23 (8.1)	23 (8.1)
Trees/PMH	77	76
Productivity CT/PMH (m^3/PMH)	3.4 (9.6)	3.4 (9.6)

OTHER COMMENTS:

CITATION: McLeish, G. 1975. OWNER-OPERATORS GET HIGH UTILIZATION FROM RW-30 HARVESTER. Pulp and Paper Canada. 76(12):17-19.

MACHINE SYSTEM: (1) Timberjack RW-30 tree length harvester with 16 inch shears. Machine was about 6 months old.

OPERATOR RATING: Operator had taken a 2 week training course.

DESCRIPTION OF SYSTEM:
(1) Timberjack RW-30 harvester → (1) Timberjack 240 grapple skidder → (1) Prentice D600 hydraulic loader → (1) Slasher

DESCRIPTION OF OPERATION: Clearcutting. Harvester sheared, delimbed and accumulated wood, then dumped the load when it had accumulated 4 cords. Grapple skidder skidded the tree length material to roadside, where it was cut into 4 ft. bolts by a slasher and then loaded.

DESCRIPTION OF SITE:

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Operation was producing 4 foot pulp bolts.

PRODUCTION DATA:

Performance Report for RW-30 Harvester
(6 months of observation)

Availability (%)	74
Utilization (%)	67
Cunits/PMH	3.64
Trees/PMH	82

OTHER COMMENTS:

CITATION: Baumgras, J.E. 1986. PRODUCTION STUDY OF THE SWEDISH ROTTNE SNOKEN 810 HARVESTER/PROCESSOR IN PENNSYLVANIA SOFTWOOD PLANTATIONS. *IN* Proceedings of the Council on Forest Engineering, 9th Annual Meeting. "Improving Productivity Through Forest Engineering." Mobile, AL. September 29 - October 2, 1986. pp. 63-68.

MACHINE SYSTEM: Rottne Snoken 810 Harvester/Processor

OPERATOR RATING:

DESCRIPTION OF SYSTEM: The harvester felled, delimbed and bucked the material and then piled the roundwood for forwarding.

DESCRIPTION OF OPERATION: Clearcut on slopes greater than 10%. The operator harvested and processed a swath perpendicular to the contour and worked from top to bottom on level terrain, the operator worked in both directions.

DESCRIPTION OF SITE: Pennsylvania
Site 1: Slopes ranged from 0-34%
Site 2: Slopes ranged from 0-41%
Site 3: Slopes ranged from 0-15%
Site 4: Slopes ranged from 0-25%

DESCRIPTION OF STAND:

Site 1:	275 trees/acre	Norway spruce
Site 2:	405 trees/acre	Norway spruce
Site 3:	745 trees/acre	Scotch pine
Site 4:	475 trees/acre	Norway spruce

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Site	1	2	3	4
Merch. Trees/acre	140	220	375	230
DBH (Avg.)(Inches)	11	9.3	7.1	8.8
DBH (Range)(Inches)	5-19	5-15	5-10	5-13
Volume (Avg.)(Ft^3)	25.2	17.0	5.2	16.2
Volume (Range)(Ft^3)	3-75	3-47	3-12	3-38
Total Ht. (Ft)	58 ft, ranging from 29-90 Ft.			
Stump DOB (inches)	11.6 inches ranging from 6-22 in.			
Number of Limbs > 2 inches	Average of 2.2, ranging from 0-35			

PRODUCTION DATA:

Site	1	2	3	4
Trees sampled	49	69	133	59
Total cycle time (min/tree)				
Mean	3.15	1.61	1.12	1.65
Range	0.9-7.0	0.5-4.8	0.5-2.8	0.5-3.6
Trees/PMH	19	37	54	36
Cubic Feet/PMH	480	630	280	580
Utilization		----------------78%---------------		

(1) $MT = -0.1831 + 0.5993\ X_1 + 0.8319\ X_2 + 0.0488\ X_3$ [R^2=0.58]

Where MT = Move time in minutes/move
X1 = 1 if slash was scattered during move, 0 if slash not scattered
X2 = 1 if unmerch trees cut during move, 0 if not
X3 = move distance in feet.

(2) $FLPT = 0.5546 + 0.4233\ X_1 + 0.5310\ X_2 + 0.0039\ X_3 + 0.0007\ X_4 + 0.2898\ X_5 + 0.0010\ X_6$

Where FLPT = Fell-load-process time (min/tree) [R^2=0.62]
X_1 = 1 if slash was scattered during the cycle, 0 if not
X_2 = 1 if unmerchantable trees were cut during the cycle, 0 if not
X_3 = merch. tree volume in ft^3
X_4 = $(X_3)^2$
X_5 = (feet of clear bole)$^{-1}$
X_6 = (number of limbs > 2 inches)^2

OTHER COMMENTS:

CITATION: Sterle, J.S. 1973. TIMBERJACK RW-30 TREELENGTH HARVESTER IN THE SOUTHEAST. American Pulpwood Association. 73-R-49.

MACHINE SYSTEM: Timberjack RW-30 tree-length harvester. Maximum shearing capacity = 12" DBH. Maximum delimbing length = 50 feet.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Felled, limbed, topped, accumulated and dumped treelength material into a pile or bundle for subsequent skidding.

DESCRIPTION OF OPERATION: Clearcutting. The machine felled, limbed, topped and accumulated treelength material. When the 5,000 lb capacity was reached, the material was dumped in a pile for subsequent skidding.

DESCRIPTION OF SITE: Taylor County, Florida.

DESCRIPTION OF STAND: 18 year old slash pine plantation. Average DBH = 6 inches. Merchantable trees = 365 stems/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Heights varied from 20 to 45 feet to a 3 inch top.
Volume = 18 trees to a cord.

PRODUCTION DATA:

Time and Production Data

	Avg.	Max.
Total No. trees (counter)	2,097	572
Trees/available machine hour	81.3	108.8
Availability (%)	86	72
Cords/available hour	3.56	4.77

OTHER COMMENTS:

CITATION: Powell, L.H. 1974. EVALUATION OF NEW LOGGING MACHINES: TANGUAY TREE-LENGTH HARVESTER. Pulp and Paper Research Institute of Canada. Logging Research Reports LRR/56.

MACHINE SYSTEM: Tanguay tree-length harvester with 230 hp Cat D333 diesel engine.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. The harvester produced bunches of tree length material, which was collected by the forwarder and forwarded to roadside piles.

DESCRIPTION OF SITE: Quebec. Terrain was flat to slightly rolling with thin sandy soils. Slopes averaged 7%.

DESCRIPTION OF STAND: Black spruce and jack pine.

	Avg.	SD	Range
Vol/merch tree (Ft^3)	5.1	3.3	0.4-19.2
Merch. trees/acre	688	164	290-1016
Unmerch. trees/acre	171	113	0-508

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Harvesting time/tree (cmin) = 54 - 7 F + 0.5 SL + 25 VT [R^2 = 0.22]

Where: F = 1 when operator is fast, 0 otherwise.
VT = Proportion of unmerch. trees to merch. trees.
SL = Slope in direction of travel

Limbing & topping time/tree (cmin) = 26 + 7 S + 0.5 VT [R^2 = 0.13]

Where S = 1 for slow operator, or 0 for fast operator
VT = Volume per tree, cu.ft.

	N	Avg.	SD	Range
Time per tree, harvesting cycle (cmin)	500	60	14	31-121
Time per tree, limbing & topping cycle (cmin)	400	31	10	11-99

Average production/PMH for tree length harvesting = 100 trees/PMH
Average production/PMH for tree length harvesting = 5.1 cunits/PMH

Time Distribution	
Felling Cycle	
Swing empty (%)	36
Position and shear (%)	22
Lift and swing (%)	31
Transfer to delimbing unit (%)	11
Non-Felling Delays	
Brush (%)	5
Misc. Delays (%)	12

OTHER COMMENTS:

CITATION: MacDonald, C.R. 1988. EVALUATION OF THE BRUUN T610-H A SINGLE-GRIP HARVESTER. B.Sc. Thesis. University of New Brunswick.

MACHINE SYSTEM: Bruun T610-H single-grip harvesters which had a combined felling and processing head mounted on a 5.1 meter boom circular saw felling head with 28 cm felling capacity.

OPERATOR RATING: The operator had reached a high level of proficiency when the data were collected.

DESCRIPTION OF SYSTEM:
Harvester → Timberjack 230 forwarder → Cranab 60 loader

DESCRIPTION OF OPERATION: Harvesting short wood (unsorted).

DESCRIPTION OF SITE: Area 1: near Indian River. Guysborough County.
Area 2: Country Harbour, Guysborough County.

DESCRIPTION OF STAND: Area 1: Small, limby balsam fir, with scattered black spruce and unmerchantable hardwood.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Area 1: Average tree size = 0.112 m^3, Volume = 170 m^3 (stacked) per hectare.
Area 2: Average tree size = 0.115 m^3.

PRODUCTION DATA: Study Period: June - July 1987

Simple linear regression for productivity.

PRODUCTIVITY (m^3/PMH) = 4.59 + 67.84 x tree size (m^3/tree) [R^2 = 0.74]

Multiple regression

PRODUCTIVITY (m^3/PMH) = 4.545 + 82.295 x tree size (m^3/tree) - 1.335 X_1 - 1.647 X_2
[R^2 = 0.89]
Where X_1 and X_2 = Dummy Variables

Variable	X_1	X_2
Balsam fir	0	
Black spruce	1	
Open (felling into open)		0
Close (felling into stand)		1

Bruun Shortwood Production Study (Black Spruce)

Sample No.	No. of Trees	Time (min)	Volume (m^3)	Production (Tree/PMH)	Production (m^3/PMH)	Tree/m^3	Min/ Tree
BS-1	25	17.00	4.165	88.2	14.700	6.0	0.680
BS-2	25	15.75	4.046	95.2	15.413	6.2	0.630
BS-3	26	18.50	3.982	84.3	12.915	6.5	0.712
BS-4	25	15.25	3.206	98.4	12.614	7.8	0.610
BS-5	24	16.50	4.342	87.3	15.789	5.5	0.687
BS-6	23	13.70	2.549	100.7	11.164	9.0	0.596
BS-7	26	13.15	2.125	118.6	9.696	12.2	0.506
BS-8	24	14.00	2.330	102.9	9.986	10.3	0.583
BS-9	25	12.50	1.941	120	9.317	12.9	0.500
BS-10	25	11.45	2.158	131	11.308	11.6	0.458
Overall Average:				102.7	12.3	8.8	0.596
Average 1-6:				92.4	13.8	6.8	0.653
Average 7-10:				118.1	10.1	11.8	0.512

For studies 1-6 machine was felling into stand
For studies 7-10 machine was felling into clearing

OTHER COMMENTS: Producing tree-length material or sorting with the Bruun was not favorable was because of its short boom.

CITATION: Raymond, K. 1990. SILVER STREAK TREE HARVESTER. FERIC. Field Note No. Processing-14.

MACHINE SYSTEM: Silver streak stroke-type processor with chainsaw felling head (max. dia. 38 cm) mounted on John Deere 490D tracked carrier.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Silver Streak tree harvester → forwarder

DESCRIPTION OF OPERATION: Pulpwood clearfelling. Silver Streak felled, delimbed and bucked pulpwood into 2.5 meter lengths, and stacked logs for later forwarding.

DESCRIPTION OF SITE: Michigan, USA. Terrain: flat, firm ground, no major obstacles.

DESCRIPTION OF STAND:

	Stand 1	Stand 2
Species composition (%)		
White birch	35	10
Balsam fir	30	30
Maple	15	15
Aspen	---	45
Cedar	20	---
Merch., density (stems/ha)	990	1,100
Unmerch. density (stems/ha)	350	1,060
Merch. tree dia. (cm)	15.9	18.6
Merch. stem volume (m^3)	0.18	0.21

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

	Stand 1	Stand 2
Average work cycle (min)		
Move machine	0.06	0.07
Position head	0.20	0.18
Fell	0.24	0.26
Process	0.63	0.70
Clear slash	0.04	0.10
Total cycle (min)	1.17	1.22
No. of trees/cycle	1.1	1.2
No. of bolts/tree	3.9	4.1
Cycles/PMH	51.3	49.3
Trees/PMH	54.5	60.7
m^3/PMH	10.0	13.0

OTHER COMMENTS: In the author's opinion, the maximum potential productivity of the machine was reached while harvesting large diameter aspen of good form (stand 2): 45.8 trees/PMH, 20.3 m^3/PMH or 285 bolts/PMH.

CITATION: Chabot, G. 1989. THE DENIS FELLER-DELIMBER PROTOTYPE. FERIC. Field Note No. Felling-7.

MACHINE SYSTEM: **Prototype Denis feller-delimber utilizing a modified Denis stroke-boom delimber (11 m boom) with chainsaw felling head (max. dia. 51 cm) mounted on a Hitachi Ex-200 carrier.**

OPERATOR RATING: Day operator: Little experience (2 months). Night operator: Very experienced but only 3 weeks on the machine.

DESCRIPTION OF SYSTEM: Denis Feller-Delimber →

DESCRIPTION OF OPERATION: Clearcutting and delimbing trees in 15 to 20 metre swaths, leaving slash at felling face.

DESCRIPTION OF SITE: Forestville, Quebec, Canada. Ground strength good, ground roughness low. Slopes = 10 to 15%, rarely more than 25%.

DESCRIPTION OF STAND: Black spruce. Merch. density 2,200 stems/ha, non-merch. density 850 stems/ha. Mortality 10%. Average DBH = 10-20 cm.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average volume per stem 0.09 m^3

PRODUCTION DATA:

Day operator	59 trees/PMH	5.3 m^3/PMH
Night operator*	68 trees/PMH	6.1 m^3/PMH

*Peak production under ideal conditions 85 trees/PMH, 7.6 m^3/PMH.

OTHER COMMENTS: The machine was stable on slopes up to 25%. On steeper sections, the boom was used as a counterweight. The low cab on the carrier caused visibility problems for the operator.

CITATION: Richardson, R. 1989. EVALUATION OF FIVE PROCESSORS AND HARVESTERS. FERIC. Technical Report No. TR-94.

MACHINE SYSTEM: Timberjack FMG 990 one-grip harvester, 6 wheel drive model. 10 meter telescopic stickboom with 950 kg FMG 762 harvester head.

OPERATOR RATING: Two operators were good, the other two were learning.

DESCRIPTION OF SYSTEM: Timberjack FMG 990 (2) →

DESCRIPTION OF OPERATION: FMG 990 producing shortwood bolts at the stump.

DESCRIPTION OF SITE: Central Newfoundland, Canada. Ground was swampy with poor bearing capacity; machines broke through after one or two passes. C.P.P.A. terrain classification 4.2.1. Slope range: 0-15%.

DESCRIPTION OF STAND:

89% fir, 8% spruce, 3% hardwood.
Average DBH = 13.5 cm, range = 10-32 cm.
Average merch tree length = 5.8 m, range = 2.5 - 12.7 m.
Average tree volume = 0.07 m^3, range = 0.03 - 0.48 m^3.
Vol/ha = 160 m^3/ha (60 m^3/ha in low volume areas).
Average merch. trees/ha = 2,200.
Average unmerch. trees/ha = 2,300.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

	Including harvest of low-volume recovery areas	Excluding harvest of low-volume recovery areas
Productive time measured (PMH)	18.9	17.2
Total merchantable trees	1,371	1,299
Average productivity		
trees/PMH ± conf. int.*	74 ± 6	77 ± 5
m^3/PMH ± conf. int.	5.3 ± 0.4	5.9 ± 0.04

Average cycle time was 0.86 min., with an average of 1.04 trees processed per cycle.
* 95%

OTHER COMMENTS: Since the study was done, shifting the regime and making personnel changes have led to improved machine productivity.

CITATION: Richardson, R. 1989. EVALUATION OF FIVE PROCESSORS AND HARVESTERS. FERIC. Technical Report No. TR-94.

MACHINE SYSTEM: Rottne EGS-85 one-grip harvester. Uses the same carrier as the Rottne Rapid but has a 600 kg EGS-85 harvesting head.

OPERATOR RATING: Nova Scotia operator had 6 weeks on machine. Newfoundland operators had 6 weeks to 6 months experience.

DESCRIPTION OF SYSTEM: Rottne EGS-85 harvester →

DESCRIPTION OF OPERATION:
Nova Scotia: Clearfell operation producing tree-length and shortwood (2.43 m).
Newfoundland: Clearfell operation producing shortwood (2.55 m).

DESCRIPTION OF SITE: Both sites had good ground strength, and slightly uneven to gentle slopes. (0-28% in Nova Scotia, , 0-24% in Newfoundland). Underbrush was very dense (NS) or very light (NF).

DESCRIPTION OF STAND:

	Nova Scotia	Newfoundland
Stand Composition (%)		
spruce	47	1
fir	47	96
white pine	6	0
birch	0	3
Average diameter (cm)(+ range)	Butt 16.0 (10-44)	dbh 14.4 (10-40)
Avg. merch. tree length (m)(+ range)	7.5 (2.4-14.5)	7.6 (2.5-17.7)
Avg. tree volume (m^3)(+ range)	0.11 (0.03-1.15)	0.10 (0.03-0.95)
Vol/ha (m^3/ha)	170	270
Avg. merch. trees/ha	1,600	2,700
Avg. unmerch. trees/ha	600	2,700

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

	Nova Scotia		Newfoundland
	Tree length	Shortwood	Shortwood
Productive time measured (PMH)	7.7	3.6	14.9
Total merch. trees	701	307	1,117
Avg. Productivity			
trees/PMH ± conf. int.	91 ± 11	86 ± 31	75 ± 6
m^3/PMH ± conf. int.	10.2 ± 1.2	9.6 ± 3.5	1.5 ± 0.6

Long term productivity of harvester in Nova Scotia:

No. of shifts	11
Trees/PMH	63
Utilisation (%)	72
Mechanical availability (%)	76

OTHER COMMENTS: In Newfoundland, the high number of unmerchantable trees reduced productivity.

CITATION: Richardson, R. 1989. EVALUATION OF FIVE PROCESSORS AND HARVESTERS. FERIC. Technical Report No. TR-94.

MACHINE SYSTEM: Bruun 7610H single-grip harvester, (Study I) and substantially modified Bruun 7610H (Study II).

OPERATOR RATING: Study I: operator inexperienced. Study II: same operator with one year experience on machine.

DESCRIPTION OF SYSTEM: Bruun 7610H →

DESCRIPTION OF OPERATION: Bruun 7610H felled, delimbed, topped and bucked to produce pulpwood bolts (2.42 m long).

DESCRIPTION OF SITE: Nova Scotia, Canada.
Study I: Flat, even, good bearing capacity.
Study II (Two sites): Both flat, fairly even with good bearing capacity.

DESCRIPTION OF STAND:

	Study I	Study IIa	Study IIb
Stand Composition (%)			
- spruce	70	0	54
- fir	29	89	37
- birch	1	3	0
- maple	0	8	9
Underbrush	medium	medium	medium
Average diameter (cm)(+ range)	14.5(10-32)	14.1(10-34)	15.5(10-36)
Avg. merch. tree length (m)(+ range)	5.9(2.4-16.9)	5.4(2.4-9.7)	4.8(2.4-12.1)
Avg. tree volume (m^3)(+ range)	0.09(0.03-0.60)	0.08(0.03-0.63)	0.09(0.03-0.97)
Vol/ha (m^3/ha)	280	250	180
Avg. merch. trees/ha	3,200	3,300	2,000
Avg. unmerch. trees/ha	3,000	1,200	2,100

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

	Study I	Study IIa	Study IIb
Productive time measured (PMH)	6.8	6.6	2.3
Total merch. trees	752	696	196
Average productivity			
- trees/PMH ± conf. int.	111 ± 15	111 ± 10	84 ± 13
- m^3/PMH ± conf. int.	9.7 ± 1.3	8.3 ± 0.7	7.4 ± 1.1

Long term productivity of two Bruun harvesters.

		Machine 1	Machine 2
No. of shifts	11	27	41
Trees/PMH	58	---	---
m^3/PMH	---	4.8	3.8
Utilisation (%)	75	67	60
Mechanical availability (%)	85	75	75

* Machine 1 had a more skilled operator

OTHER COMMENTS: The Bruun lacked power to easily delimb the bigger branches found on stems greater than 30 cm in diameter. Productivity starts to decrease at 0.3 m^3/tree or at approximately 24 to 26 cm dbh.

CITATION: Johnson, L.R. 1981. SMALL TREE HANDLING SYSTEM IN THE INTER-MOUNTAIN REGION. *IN* Proceedings: "Harvesting Small Timber: Waste Not, Want Not". Forest Products Research Society. Portland, OR. April 28-30, 1981. pp. 52-58.

MACHINE SYSTEM: J.I. Case Fleethoe 30, with a 30 horsepower gas power four-wheel, hydrostatic drive with articulated steering. Backhoe on the unit was modified into 8 foot knuckle boom grapple and with a shop-built hydraulic grapple (1979).

OPERATOR RATING: Different machine operators were used in the two tests. Both were relatively inexperienced at the beginning of the studies.

DESCRIPTION OF SYSTEM:
1979 1st Half: Trees were skidded from the stump to the landing.
2nd Half: Trees were pre-bunched at a main trail for subsequent transport by a larger skidder.
1980 Trees with butt diameters less than 8 inches were skidded as whole trees. Trees with butt diameters >8 inches were first bucked, then skidded.

DESCRIPTION OF OPERATION: Thinning.

DESCRIPTION OF SITE: Near Moscow, Idaho.

DESCRIPTION OF STAND: 6.6 acre tract of lodgepole pine and grand fir.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Study Periods: Summer 1979 and 1980

Results of production studies on the first and second versions of the converted backhoe.

	1979 Production Test		
	1st Half	2nd Half	1980 Production Test
Total turn time (min.)	7.26	6.79	9.57
Average skid distance (Ft)			
Woods	179	246	199
Road	245	---	189
Average travel speed (MPH)			
Unloaded - Road	3.48		3.95
Unloaded - Woods	2.23	2.47	2.71
Loaded - Woods	1.85	1.98	3.87
Loaded - Road	3.48		3.77
Total volume skidded (Ft^3)	3,097	1,363	3,544
Total # of pieces	486	276	1,071
Total productive time (hrs)	31.08	13.91	63.96
Total # of turns	257	123	402

	1979 1st Half	1979 2nd Half	1980
Averages:			
Diameter (DBH)			
Ft^3/Piece	6.46	5.87	5.40
Ft^3/Turn	6.37	4.94	3.31
Pieces/Turn	12.05	11.08	8.82
Production rate:	1.89	22.24	2.66
Ft^3/Hour			
Pieces/Hour	99.65	97.99	55.41
	15.64	19.84	16.74

OTHER COMMENTS: In 1979 the number of pieces per turn was limited by machine capacity. In 1980 the pieces per turn were limited by design of the grapple, and in general the machine was not loaded to capacity.

CITATION: Czerepinski, F.P. 1978. EVALUATION OF HARVESTING SYSTEMS USED IN PINE PLANTATIONS IN THE SOUTHEAST. American Pulpwood Association. 78-P-7.

MACHINE SYSTEM: Franklin 170 XL power shift grapple skidder.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-bunchers → Grapple skidders

DESCRIPTION OF OPERATION: Clearcut.

DESCRIPTION OF SITE: Georgia.

DESCRIPTION OF STAND: Pine plantations. 19 to 21 years old.
Average Height = 53 to 58 feet.
Average DBH = 6.7 to 7.4 inches.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Skidding in clearcuttings with Franklin 170 XL PS GS Skidders

Skid Distance (feet)	Time Per Turn Clearcut (min.)	Turns Per Hour Clearcut
700	3.17	18.9
800	3.30	18.2
900	3.42	17.5
1,000	3.53	17.0
1,100	3.63	16.5
1,200	3.70	16.2
1,300	3.77	15.9
1,400	3.81	15.7

Production -- Cords Per Hour by DBH and Skid Distance

DBH	700' Skid	900' Skid	1,100' Skid	1,300' Skid
5	7.3	6.8	6.4	6.2
6	9.2	8.6	8.1	7.8
7	12.2	11.4	10.7	10.3
8	15.1	14.0	13.2	12.7

OTHER COMMENTS:

CITATION: Tufts, R.A., B.J. Stokes and B.L. Lanford. 1988. PRODUCTIVITY OF GRAPPLE SKIDDERS IN SOUTHERN PINE. Forest Products Journal. 38(10):24-30.

MACHINE SYSTEM: 12 different models of rubber-tired, grapple skidders. Horsepower ranged from 75.5 to 185.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-buncher → Grapple skidder → Loader → Gate delimber → Loader

DESCRIPTION OF OPERATION: 1) Full-tree from woods to deck, 2) Skidding plus gate delimbing, 3) Length from woods to deck, 4) Unbunched.

DESCRIPTION OF SITE: 24 study sites, 21 were located throughout central Alabama, two were in Louisiana and one was in South Carolina. Relatively level terrain, and slope averaged less than 4% with a maximum of 16%.

DESCRIPTION OF STAND: Southern pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: Pulpwood Operation. Avg. No. of bunched trees = 9.25; Avg. No. of bunches = 1.25; Avg. No. of unbunched trees = 3.43.

PRODUCTION DATA:

	Average	Minimum	Maximum
Skidding distance (Ft.)			
Gate delimbing	750	185	2,490
Full tree	781	40	2,017
Tree length	323	50	1,000
Load weight (Lbs.)	3,405	518	13,190
Slopes (%)	3.74	0	16
Trees/Bunch	9.25	1	42
Bunches/Cycle	1.25	1	4
Cycle times (min.)			
Gate delimbing	5.03	1.44	12.73
Full tree	5.16	1.18	14.35
Tree length	4.03	1.31	9.43

<u>Total Cycle Regression Equations</u>

(Bunched trees)

Skidding plus gate delimbing time (min.) =

$$0.004509 \times DIST + 0.000000239 \times DIST \times LOAD + 0.01579 \times HP - 0.00002328 \times DIST \times HP + 0.001293 \times DIST \times NBNCH \quad [R^2 = 0.707]$$

Skidding full trees to deck time (min.) =

- 0.5988 + 0.004539 x DIST + 0.01119 x HP - 0.00001554 x DIST x HP + 0.0003782 x DIST x NBNCH + 1.616 x NBNCH - 0.005599 x NBNCH x HP + 0.01398 x NBNCH x NTREES

Skidding tree length stems to deck time (min.) =

- 0.0158 + 0.005234 x DIST - 0.000443 x HP + 1.650 x NBNCH + 0.0000002581 x HP x LOAD - 0.000003336 x DIST x HP + 0.01398 x NBNCH x NTREES - 0.005599 x NBNCH x HP

(Unbunched trees)

Skidding tree length to deck time (min.) =

1.0529 + 0.005234 x DIST - 0.000443 x HP + 0.0000002581 HP x LOAD + 0.3916 x NBNCH - 0.000003336 x DIST x HP

Where:
DIST = one way distance travel in feet
LOAD = load weight in pounds
HP* = machine flywheel horsepower
NBNCH = number of bunches grappled
NTREES = number of trees per load

* HP ranged from 75.5 to 185

OTHER COMMENTS: Skid distance is the most significant variable affecting cycle time, but load weight is as important as skid distance for predicting production.

CITATION: Johnson, L.R. 1988. SUMMARY OF PRODUCTION AND TIME STUDIES OF MECHANIZED HARVESTING EQUIPMENT IN THE INTERMOUNTAIN WEST. Forest Products Department, University of Idaho (Unpublished).

MACHINE SYSTEM: Caterpillar Model 518 grapple skidder.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Koehring feller-buncher → Caterpillar 518 grapple skidder

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: Average slope = 17%.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average butt diameter = 10.87" (SD = 4.06)

PRODUCTION DATA:

Time Distribution		Production Statistics (number of turns = 100)	Avg.	SD
Travel unloaded (%)	12.5			
Load grapple (%)	26.3	Trees/turn	6.691	2.712
Travel loaded (%)	11.2	Minutes/delay	1.16	----
Delimb trees (%)	9.4	Total turn time (min.)	7.465	3.689
Decking (%)	14.8	Slope (%)	-15.44	8.09
Delays (%)	25.8	Distance out (ft)	745	----
	100	Distance in (ft)	719	----
		Trees/PMH	53.8	----
Utilization (%)	74.2	Trees/SMH	39.9	----

Regression Eqn: Turn time (min.) = 0.339 + 0.0064 (DISTANCE OUT) + 0.5309 (SUM OF END AREAS) + 6.2732 EXP(SLOPE) [R^2 = 0.78]

OTHER COMMENTS:

CITATION: Johnson, L.R. 1988. SUMMARY OF PRODUCTION AND TIME STUDIES OF MECHANIZED HARVESTING EQUIPMENT IN THE INTERMOUNTAIN WEST. Forest Products Department, University of Idaho (Unpublished).

MACHINE SYSTEM: John Deere 6480 grapple skidder.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Caterpillar 227 feller-buncher → JD 648D grapple skidder → Chunkwood chipper.

DESCRIPTION OF OPERATION: Clearcutting. Skidder moved bunches created by the feller-buncher to the chipper. The skidder worked directly with the chipper and was subject to all chipper delays.

DESCRIPTION OF SITE: Average slope = 6%.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Time Distribution		Production Statistics	Avg.	SD
Travel unloaded (%)	8.4			
Load grapple (%)	2.7	Trees/turn	14.39	3.69
Travel loaded (%)	8.1	Turn/time (min.)	4.79	1.48
Decking (%)	1.1	Minutes/delay	4.41	
Delays (%)	79.5	Slope (%)	-6.451	3.874
	100	Distance out (ft)	572	----
		Distance in (ft)	551	----
Utilization (%)	20.4	Trees/PMH	169.6	----
		Trees/SMH	34.6	----

Turn time (min.) = 2.530 + 0.0036 (DISTANCE IN) - 0.0831 (SLOPE) + 0.00083 (Pieces per turn)^3 + 0.1256 LN (Deck height)

OTHER COMMENTS:

CITATION: Johnson, L.R. 1988. SUMMARY OF PRODUCTION AND TIME STUDIES OF MECHANIZED HARVESTING EQUIPMENT IN THE INTERMOUNTAIN WEST. Forest Products Department, University of Idaho (Unpublished).

MACHINE SYSTEM: Caterpillar Model 518 grapple skidder.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Timbco feller-buncher → Caterpillar 518 grapple skidder → Hahn harvester

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: Average slope = 5%.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average butt diameter = 10.44 inches (SD = 4.15)

PRODUCTION DATA:

Time Distribution	
Travel unloaded (%)	29.8
Load grapple (%)	15.9
Travel loaded (%)	27.4
Decking (%)	0.2
Delays (%)	26.6
	100
Utilization (%)	73.4

Production Statistics (number turns = 154)

	Avg.	SD
Trees/turn	4.890	1.570
Minutes/delay	1.12	----
Turn time (min.)	4.38	1.65
Slope (%)	-5.38	4.05
Distance out (ft)	67.1	----
Distance in (ft)	49.2	----
Trees/PMH	431	----
Trees/SMH	402	----

Regression Eqn: Turn time (min.) = 1.068 + 0.0056 (DISTANCE OUT) - 0.1682 (SLOPE) [R^2 = 0.61]

OTHER COMMENTS:

CITATION: Swan, D.A. 1971. THE CLARK RANGER GRAPPLE SKIDDER. American Pulpwood Association. 71-R-61.

MACHINE SYSTEM: Two Clark Ranger skidders equipment with 72" grapples.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Grapple skidders used to skid full trees to the processor.

DESCRIPTION OF OPERATION: Clearcut.

DESCRIPTION OF SITE: Maine.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Operating Data for 4 Weeks - Clark Grapple Skidder

	"Week 1"	"Week 2"	"Week 3"	"Week 4"
Total Scheduled Hours	40.00	40.00	40.00	40.00
Mechanical Availability (%)	93.70	---	92.59	88.00
Utilization (%)	74.37	---	78.12	72.5
Prod./Effective Hour				
- trees/hour	26.38	42.73	36.08	42.5
- cords/hour	2.01	3.39	3.00	3.5

Average skidding distance = 10 chains.

OTHER COMMENTS: Production was geared to the availability of the processor.

CITATION: MacDonald, A.J. 1990. A CASE STUDY OF ROADSIDE LOGGING IN NORTHERN INTERIOR OF BRITISH COLUMBIA. FERIC Technical Report No. TR-97.

MACHINE SYSTEM: Three Cat 528 grapple skidders. Only two were used at a time. A third skidder (528 #3) was purchased partway through the study to replace the 528 #2 skidder.

OPERATOR RATING: One operator had 12 years experience on grapple skidders, the other less than one year.

DESCRIPTION OF SYSTEM:
Cat FB 227 feller-buncher → (3) Cat 528 grapple skidders → (1) Lim-mit processor → Cat LL229 loader

DESCRIPTION OF OPERATION: Feller-bunchers clearcut the trees, which were then grapple skidded to the roadside for limbing and topping. The trees were then loaded tree-length on off-highway trucks.

DESCRIPTION OF SITE: 75 km South of Houston, B.C. Terrain rolling with occasional guillies or steeper ground. Average slope = 8%. Road density = 58 m/ha.

DESCRIPTION OF STAND:

	Large wood area	Smallwood area
Average tree size (m^3)	0.86	0.24
Stems/ha merch.	388	976
unmerch.	77	13
Average tree diameter (cm)	35.8	10.7
Species distribution (%) Pine	32	97
Spruce	47	2
Balsam fir	21	1

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Butt diameter class (cm)	% Distribution by class	Tree volume (m^3)
10	4	0.08
20	56	0.21
30	30	0.52
40	9	1.07
50	1	2.04
ALL	100	0.41

PRODUCTION DATA:

	528 #1	528 #2	528 #3
Production (m^3)	17,764	4,658	3,820
Production shifts	40	16	13
PMH (hr)	264.5	105.3	86.4
m^3/PMH	67.2	44.2	44.2
SMH (hr)	367.0	128.8	109.2
Utilisation (%)	72	82	79
Production/8 hr shift (m^3)	387	289	280
Utilisation (wait-for-wood delays removed) (%)	83	82	81
Production/8 hr shift (m^3)	448	289	286

OTHER COMMENTS: Rates for skidder 528 #1 are more representative of average production due to the small sample sizes for the other two skidders. Typical distance from block boundary to road was 130 meters.

CITATION: Legault, R. and L.H. Powell. 1975. EVALUATION OF FMC 200 BG GRAPPLE SKIDDER. FERIC. Technical Report No. TR-1.

MACHINE SYSTEM: FMC 200 BG grapple skidder equipped with Omark Prentice Model 50 hydraulic loader and a rear-built grapple enclosing 14.4 Ft2 (area within grapple tip to tip).

OPERATOR RATING: Operator had approximately 4 months experience on the machine.

DESCRIPTION OF SYSTEM:
Belott harvester → Timmins Fel-Del harvester on Liebherr carrier → FMC 200 BG grapple skidder

DESCRIPTION OF OPERATION: Clearcutting. The harvesters worked at right angles to the road. The skidder followed the same pattern, using the same trail the harvester used.

DESCRIPTION OF SITE: Lebel-sur-Guevillon, Quebec. The site was a clay soil with 8-10 inches of humus under undulating topography. Skid trail slope = 12.5%.

DESCRIPTION OF STAND: 85% black spruce, 15% jack pine. Merchantable trees/acre = 502. Merchantable volume = 28 cunits/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume per stem = 4.8 Ft^3

PRODUCTION DATA:

<u>Productivity of FMC 200 BG Grapple Skidder</u>

Average skidding distance (Ft)	1,033
Volume/tree (Ft^3)	4.9
Trees per load	37
Average total time/turn (min.)	19.3
Average load size (cunits)	1.76
Cunits/PMH	5.6

<u>Regression equations</u>

TEL = - 42 + 0.73 DIA [R^2=0.93]
TT = 1191 + 0.72 DIA [R^2=0.49]

Where
- TEL = Travel empty and loaded, cmin/turn
- DIA = Average travel distance, Ft
- TT = Total time per turn
- R^2 = Coefficient of determination

39 turns were observed and timed.

OTHER COMMENTS: The only controllable time element that appeared to affect productivity was piling. Piling consisted 9.5% of the total time per turn.

CITATION: Powers, L.H. 1978. PRODUCTION AND PERFORMANCE STUDIES OF FMC 200 SERIES SKIDDERS. FERIC. Technical Report No. TR-29.

MACHINE SYSTEM: (3) FMC 200 BG bunk grapple skidders.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-buncher → Skidder

DESCRIPTION OF OPERATION: Machine 1 operated in clearcuts and right-of-ways. Machines 7 and 8 operated in clearcuts.

DESCRIPTION OF SITE:
Machine 1: Purcell Mountains, BC; skid trail slopes ranged from 0 to 10%.
Machine 7 & 8: N.E. Ontario; skid trail slopes ranged from 0 to 10%.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Machine 1: Average log volume = 17 Ft^3
Machine 7 & 8: Average log volume = 7 Ft^3

PRODUCTION DATA:

	Premodification		Post Modification		
	1		1	7	8
No. of shifts studied	155		133	174	168
Machine availiability (%)	62.9		82.9	82.6	89.2
Machine utilization (%)	58.1		78.6	76.9	80.8
Production/PMH (cunits)	→	5.29	←	6.76	7.29
Production/SMH (cunits)	→	3.58	←	5.20	5.89

OTHER COMMENTS: Machine 1 modifications involved improving the undercarriage and track assembly, chassis, and frame. Machines 7 and 8 were studied after the modifications were performed.

CITATION: McMorland, B.A. 1977. EVALUATION OF VOLVO BM 971 CLAM BUNK SKIDDER. FERIC. Technical Report No. TR-16.

MACHINE SYSTEM: Volvo BM 971 clambunk skidder is a rubber-tired, six-wheel drive, articulated unit that uses a loading boom to load full-tree into an inverted grapple on the rear chassis. Tractor-mounted shear. Drott feller-buncher. The Volvo BM 971 was undergoing experimental trials.

OPERATOR RATING: Study A: Swedish instructor. Study B: Canadian trainee, with 7-1/2 weeks of experience.

DESCRIPTION OF SYSTEM:
Study A: Feller-buncher or manual felling → Volvo BM 971 clambunk skidder → processor → loader.
Study B: Feller-buncher → Volvo clambunk → loader

DESCRIPTION OF OPERATION: Clearcutting. Study A: Trees were felled with a tractor-mounted shear or manually, skidded full-tree to the landing by the Volvo and then processed. Study B: Trees were felled by a feller-buncher, skidded full-tree to the landing and then hauled to the mill.

DESCRIPTION OF SITE: Kelowa, Canada.
Study A: Trail slope = 10%.
Study B: Trail slope = 5%.

DESCRIPTION OF STAND: Study A: Lodgepole pine and Engelman spruce. Merchantable trees per acre = 215. Merchantable volume = 42 cunits/acre. Study B: Lodgepole pine. Merchantable trees per acre = 350. Merchantable volume = 60 cunits/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Volume per tree (Ft^3):
Study A: 27.1
Study B: 20.8

PRODUCTION DATA:

Results of Detailed Time and Production Studied
Study Duration: Summer and early Fall, 1976 (2 weeks in total)

	Study A	Study B
Turn time (min)	23.5	46.1
Piece count/turn	19.1	38.1
Volume/turn (cunits)	5.4	7.9
Average skid distance (ft)	1140	3240
Load assembly time/tree (min)	Power saw 0.92 Tractor-mounted shear 0.65	Feller-buncher 0.49

Shift-Level Production Summary
Study Duration: 3 months in 1976

	Study A	Study B
Shifts worked	34	19
Overall avg. piece size (Ft^3)	20.1	20.3
Volume per turn (cunits)	4.2	5.6
Pieces per turn	21.1	27.5
Cunits/SMH	4.3	5.7
Cunits/PMH	7.4	8.0
# Turns	328	158

Shift-Level Time Summary	% of Scheduled Time
Productive machine hours (PMH)	62.3
Mechanical delays	31.2
Non-mechanical delays	6.5
Scheduled machine hours (SMH)	100
Mechanical availability (%)	68.8
Machine utilization (%)	62.3
No. of scheduled shifts	64

OTHER COMMENTS: Comparison of average piece count per turn suggests that in the clearcut the operator working with powersaw on tractor-sheared wood was not loading the Volvo to optimum capacity.

CITATION: Johnson, J.T. 1977. SKIDDING WITH THE CS-21 BUNK GRAPPLE SKIDDER. Pulp and Paper Canada. 78(11):102-103.

MACHINE SYSTEM: Kockums CS-21 Bunk grapple skidder

OPERATOR RATING: Operators with differing experience were being trained to operate the machine.

DESCRIPTION OF SYSTEM: Manual felling → Bunk grapple skidder → Rubber-tired loader

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: Interior of B.C. Gentle to rolling terrain with some wet areas.

DESCRIPTION OF STAND: Pine stand containing 200-250 trees/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree = 0.17 - 0.20 cunits.

PRODUCTION DATA:

Productivity Information 3 Month Period

Study	# of Days	Availability	Trees/PMH	Trees/cunit
1	24	65%	38	5.0
2	17	86%	44	4.5
3	20	51%	33	5.0
4	22	78%	59	7.0

OTHER COMMENTS: Machine appeared to be underpowered.

CITATION: Selby, J.S. and F. McCrackin. 1986. TIMBER JACK TJ 520 CLAMBUNK SKIDDER. Non-Published Paper Presented at the IUFRO World Congress, Yugoslavia. September 1986.

MACHINE SYSTEM: Timberjack TJ 520 clambunk skidder.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: The TJ 520 clambunk skidder was tested with 3 different systems (clearcutting):

1) Unbunched, manually felled wood.
2) Manually felled, grapple skidder prebunched wood.
3) Feller-buncher felled and bunched wood.

DESCRIPTION OF OPERATION:

DESCRIPTION OF SITE: 140 meter average skid distance, 15% adverse slopes.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Volume/stem: 0.28 m^3 bunched
0.52 m^3 unbunched

PRODUCTION DATA:

	Bunched	Unbunched
Stems/turn	24	11
Volume/turn (m^3)	6.7	5.7
Productive time/turn (min.)	14.7	27.6
Volume/SMH (m^3)	16.7	7.6
Turns/hectare	10	15

OTHER COMMENTS: The clambunk skidder was only used with bunched wood, where adverse slopes exceeded 20%, and skid distances were mostly greater than 150 meters.

CITATION: Reymond, Keith. 1988. FORWARDER OPERATIONS IN AUSTRALIA. Logging Industry Research Association, New Zealand. Vol. 13, No. 27, pp. 1-6.

MACHINE SYSTEM: The OSA 280 Master is rated at 18 tonne capacity and is powered by a 155 kW turbo engine.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Kockums 880 shear feller-buncher, a Harricana stroke-delimber mounted on a Cat 215 base and an OSA 280 Master forwarder.

DESCRIPTION OF OPERATION: In this clearfelling operation the forwarder was sorting sawlogs from pulpwood while loading. The forwarder was extracting directly to the roadside.

DESCRIPTION OF SITE: Easy terrain.

DESCRIPTION OF STAND: 28 year old radiata pine. Tree size approximately 2.0 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Pulpwood log (tonnes/piece)	0.27
Sawlog (tonnes/piece)	0.62
Average length (m)	5.5

PRODUCTION DATA:

Forwarder productivity (tonnes/PMH)	51
Average daily productivity (tonnes)	310

Work Cycle of the OSA 280 Forwarder

Element	Mean per cycle (min)	# of Total Cycle
Travel empty	4.80	19.0
Load	7.66	30.3
Move (while loading)	1.76	7.0
Travel loaded	4.28	16.9
Position	0.98	3.9
Unload (to truck)	5.79	22.9
Total cycle (net of delays)	25.27	100.0
Average haul distance (m)	150	
Number of pieces loaded	34	
Volume per load (tonnes)	21.3	

OTHER COMMENTS: Productivity is comparable to high productivity skidder operations. Developments in mechanized processing in New Zealand may result in a trend towards forwarder extraction in the future.

CITATION: Waycott, R. 1977. KOCKUM FORWARDER MOST PROFITABLE WHEN ROAD BUILDING COSTS HIGH. Pulp and Paper Canada. 78(11):67-70.

MACHINE SYSTEM: Kokum 875-66 forwarder with six cord capacity, equipped with a 178 hp diesel engine and a Jonsered JET 66 loader.

OPERATOR RATING: 3 years experience.

DESCRIPTION OF SYSTEM:
(?) Kockum Processors - (9) Kockum forwarders

DESCRIPTION OF OPERATION: Clearcutting. The forwarder follows the same operating strips as the processor. Maximum normal forwarding distance = 2000 feet.

DESCRIPTION OF SITE: Near Port Hawksbury, Nova Scotia. Slopes ranged from 0-30%. Terrain is rough and irregular.

DESCRIPTION OF STAND: Stands averaged 15-25 cords/acre. Tree size averaged about 15-20 trees/cord.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Productivity (1976 summary)

	Avg.	Range
Utilization (%)	69	66-75
Mech. Avail. (%)	84	76-90
Cords/PMH	4.53	3.4-5.5
Forwarding distance (ft)	1,200	max of 2,000

Time Distribution

Non-mechanical delay (%)	15
Service (%)	5
Wait for repair (%)	3
Active repair (%)	8
Productive time (%)	69

OTHER COMMENTS: Productivity was most affected by transport time, then loading and unloading.

CITATION: Moore, T. 1990. PILOT TRIALS WITH LOADER LOGGING IN NEW ZEALAND. Logging Industry Research Association, New Zealand. Vol. 15, No. 2.

MACHINE SYSTEM: Sumitomo LS 4300 30 tonne hydraulic loader with a Prentice 610 boom, a Pierce live-heel and a Prentice 8-48W continuous rotation grapple. Extra guarding on underside of machine.

OPERATOR RATING: Inexperienced in cutover.

DESCRIPTION OF SYSTEM: Manual cutters → Sumitomo LS 4300 loader

DESCRIPTION OF OPERATION: Working parallel to roads, loader swung tree-lengths 50 meters from stump to roadside in an average of 4 swings.

DESCRIPTION OF SITE: Wainui Forest, New Zealand. Sharp incised gullies, slopes to 18°.

DESCRIPTION OF STAND: Windthrown thinned radiata pine with uneven distribution.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average piece size 0.4 m^3

PRODUCTION DATA:

Maximum swing distance (m)	50
Average daily production (tonnes)	140

OTHER COMMENTS: Maximum swing distance of 50 meters, with small piece size, made productivity low and unit cost of wood at roadside (NZ $5.95/tonne) too expensive.

CITATION: Powell, L.H. and G. St. Jean. 1979. TRIAL OF OSA 670 FELLER BUNCHER AND OSA 705 PROCESSOR IN BRITISH COLUMBIA. FERIC. Technical Report No. TR-31.

MACHINE SYSTEM: OSA 705 processor mounted on an OSA 260 forwarder. The machine was equipped with a 48 inch circular slashing saw and a 25 inch topping chain-saw. Modifications included a longer feed tray and a loader capacity topping shear.

OPERATOR RATING: Experienced.

DESCRIPTION OF SYSTEM: Skidders → OSA 705 processor

DESCRIPTION OF OPERATION: Clearcutting. A trial operation. The processor worked on the landing.

DESCRIPTION OF SITE: British Columbia. Range of slopes = 0-10%.

DESCRIPTION OF STAND:

Species	Lodgepole pine
Stand volume (cunits/acre)	19
Volume/tree (Ft^3)	6.9
Average height (Ft)	55

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

<u>Production Summary for the OSA 705</u>

Availability (%)	69.0
Utilization (%)	59.0
Average piece size (Ft^3)	8.3
Trees/PMH	105
Cunits/PMH	8.8
No. shifts studied	38

<u>Time Distribution</u>

Productive time (%)	59
Mechanical delay (%)	23
Non-mechanical delay (%)	18

OTHER COMMENTS: The major cause of low utilization was an inadequate supply of material at the landing.

CITATION: Anon. 1974. VOLVO PROCESSOR CUTS 6.7 CUNITS PER HOUR. Canadian Forest Industries. 94(3):42.

MACHINE SYSTEM: BM Volvo SM-880 processor with 147 hp diesel engine.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Drott 40 feller-buncher → Volvo processor → Timberjack forwarder

DESCRIPTION OF OPERATION: Trees were clear-felled and placed into windrow by a Drott 40 feller-buncher. The trees were then processed by the Volvo and forwarded to the roadside by a Timberjack Pulpjack.

DESCRIPTION OF SITE: St. Felicien, Quebec. Terrain: flat to slightly rolling. Soil: sandy loam.

DESCRIPTION OF STAND: Black spruce and jack pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Product was 8 foot pulpwood. Average volume/tree = 4.9 Ft^3. Average number of 8 foot sticks per tree = 3.8.

PRODUCTION DATA:

Production Summary:

Average time/tree (min)	0.44
Average productivity (cunits/PMH)	6.7
Sample size (trees)	1,500

Sensitivity

Each additional 8 ft. stick increased total time by 5 cmin.

Time Distributions

Processing Cycle	
Waiting for tree (%)	5
Processing (%)	84
Delays (%)	2
Moving (%)	9

Loading Cycle	
Waiting for processor (%)	11
Loading (%)	55
Prelimbing (%)	18
Delay (%)	5
Moving (%)	11

OTHER COMMENTS:

CITATION: Kellogg, L.D. et al. 1987. EVALUATION OF A GRAPPLE PROCESSOR. ASAE Paper No. 87-1566.

MACHINE SYSTEM: (2) Steyr KP-40 grapple processors, mounted on used 93 kW John Deere 690-13 excavation carriers.

OPERATOR RATING: No prior experience with grapple processors.

DESCRIPTION OF SYSTEM:
Site 1. Grapple skidder → grapple processor → loader → transport → chipper.
Site 2. Grapple skidder → grapple processor → sawlogs → pulpwood → loader → transport.

DESCRIPTION OF OPERATION: 2 operations
Site 1: Clearcut and partial cut.
Site 2: Clearcut.

DESCRIPTION OF SITE:
Site 1: Mount Hood National Forest. Mixed conifer.
Site 2: Bend, Oregon. The stems were processed to a 4 inch top diameter.

DESCRIPTION OF STAND:
Site 1: Average merch. tree = 0.47 m^3.
Site 2: Average merch. tree = 0.39 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Site 1: Sawlogs processed to a minimum 6 inch top, pulp logs also taken.
Site 2: Processed to a 4 inch top diameter (50 foot max length) prior to transport and chipping.

PRODUCTION DATA:

Grapple Processor Productivity

	Site 1	Site 2
Scheduled hours	449	974
Productive hours	261	546
Utilization (%)	58.1	56.1
Trees/productive hour	93	109
m^3/productive hour	43.9	41.8
Mechanical availability (%)	78.3	70

OTHER COMMENTS: Good delimbing quality but low mechanical availability.

CITATION: MacDonald, A.J. 1988. EVALUATION OF THE STEYR KP 40 CRANE PROCESSOR. FERIC. Technical Note No. TN-118.

MACHINE SYSTEM: Steyr KP40 crane processor mounted on Caterpillar's 215B LC (< 1 yr). The processor used was the Steyr KP40 (series 2) to be put in service. Clark Ranger 668C grapple skidder. Steyr KP40 had been operated for two months.

OPERATOR RATING: The operator had not yet reached his maximum potential.

DESCRIPTION OF SYSTEM: Feller-buncher → grapple skidder → Processor → Loader

DESCRIPTION OF OPERATION: Clearcutting. The processor worked on a pile of logs while a Clark Ranger 668C grapple skidder built another pile at the same landing.

DESCRIPTION OF SITE: 70 km South of Vanderhoof, B.C.

DESCRIPTION OF STAND: Pine >99%. Spruce <1%. Average butt diameter = 27.1 cm.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Two log lengths were preferred: 16.8 m for logs over a 28-cm butt diameter and 14.3 m for smaller logs. 20% of the trees had one log per tree.

PRODUCTION DATA: Study Period: January 1987

Productive-Time Summary

Move (%)	2
Net process (%)	98
Minor delays (%)	0
No. of trees	98
Productive time (min)	48
Tree/PMH	122
Log per tree	1.62
Swing/grasp time (min/tree)	0.24
Feed/cut time (min/tree)	0.24
Net processing time (min/tree)	0.48

OTHER COMMENTS: The trees were piled 2-3 meters high to conserve landing space, which results in the tops and branches becoming more tangled than a low pile. Also the operator placed, rather than dropped, the tops in debris pile to maintain a tidy work area, and this time was included in swing/grasp time.

CITATION: MacDonald, A.J. 1988. EVALUATION OF THE STEYR KP40 CRANE PROCESSOR. FERIC. Technical Note No. TN-118.

MACHINE SYSTEM: Steyr KP40 crane processor mounted on a Komatsu PC 220 carrier. Later the same Steyr was mounted on a Caterpillar 225LC carrier with a Koehring felling head. Clark Ranger 667 grapple skidder. Caterpillar 950 wheel-loader.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-buncher → Grapple skidder → Processor → Loader

DESCRIPTION OF OPERATION: Clearcutting. A Caterpillar 225 with a Koehring felling head was used for felling and bunching, and a Clark Ranger 667 grapple skidder was used for skidding. Trucks were loaded by a Caterpillar 950 wheel loader. The processor operated in windrows separately from the skidder.

DESCRIPTION OF SITE: 30 km South of Savona, B.C. The side slope was generally less than 10% with occasional gullies.

DESCRIPTION OF STAND: Aug. 86: 80% pine, 20% spruce. Avg. butt diameter = 25.3 cm. Dec. 86: 96% pine, 4% spruce. Avg. butt diameter = 23.4 cm.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Aug. 86: Avg. tree volume = 0.52 m^3, Avg. log length = 14.5 m.
Dec. 86: Avg. tree volume = 0.46 m^3, Avg. log length = 14.9 m.
Preferred log lengths were in multiples of 8 ft. 3 in.

PRODUCTION DATA:

Productive-Time Summary

	Aug. 86	Dec. 86
Move (%)	2	4
Net process (%)	96	85
Minor delays (%)	2	11
No. of trees	916	1,543
Productive time (min)	408	570
Tree/PMH	135	162
Log per tree	1.03	1.01
Swing/grasp time (min/tree)	0.23	0.13
Feed/cut time (min/tree)	0.20	0.19
Net processing time (min/tree)	0.43	0.32
Utilization (%)	---	95

OTHER COMMENTS: The contractor was not satisfied with the Komatsu PC 220's performance, and changed to the Caterpillar 225.

CITATION: MacDonald, A.J. 1988. EVALUATION OF THE STEYR KP40 CRANE PROCESSOR. FERIC. Technical Note No. TN-118.

MACHINE SYSTEM: Steyr KP40 crane processor, mounted on a 10 year old Drott Cruz-aire wheeled carrier. Maximum delimbing diameter is 40 cm.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Drott 50 auger feller-buncher → John Deere 740A grapple skidder → Steyr processor → Hough 90 wheel loader.

DESCRIPTION OF OPERATION: Trees were felled with a Drott 50 auger feller-buncher, the bunches were skidded to the landing with a John Deere 740A grapple skidder and a Hough 90 wheel loader was used for loading. The Steyr KP40 operated in the landing simultaneously with the skidder and loader.

DESCRIPTION OF SITE: 70 km southwest of Prince George, B.C. The site was rolling, with occasional gullies.

DESCRIPTION OF STAND: July 86: >99% pine, <1% spruce. Average butt diameter = 26.8 cm. Jan. 87: 98% pine, 2% spruce. Average butt diameter = 27.6

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
July 86: Average tree volume = 0.65 m^3, Average log length = 17.9 m.
Jan. 87: Average tree volume = 0.75 m^3, Average log length = 19.3 m.
The contractor was required to separately bundle any logs under 6.1 m in length.

PRODUCTION DATA:

Productive-Time Summary

	July 87	Jan. 88
Move (%)	1	2
Net process (%)	96	81
Minor delays (%)	3	17
No. of trees	468	1,075
Productive time (min)	203	570
Tree/PMH	138	113
Log per tree	1.03	1.06
Swing/grasp time (min/tree)	0.15	0.12
Feed/cut time (min/tree)	0.27	0.31
Net processing time (min/tree)	0.42	0.43
Utilization (%)	---	69

OTHER COMMENTS: The Steyr KP40 operator felt his productivity was decreased by pulling trees from a cold deck and he instructed the skidder operator to stop skidding when the Steyr KP40 was delayed. Overall productivity may have increased by accepting the longer processing times with cold decks and eliminating the delays waiting for wood.

CITATION: Folkema, M.P. 1981. THE KOEHRING ROLL DELIMBER LONGER-TERM DATA COLLECTION FROM THREE MACHINES. FERIC. Technical Note No. TN-44.

MACHINE SYSTEM: Koehring roll-delimber mounted on converted Koehring KFB-3 wheeled carrier. Equipped with a Caterpillar 3306 engine (215 hp).

OPERATOR RATING: The two operators on the delimber had one year of experience on that unit.

DESCRIPTION OF SYSTEM:
(2) Koehring feller-forwarders → delimber
(1) Koehring K4FB feller-buncher → John Deere 740 grapple skidder → delimber.

DESCRIPTION OF OPERATION: Clearcutting. Felling and forwarding to roadside by feller-forwarders, feller-buncher and grapple skidder. The delimbers processed at the roadside.

DESCRIPTION OF SITE: 60 km southwest of Long Lac, Ontario. Terrain: generally hilly with some broken ground and rock outcrops.

DESCRIPTION OF STAND: Species harvested: black spruce, jack pine and balsam fir.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree size = 8.1 Ft^3

PRODUCTION DATA: Study Duration: 6 months

Time Distribution: Percent of Total Time		Productive Summary	
Productive (PMH) (%)	48.3	Trees per PMH	133
Repair and maintenance (%)	32.1	Productivity (cunits/PMH)	10.8
Non-productive (%)	8.2	Production/shift (cunits/shift) (8 hr x UTIL. x VOL/PMH)	42
Delays (%)	11.4	Trees/cunit	12.3
Availability (%)	69		
Utilization (%)	49		

OTHER COMMENTS: The poorest delimbing quality was observed during early June while delimbing freshly-cut Balsam fir.

CITATION: Folkema, M.P. 1981. THE KOEHRING ROLL DELIMBER: LONGER-TERM DATA COLLECTION FROM THREE MACHINES. FERIC. Technical Note No. TN-44.

MACHINE SYSTEM: Koehring roll-delimber mounted on converted Koehring KFB-3 wheeled carrier, equipped with Caterpillar 3306 engines (215 hp). Modifications: Boom adaptor, boom and head.

OPERATOR RATING: The operators of the KR delimber had only 3 months experience.

DESCRIPTION OF SYSTEM:
(2) Koehring feller-forwarders → delimber
(1) Koehring K4FB feller-buncher → John Deere 740 grapple skidder → delimber.

DESCRIPTION OF OPERATION: Clearcutting. Softwood stands were felled and forwarded to roadside by feller-forwarders or by a feller-buncher grapple skidder system.

DESCRIPTION OF SITE: 60 km southwest of Longlac, Ontario. Terrain: generally hilly with some broken ground and rock outcrops.

DESCRIPTION OF STAND: Species harvested: black spruce, jack pine and balsam fir.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree size = 7.8 Ft^3

PRODUCTION DATA: Study Duration: 7 months

Time Distribution: Percent of Total Time		Productive Summary	
Productive (PMH) (%)	54.2	Trees per PMH	113
Repair and maintenance (%)	29.2	Productivity (cunits/PMH)	8.8
Non-productive (%)	9.7	Production/shift (cunits/shift) (8 hr x UTIL. x VOL/PMH)	38
Delays (%)	6.9	Trees/cunit	12.8
Availability (%)	71		
Utilization (%)	54		

OTHER COMMENTS: The main mechanical problem with the delimber was caused by the heavy weight of the delimber head (4,000 kg). The heavy weight contributed to 'shock loading' or torque stresses on the supporting components.

CITATION: Folkema, M.P. 1981. THE KOEHRING ROLL DELIMBER: LONGER-TERM DATA COLLECTION FROM THREE MACHINES. FERIC. Technical Note No. TN-44.

MACHINE SYSTEM: Koehring roll-delimber mounted on a Koehring 266 tracked carrier equipped with a GM4-7IN engine (143 hp) Koehring feller-forwarders, feller-buncher, grapple skidder, KR delimber was on a 6-month trial.

OPERATOR RATING: Both operators had 3 to 4 months of experience on the KR delimber at the start of FERIC's study.

DESCRIPTION OF SYSTEM:
(2) Koehring feller-forwarders → delimber.
(1) Koehring K4FB feller-buncher → (John Deere 740) grapple skidder → delimber.

DESCRIPTION OF OPERATION: Clearcutting. Softwood stands were felled and forwarded to the roadside by feller-forwarders or by a feller-buncher/grapple skidder system.

DESCRIPTION OF SITE: Northern Maine. Terrain: flat to gently rolling with occasional lowland areas.

DESCRIPTION OF STAND: Uniform softwood stands.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average volume per merchantable stem = 6.8 Ft^3

PRODUCTION DATA: Study Duration: 2 months

Time Distribution:

Percent of Total Time		Productive Summary	
Productive (PMH) (%)	57.4	Trees per PMH	116
Repair and maintenance (%)	23.6	Productivity (cunits/PMH)	8.0
Non-productive (%)	2.5	Production/shift (cunits/shift)	36
Delays (%)	13.4	(8 hr x UTIL. x VOL/PMH)	
		Trees/cunit	14.6
Availability (%)	73		

OTHER COMMENTS: Most of the downtime could be attributed to the large size and weight of the delimbing head, which resulted in shock loading and metal failure on the swing reducer/turntable assembly components.

CITATION: MacDonald, A.J. 1990. A CASE STUDY OF ROADSIDE LOGGING IN NORTHERN INTERIOR OF BRITISH COLUMBIA. FERIC Technical Report No. TR-97.

MACHINE SYSTEM: Prototype Lim-mit processor mounted on a Cat 225 carrier. Operated for two 10 hour shifts per day (day/night).

OPERATOR RATING: Experienced operators (2) working with machine from 1986.

DESCRIPTION OF SYSTEM:
Cat FB 227 feller-buncher → (3) Cat 528 grapple skidders → (1) Lim-mit processor → Cat LL229 loader

DESCRIPTION OF OPERATION: Feller bunchers clearcut the trees, which were then grapple skidded to the roadside for limbing and topping. The trees were then loaded tree-length on off-highway trucks.

DESCRIPTION OF SITE: 75 km South of Houston, B.C. Terrain rolling with occasional guillies or steeper ground. Average slope = 8%. Road density = 58 m/ha.

DESCRIPTION OF STAND:

	Large wood area	Smallwood area
Average tree size (m^3)	0.86	0.24
Stems/ha merch.	388	976
unmerch.	77	13
Average tree diameter (cm)	35.8	10.7
Species distribution (%) Pine	32	97
Spruce	47	2
Balsam	21	1

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Butt diameter class (cm)	% Distribution by class	Tree volume (m^3)
10	4	0.08
20	56	0.21
30	30	0.52
40	9	1.07
50	1	2.04
ALL	100	0.41

PRODUCTION DATA:

	Day	Night
Production (m^3)	17,980	17,859
Production (stems)	31,958	31,744
Production shifts	40	39
PMH (hr)	236.4	224.8
m^3/PMH	76.1	79.4
Stems/PMH	135	141
SMH (hr)	358.3	370.4
Utilisation (%)	66	61
Production/8 hr shift (m^3)	402	386
Utilisation (wait-for-wood delays removed) (%)	72	66
Production/8 hr shift (m^3)	439	421

Processing time by butt-diameter class.

Butt diameter class (cm)	No. Cycles	No. Trees	Min/Cycle
10	6	6	0.20
20	60	68	0.28
30	51	56	0.32
40	26	26	0.39
50	13	13	0.43
60	4	4	0.78
70	1	1	0.54
ALL	161	174	0.33

OTHER COMMENTS: Net processing time = 82% of productive time. Times given are for limbing and topping the stem, as the logs were hauled tree-length to the mill.

CITATION: Richardson, R. 1989. EVALUATION OF FIVE PROCESSORS AND HARVESTERS. FERIC. Technical Report No. TR-94.

MACHINE SYSTEM: Steyr KP40 processing head mounted on a Mitsubishi M5180 LC excavator.

OPERATOR RATING: Inexperienced.

DESCRIPTION OF SYSTEM: (1) Case 1187 feller-buncher → Steyr KP 40
(2) Skidder → Steyr KP40

DESCRIPTION OF OPERATION: (1) Produced tree-length logs in the stand, (2) Produced shortwood (2.54 or 4.01 m lengths) piles from full tree bunches at roadside.

DESCRIPTION OF SITE: Thunderbay, Ontario, Canada. C.P.P.A. Terrain classification 1.2.1. Slope range: 0-5%.

DESCRIPTION OF STAND: 73% spruce, 24% jack pine, 3% aspen.

	Butt Diameter (cm)	Merch. Tree length (m)	Tree volume (m^3)
Average:	20	11.0	0.24
Range:	10-46	6.0-18.5	0.03-1.29

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
(1) Tree-length logs.
(2) 2.54 or 5.01 m bolts.

PRODUCTION DATA:

	System 1 (tree-length)	System 2 (shortwood)
Productive time measured (PMH)	4.1	2-6
Total merchantable trees	344	201
Average productivity	84 ± 19	76 ± 13
- trees/PMH ± conf. int.	20.0 ± 4.6	18.0 ± 3.1
- m^3/PMH ± conf. int.		

Cycle Times

Work Element	System 1 [N = 282] Avg. Time (min.)	% of total	System 2 [N = 110] Avg. Time (min.)	% of total
Load	0.25	33	0.38	49
Process	0.28	37	0.32	41
Move slash	---	---	0.03	4
Straighten pile	0.04	5	0.02	3
Move machine	0.13	18	0.01	1
Delays	0.04	6	0.01	2
Total cycle time	0.74	100	0.78	100

OTHER COMMENTS: Cycle times correlated with tree diameter ($R^2 = 0.37$) in system 1. Productivity in m^3/PMH was highly correlated with volume per tree ($R^2 = 0.90$). Machine equipped with accurate length measuring equipment.

CITATION: Richardson, R. 1989. EVALUATION OF FIVE PROCESSORS AND HARVESTERS. FERIC. Technical Report No. TR-94.

MACHINE SYSTEM: Rottne Rapid 860 two-grip processor.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Manual felling → Rottne Rapid 860 processor

DESCRIPTION OF OPERATION: Processor travelled at right angles to prefelled trees and delimbed and slashed them into three different lengths (veneer logs, sawlogs, pulpwood bolts).

DESCRIPTION OF SITE: Newcastle, N.B., Canada. C.P.P.A. terrain classification 1.1.1. Slope range: 0-10%.

DESCRIPTION OF STAND: 66% black spruce, 34% balsam fir. Trees/ha = 1,900.

	Butt Diameter (cm)	Merch. Tree length (m)	Tree volume (m^3)
Average:	18	8.3	0.16
Range:	10-38	2.5 - 20.3	0.06 - 0.80

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

	Cycle Times	
Element	Avg. time (min)	% of Total Time
Swing Empty	0.15	24
Swing with tree	0.14	21
Load bunk	0.07	11
Process	0.22	35
Straighten pile	0.01	1
Move slash	0.02	3
Move machine	0.03	5
Total Cycle Time	0.64	100

Productive time measured (PMH) = 6.9
Total merchantable trees = 697
Average Productivity:
- trees/PMH ± conf. int. = 101 ± 11
- m^3/PMH ± conf. int. = 16.2 ± 1.8

OTHER COMMENTS: Cycle time correlated to diameter class (R^2 = 0.31). Productivity (m^3/PMH) correlated to vol/tree (R^2 = 0.85).

CITATION: McMorland, B. 1984. PRODUCTION AND PERFORMANCE OF MECHANICAL DELIMBING EQUIPMENT IN INTERIOR B.C.: DENIS AND ROGER "STROKE" DELIMBERS. FERIC. Technical Note No. TN-75.

MACHINE SYSTEM: Roger "funnel-type" delimber-topper. This delimber attachment was the short-boom model with the 58-cm diameter capacity and was mounted on a used Drott 40 undercarriage. Started operating in early January 1982. FMC 200BG. Two D-6 tractors.

OPERATOR RATING: The operator had no experience with mechanical delimbers when the study began. By the final three weeks, he had reached his potential.

DESCRIPTION OF SYSTEM:
(1) FMC → Delimber
(2) Tractors → Delimber

DESCRIPTION OF OPERATION: Clearcut. The delimber worked at roadside piles delimbing and topping trees that had been skidded by a FMC and 2 tractors.

DESCRIPTION OF SITE: Interior B.C. Slopes = 5% - 15%.

DESCRIPTION OF STAND: 85% pine, 13% fir, 1% spruce and 1% cedar.
Merchantable volume/ha = 348 m^3. Merchantable stems/ha = 1,179. Average DBH = 20.3 cm.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree size = 0.29 m^3

PRODUCTION DATA:

Time and Production Summary

	Full Period	First 3 Weeks	Last 3 Weeks
Usual shift length (hours)	9.5	9.5	9.5
Number of shifts worked	31	16	15
Productive time ratio (productive hrs/total hrs) (%)	77.0	76.1	78.1
Volume per PMH (m^3)	26.6	23.0	30.5
Trees per PMH	91.8	79.4	105.0
Volume per shift worked (m^3)	195.0	169.5	222.3
Tree count per shift worked	673	585	766
Production per 8-hour shift:			
m^3	164.2	139.8	191.2
Tree count	567	482	659

OTHER COMMENTS: Operator does not seem to take full advantage of the extra stroke length.

CITATION: Folkema, M.P. 1983. EVALUATION OF THE S.L.R.-2000 DUAL HEAD DELIMBER ATTACHMENT. FERIC. Technical Note No. TN-67.

MACHINE SYSTEM: Mark II prototype S.L.R.-2000 dual head delimber mounted on a modified 6-wheel Lokomo 928 carrier. Built in October 1982, the attachment uses two sets of delimbing grapples to delimb two or more trees at one time. This unit incorporated many improvements over the Mark I.

OPERATOR RATING: Operator was rated as excellent.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Full trees had been skidded to the roadside and piled at right angles to the road using cable skidders. The delimber travels on the road, working from roadside piles.

DESCRIPTION OF SITE:
Study II: Chapais, Quebec. Ambient temperature = -15°C.
Study III: Senneterre, Quebec. Ambient temperature = -10°C.
Study IV: Lebel-sur-Queuillon, Quebec. Ambient temperature = -20°C.

DESCRIPTION OF STAND:
Study II: 100% jack pine.
Study III: 70% black spruce, 30% jack pine.
Study IV: 100% black spruce.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

	Volume/Tree (Ft^3)
Stand II	4.9
Stand III	2.9
Stand IV	3.9

PRODUCTION DATA: Study Length: Two-days

Study Results

	Study II	Study III	Study IV
Operator-experience on S.L.R.-2000 (months)	2	2	4
Study duration (hours (PMH))	3.53	5.72	5.01
Trees delimbed/cycle	2.87	3.19	5.01
Volume per cycle (Ft^3)	14.0	9.3	19.6
Cycle per PMH	86	74	80
Trees per PMH	245	237	400
Production per PMH (cunits/PMH)	12.0	6.9	15.7

	Time Per Cycle		
	Study II	Study III	Study IV
Load full tree(s) (%)	42	42	42
Delimb (%)	24	29	27
Reverse tree(s) to unload (%)	14	17	12
Moving time (%)	4	1	3
Delays (%)	16	11	16

OTHER COMMENTS: S.L.R. reported some topping knives had been bent or twisted. In spite of several attempts by S.L.R. to overcome the multi-tree topping problem, it has not been completely resolved at the time of writing.

CITATION: Folkema, M.P. 1983. EVALUATION OF THE S.L.R.-2000 DUAL HEAD DELIMBER ATTACHMENT. FERIC. Technical Note No. TN-67.

MACHINE SYSTEM: Mark I prototype S.L.R.-2000 dual head delimber mounted on a modified 6-wheel Lokomo 928 carrier. Built in mid-1982 the attachment uses two sets of delimbing grapples to delimb two or more trees at one time.

OPERATOR RATING: Operator was rated as good, and had 3 weeks experience with the S.L.R.-2000.

DESCRIPTION OF SYSTEM:
Cable Skidders → Delimber

DESCRIPTION OF OPERATION: Clearcutting. Full trees had been skidded and piled at right angles to the road using cable skidders. The delimber travels on the road, working from roadside piles.

DESCRIPTION OF SITE: Alma, Quebec. Ambient temperature = 10°C.

DESCRIPTION OF STAND: Species: 60% black spruce, 15% white spruce and 25% balsam fir.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume per tree = 6.5 Ft^3

PRODUCTION DATA: Study Date: Sept. 9 & 10, 1982.

Study Results

Study duration (hrs (PMH))	4.38
Trees delimbed/cycle	2.28
Volume per cycle (Ft^3)	14.8

	Time Per Cycle
Load full tree(s) (%)	46
Delimb (%)	25
Reverse tree(s) to unload (%)	15
Moving time (%)	6
Delays (%)	8

Cycles per PMH	85
Trees per PMH	195
Production per PMH (cunits/PMH)	12.7

OTHER COMMENTS:

CITATION: Pickering, R.R. 1975. LOGMA LIMBS IT ALL. Pulp and Paper Canada. 76(9):87-91.

MACHINE SYSTEM: Logma T-310 limber-buncher mounted on the SMV 21-P carrier.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-buncher → Skidder → Logma T-310 limber-buncher

DESCRIPTION OF OPERATION: Clearcutting operation with the delimber operating both at roadside and at the stump.

DESCRIPTION OF SITE: Granomere, Quebec. Flat terrain.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Location	Scheduled Hours	Tree Size	Productivity	Availability	Utilization
Roadside	7,735	15.5 trees/cunit	100.5 trees/PMH 6.48 cunits/PMH	54	46
Stump	----	8.3 trees/cunit	69.6 trees/PMH 8.39 cunits/PMH	----	----

OTHER COMMENTS: The Logma T-310 is limited to gentle terrain because of its high center of gravity. Low availability and utilization mainly due to lack of spare parts.

CITATION: Giguere, Pierre. 1981. ROGER, HARRICANA AND LOGMA DELIMBERS: LONG TERM EVALUTATION. FERIC. Technical Note No. TN-42.

MACHINE SYSTEM: (2) Roger stroke-boom delimbers on JCB-808 carriers.

OPERATOR RATING: Machine (A): 6 months experience. Machine (B): 9 months experience.

DESCRIPTION OF SYSTEM: Both delimbers observed processing at road side cold decks.

DESCRIPTION OF OPERATION: Clearcutting. Delimbers operating at road side decks.

DESCRIPTION OF SITE: Roadside cold-decks in Quebec.

DESCRIPTION OF STAND:
(A) Black spruce with an average volume of 0.11 m^3 tree.
(B) Black spruce and jack pine with an average volume of 0.14 m^3 tree.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Machine	A	B
Study length (days)	55	128
Utilization (%)	84.6	80.0
Trees/PMH	174	186
Volume/PMH (m^3)	18.9	25.4
Trees/m^3	9.19	7.35

Repairs	A	B
Repair hours/100 productive hours	11	8.5
Average time/repair (hrs)	2.2	1.5
Average time between repairs (hrs)	20.1	17.9

OTHER COMMENTS: All material went to a Sawmill.

CITATION: Giguere, Pierre. 1981. ROGER, HARRICANA AND LOGMA DELIMBERS, LONG TERM EVALUATION. FERIC. Technical Note No. TN-42.

MACHINE SYSTEM: (3) Logma T-310 delimbers on Logma SMV-21P chassis.

OPERATOR RATING: (E) 5 years, (F) 4 years, and (G) 6 years of experience.

DESCRIPTION OF SYSTEM: Clearcutting. Delimbers observed operating on roadside cold decks.

DESCRIPTION OF OPERATION:

DESCRIPTION OF SITE: All in Quebec.

DESCRIPTION OF STAND:
(E) 70% black spruce, 30% jack pine.
(F) 20% black spruce, 20% balsam fir, 60% jack pine.
(G) 30% white spruce, 70% balsam fir.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
(E) Average volume/tree = 0.17 m^3
(F) Average volume/tree = 0.13 m^3
(G) Average volume/tree = 0.21 m^3

PRODUCTION DATA:

Machine	E	F	G
Days	122	94	107
Scheduled time (hrs)	1,001	1,538	1,756.3
Utilization (%)	65.3	60.0	70.2
Trees/m^3	5.79	7.61	4.73
Trees/PMH	107	132	103
Volume/PMH (m^3)	18.53	17.30	21.79

Repairs	E	F	G
Average time between (hrs)	10.9	8.1	5.7
Average time per (hrs)	3.4	2.9	1.3

OTHER COMMENTS:
(E) All to sawmill.
(F) All to pulpmill.
(G) 30% to sawmill, 70% to pulpmill.

CITATION: Giguere, Pierre. 1981. ROGER, HARRICANA AND LOGMA DELIMBERS, LONG TERM EVALUATION. FERIC. Technical Note No. TN-42.

MACHINE SYSTEM: (2) Harricana stroke-boom delimbers mounted on a JD 693 carrier.

OPERATOR RATING: 9 months experience.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. Delimbers operating on roadside cold decks.

DESCRIPTION OF SITE: Quebec, Canada .

DESCRIPTION OF STAND:
(C) 100% black spruce.
(D) 85% black spruce, 15% jack pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
(C) Average volume/tree = 0.11m^3
(D) Average volume/tree = 0.15m^3

PRODUCTION DATA:

Machine	C	D
Days	72	122
Scheduled Time (hrs)	1,609.5	2,221.0
Utilization (%)	91.5	66.9
Trees/m^3	9.3	6.54
Trees/PMH	210	147
Vol/PMH (m^3)	22.61	22.47

Repair	C	D
Average time per (hrs)	1.6	2.3
Average time between (hrs)	46.2	11.4

OTHER COMMENTS: All material to sawmill.

CITATION: Folkema, M.P. and J.M. Lavoie. 1978. COMPARISON OF THE ROGER AND HARRICANA DELIMBERS. FERIC. Technical Note No. TN-24.

MACHINE SYSTEM:
Machine (A) - Roger stroke-boom delimber mounted on a JCB 808 carrier.
Machine (B) - Harricana stroke-boom delimber mounted on an International 3966.
(Machines were compared side by side)

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-buncher → choker skidder → delimber

DESCRIPTION OF OPERATION: Tree-length logging, clearcutting. Trees were felled by a tracked feller-buncher, then skidded to the roadside with a choker skidder. Delimbing operation was performed at roadside.

DESCRIPTION OF SITE: Quebec during July. Gently rolling with swampy depressions.

DESCRIPTION OF STAND: Black spruce and balsam fir.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Machines operated side-by-side on the same operation.

	Roger	Harricana
No. of trees	165	182
Volume per tree (Ft^3)	7.7	7.7
Volume per cycle (Ft^3)	8.4	8.1
Average cycle time (min.)	0.356	0.483
Cycles/PMH	169	124
Trees/PMH	182	130
Production/PMH (m^3)	40	28

OTHER COMMENTS: Lower productivity of Harricana attributed to:
1) "Step" delimbing.
2) Slower extension and retraction speed.

CITATION: Gleason, A.P. 1984. MECHANIZED DELIMBING (CAN IT CUT COSTS?). Logging Industry Research Association, New Zealand. Vol. 9, No. 8.

MACHINE SYSTEM: Harricana delimber mounted on a Cat 215 excavator base.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-buncher → delimber → forwarder

DESCRIPTION OF OPERATION: Clearfelling. The delimber, travelling over an area that had been previously felled and bunched, delimbed and processed trees into sawlogs and long-length pulpwood. Logs were piled and left for later extraction by the forwarder.

DESCRIPTION OF SITE: Victoria, Australia.

DESCRIPTION OF STAND: Radiata pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Detailed studies have shown the following relationship (linear regression) between productivity in cubic meters per hour and tree size -

$$m^3/\text{Hour} = 18.4\ (m^3/\text{Tree}) + 20.4 \quad [R^2 = 0.95]$$

Productivity of the delimber = 24 - 42 m^3/Hour
(Tree Sizes ranging from 0.2 to 1.2 m^3)

OTHER COMMENTS:
The production figures are based on:
(1) Lighter branched radiata pine.
(2) A system where the machine travels over the cut area.
(3) The machine working behind a feller-buncher.
(4) The machine producing sawlogs and long-length pulpwood.

CITATION: McMorland, B. 1984. PRODUCTION AND PERFORMANCE OF MECHANICAL DELIMBING EQUIPMENT IN INTERIOR B.C.: DENIS AND ROGER "STROKE" DELIMBERS. FERIC. Technical Note No. TN-75.

MACHINE SYSTEM: Roger stroke-boom (short-boom) delimber mounted on a used Drott 40 undercarriage.

OPERATOR RATING: Inexperienced.

DESCRIPTION OF SYSTEM:

Skidder →
Skidder → Roger Delimber
Skidder →

DESCRIPTION OF OPERATION: Clearcutting. Delimber worked at roadside piles delimbing and topping trees, skidded by an FMC 200 BG and (2) Cat D-6 tractors.

DESCRIPTION OF SITE: British Columbia, late winter. Slopes ranged from 5 to 15 percent.

DESCRIPTION OF STAND: Stand consisted of 85% pine, 13% fir, 1% spruce and 1% cedar, and contained 348 m^3 of merch. volume per hectare. The average tree was 20.3 cm in diameter and contained 0.29 m^3 of volume.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

31 shifts were studied, with the average shift being 9.5 hours in length.
Utilization averaged 77%
Average volume processed was 26.6 m^3/PMH.
Average number of trees processed was 91.8 per PMH.

OTHER COMMENTS:

CITATION: Folkema, M.P. 1982. EVALUATION OF THE TANGUAY EC-200 DELIMBER. FERIC. Technical Note No. TN-63.

MACHINE SYSTEM: Tanguay EC-200 delimber mounted on a Caterpillar 225-D5L undercarriage. Feller-bunchers, grapple and choker skidders.

OPERATOR RATING: The operator, a Tanguay employee, had 6 months of experience on EC-200 delimber. Excellent operator.

DESCRIPTION OF SYSTEM: Feller-buncher → Grapple and choker skidders → Delimber

DESCRIPTION OF OPERATION: Clearcutting. The full trees were piled at a right angle to the road in continuous piles 2 meters high and 8 meters away from the roadside.

DESCRIPTION OF SITE: 60 km North of Level-sur-Quevillon, Quebec. Terrain: favorable; mostly level with some gradual slopes.

DESCRIPTION OF STAND: 100% black spruce.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume/tree = 5.83 Ft^3
Average merchantable length of trees = 10.5 m

PRODUCTION DATA: Study Date: April 1982.

<u>Production Summary</u>

Study duration (hours)	10.50
Average number of trees per cycle	1.645
Volume per cycle (Ft^3)	9.59
Cycle per PMH	116
Trees per PMH	191
Production per PMH (cunits/PMH)	11.1

	Time per cycle
Load full tree(s) (%)	50
Delimb (%)	21
Reverse trees(s) to unload (%)	17
Moving time (%)	4
Delays (%)	8

OTHER COMMENTS: More operator skill is required to reach out for full trees with a knuckle-boom than a sliding-boom. The sliding-boom has only 3 control movements; the Tanguay knuckle-boom has 4, or 5, if the backward stroke cylinder is included.

CITATION: Folkema, M.P. 1982. EVALUATION OF THE TANGUAY EC-200 DELIMBER. FERIC. Technical Note No. TN-63.

MACHINE SYSTEM: Tanguay EC-200 delimber mounted on a Caterpillar 225-D5L undercarriage.

OPERATOR RATING: The operator, a Tanguay employee had 7 months experience on EC-200 delimber, excellent operator.

DESCRIPTION OF SYSTEM: Mechanical feller → Clambunk skidder → Delimber

DESCRIPTION OF OPERATION: Clearcutting. Contractor-owned operation. Mechanical felling plus clambunk forwarding provided full trees piled 2 meters high at a right angle to, and about 6 meters from, the road.

DESCRIPTION OF SITE: 170 km northwest of Millinocket, Maine. Terrain: gently rolling.

DESCRIPTION OF STAND: 95% balsam fir, 5% black spruce.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume per tree = 6.15 Ft^3
Average merchantable length of trees = 11.1 m

PRODUCTION DATA: Study Date: June 1982

Production Summary

Study duration (hours)	4.53
Average number of trees per cycle	1.385
Volume per cycle (Ft^3)	8.52
Cycle per PMH	117
Trees per PMH	162
Production per PMH (cunits/PMH)	10.0

	Time per cycle
Load full tree(s) (%)	44
Delimb (%)	19
Reverse trees(s) to unload (%)	16
Moving time (%)	6
Delays (%)	15

OTHER COMMENTS: The Tanguay is basically a single stem delimber that can delimb two or more trees at one time under the following conditions: 1) The trees must be relatively small (under 0.25 m^3), 2) the trees must be of similar length to permit topping them together, and 3) the operator must have sufficient skill.

CITATION: Folkema, M.P. and R. Levesque. 1982. EVALUATION OF THE HAHN PULP/LOGGER II LIMBER-SLASHER. FERIC. Technical Report No. TR-52.

MACHINE SYSTEM: Pulp/logger II limber slasher. It required two operators: one to operate the knuckle-boom loader, and the other to operate the processing unit.

OPERATOR RATING: For each study the processor operator was the same: "Excellent". Study IV: "Good" loader operator. Studies V & VI: "Excellent" loader operator.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: The processor was set up parallel to the road and delimbed and slashed full trees into 2.5 meter pulpwood.

DESCRIPTION OF SITE: Near Ignace, Ontario.

DESCRIPTION OF STAND: Study IV: 100% jack pine Study V: 60% jack pine and 40% black spruce Study VI: 70% jack pine and 30% black spruce.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Produced only 2.5 m pulpwood.

PRODUCTION DATA:

Detailed Time Study Results

	Study IV	Study V	Study VI
Date of study	May 1981	Oct. 1981	Oct. 1981
Study duration (hours)	1.61 (100%)	1.17 (100%)	5.47 (100%)
Processing (%)	76	90	85
Move machine (%)	2	---	2
Delays (%)	22	10	13
Percentage of cuts @ 2-5 m	100	100	100
Volume/tree (Ft^3)	5.3	4.1	6.4
Trees per processing cycle	2.01	2.22	2.53
Volume per processing cycle (Ft^3)	10.6	9.2	16.1
Processing cycle/PMH	62	62	55
Trees processed/PMH	125	138	137
Volume per PMH (cunits)	6.7	5.7	8.7

OTHER COMMENTS: The accumulation of logging slash on the road represents a major limitation to the use of the pulp/logger II if the road has to be kept open for other traffic.

CITATION: Folkema, M.P. and R. Levesque. 1982. EVALUATION OF THE HAHN PULP/LOGGER II LIMBER-SLASHER. FERIC. Technical Report No. TR-52.

MACHINE SYSTEM: Hahn Pulp/Logger II limber-slasher has three axles, and is equipped with a 119 kW diesel engine. It required two operators: one to operate the knuckle-boom loader, and the other to operate the processing unit.

OPERATOR RATING: Processor unit operator was considered to be "Excellent", the operator of the loader unit was considered to be "Fair".

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. Study 1: The Hahn was stationed on the road in front of a full-tree pile. Study 2: The Hahn was positioned across (perpendicular) to the road in front of a whole tree pile. Study 3: The Hahn was situated on a large landing and skidders deposited full trees near the Hahn.

DESCRIPTION OF SITE: Near Atikokan, Ontario.

DESCRIPTION OF STAND: Study I: 60% jack pine and 40% black spruce. Study II and III: 100% jack pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume/tree (Ft^3): I = 9.6; II = 10.7; III = 11.0

Machine produced 2.5 meter pulpwood and 5.0 meter sawlogs

PRODUCTION DATA:

	Study I on the Road	Study II Across the Road	Study III Hot Logging
Date of study	Sept. 1981	Oct. 1981	Oct. 1981
Study duration (hrs)	2.08 (100%)	2.28 (100%)	2.60 (100%)
Processing (%)	63	62	70
Move machine (%)	4	5	---
Delays (%)	33	33	30
Percentage of cuts @ 2-5 m	14	36	35
at 5.0 m	86	64	65
Trees per processing cycle	2.10	1.10	1.46
Volume per processing cycle (Ft^3)	20.1	11.7	16.0
Processing cycle/PMH	40	45	43
Trees processed/PMH	85	49	63
Volume per PMH (cunits)	8.1	5.3	6.9

OTHER COMMENTS:

CITATION: Powell, L.H. 1981. INTERIOR LIMBING, BUCKING AND PROCESSING STUDY EVALUATION OF HAHN TREE-LENGTH DELIMBER. FERIC. Technical Note No. TN-51.

MACHINE SYSTEM: Hahn tree-length delimber. A self-propelled rubber-tired unit.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Skidders → Hahn → Front-end loaders

DESCRIPTION OF OPERATION: Clearcutting. The Hahn operated on landings with trees brought to the landing by skidders. A front-end loader worked with the Hahn and removed logs and debris.

DESCRIPTION OF SITE: Southeast region of B.C. Operated on landings.

DESCRIPTION OF STAND: Small pine stands.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume per tree = 0.3 m^3

PRODUCTION DATA:

Shift-Level Results

Scheduled machine hours	559
Productive machine hours	375
Repair hours	99
Service hours	8
Non-mechanical delay hours	76
CPPA machine availability (%)	78
CPPA machine utilization (%)	67
Productivity (m^3/PMH)	40.7

Detailed Timing Results for Processing Activities

	Min/Tree	%
Processing	0.31	65
Wait for tree	0.06	14
Delays (incl. move)	0.10	21
Total Time	0.47	100

No. of trees timed	1,228
Average tree size, m^3	0.28
Potential Productivity	
Trees/PMH	128
m^3/PMH	35.7

OTHER COMMENTS:

CITATION: Folkema, M.P. and P. Giguere. 1981. THE KOEHRING BUNCH LIMBER: LONG-TERM DATA COLLECTION FROM TWO OPERATIONS. FERIC. Technical Note No. TN-43.

MACHINE SYSTEM: Koehring bunch-delimber equipped with GM 6V92 engine rated at 194 kW (260 hp). The topping device had been removed.

OPERATOR RATING: Both of the operators were considered to be reliable, well-motivated and experienced.

DESCRIPTION OF SYSTEM:
(2) Koehring feller-forwarders → Bunch-limber → (2) Tanguay CC-100 slashers

DESCRIPTION OF OPERATION: Clearcutting. Felling and forwarding to roadside was carried out with two Koehring feller-forwarders, delimbing and sorting of the tree-lengths was performed by the Koehring bunch-limber. Slashing was done using 2 Tanguay CC-100 slashers.

DESCRIPTION OF SITE: 30 km South of Doaktown, New Brunswick. Terrain: Relatively flat with only a few soft areas.

DESCRIPTION OF STAND: Main species harvested: spruce, balsam fir and hemlock, as well as some hardwoods (mainly white birch). Average tree size = 6.6 Ft^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: 75% softwood pulpwood, 15% softwood sawlogs and veneer, 10% hardwood pulpwood.

PRODUCTION DATA: Study Duration: 4.5 months

Time Distribution Percent of Total Time	
Productive (PMH) (%)	72.8
Repair & Maintenance (%)	18.7
Non-productive (%)	1.2
Delays (%)	7.3
CPPA availability (%)	82
Utilization (%)	73

Productivity Summary	
Trees per PMH	157
Productivity (cunits/PMH)	10.4
Productivity/shift (cunits/shift) (8 hr x UTIL x VOL/PMH)	61

Monthly Productivity	March 1980	April	May	June	July 1980
Productivity (m^3/PMH)	32.4	30.0	28.3	28.6	30.6
Trees/PMH	173	160	151	153	163

OTHER COMMENTS: The KBL was double-shifted about 1/3 of the time since it could not otherwise keep up with the production of the two KFF's. It was estimated that the sorting reduced the potential delimbing productivity by 5 to 7%. It was reported that the cables had a life of 2 weeks resulting, in one cable breakage per week.

CITATION: Folkema, M.P. and P. Giguere. 1981. THE KOEHRING BUNCH LIMBER: LONG-TERM DATA COLLECTION FROM TWO OPERATIONS. FERIC. Technical Note No. TN-43.

MACHINE SYSTEM: Koehring bunch-limber equipped with GM 6V92 engine rated at 194 kW (260 hp). Topping device had been removed. 2 Koehring feller-forwarders. Nesco mobile slasher. KBL - capable for multi-stem delimbing.

OPERATOR RATING: Two operators. One excellent operator, with the KBL since the machines were purchased in November 1979. Second shift operator was less skilled, produced 1/3 less.

DESCRIPTION OF SYSTEM:
Feller-forwarder → bunch-limber → slasher → pulpwood → sawlogs (tree length)

DESCRIPTION OF OPERATION: Clearcutting. Full trees were placed at roadside by two Koehring feller-forwarders; delimbing was done by the KBL and slashing was done with a Nesco mobile slasher. There was no sorting done by the KBL.

DESCRIPTION OF SITE: 80 km northwest of Newcastle, New Brunswick. Terrain: Flat to gently rolling with a high ground bearing capacity.

DESCRIPTION OF STAND: Second-growth, even-aged stands. 70% balsam fir, 25% spruce spp. and 5% hardwood spp. Average tree size = 5.0 Ft^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Produced 98% pulpwood, 2% sawlogs.

PRODUCTION DATA: Study duration: 5 months.

Time Distribution Percent of Total Time	
Productive (PMH) (%)	55.2
Repair & Maintenance (%)	40.0
Non-productive (%)	3.2
Delays (%)	1.6
Mechanical availability (%)	59
Utilization (%)	54

Productivity Summary	
Trees per PMH	207
Productivity (cunits/PMH)	10.4
Productivity/shift (cunits/shift) (8 hr x UTIL x VOL/PMH)	46.0
Trees per count	15.10

Monthly Productivity	March 1980	April	May	June	July 1980
Productivity (m^3/PMH)	29.2	25.6	29.6	29.4	29.6
Trees/PMH	187	170	212	229	204
Tree size (m^3)	0.14	0.13	0.14	0.15	0.16

OTHER COMMENTS: The main mechanical problems were derived from the delimber unit on the KBL. At the end of FERIC's study, cable breakage on the KBL occured almost daily.

CITATION: Anderson, B. 1982. THE HAHN PULP/LOGGER II LIMBER-SLASHER AS A COMPONENT IN FULL-TREE HARVESTING SYSTEM. Pulp and Paper Canada. 83(3):39, 42.

MACHINE SYSTEM: Hahn Pulp/Logger II limber-slasher. Several machine modifications were done between the two trials. Machine delimb trees down to a minimum diameter of 5 cm.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Multi-stem processor. Two operators machine one controls the loader which feeds full-trees to the limber, down-piles the logs and removes debris. The other operator controls the processing unit. The machine was observed processing at roadside.

DESCRIPTION OF OPERATION: Clearcutting. 2 short field trials. Trees were manually topped at the stump area before skidding to roadside.

DESCRIPTION OF SITE: Central Canada.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume per trees = 0.24 m^3.
Operation produces pulpwood and sawlogs.

PRODUCTION DATA: Duration of study: Total of 175 PMH.

Productivity from Full-Tree Stockpile (October Trial)

Prod/PMH (m^3)	20.3 (7.1 cts)
Prod/SMH (m^3)	14.3 (5.0 cts)
% of sawlogs by volume	20
Total SMH of October's Trial	142

Desired length = 100 inches

Distribution of Sampled Bolt Length

Deviation (inches)	Cumulative Frequency (%)	Too Long (%)	Too Short (%)
≤ 0.4	57		
0.5-1.4	74	6	11
1.5-2.4	85	8	20
2.5-3.4	88	8	23
3.5-4.4	91	8	26
≥ 4.5	100	10	33

OTHER COMMENTS:

CITATION: Sterle, J.R. 1971. CAN-CAR PROCESSOR IN THE SOUTHEAST. American Pulpwood Association. 71-R-54.

MACHINE SYSTEM: Can-Car Processor. A rubber-tired, self-propelled processor capable of processing both sawlogs and pulpwood.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Felled trees were skidded to the processor with limbs and tops intact. Processor delimbing, bucking and off-loading pulpwood.

DESCRIPTION OF OPERATION: Clearcut. Felled trees were skidded to the processor with limbs and tops intact. The processor delimbed, bucked and off-loaded pulpwood.

DESCRIPTION OF SITE: Near Franklin, Georgia. Processor worked at landings.

DESCRIPTION OF STAND: Loblolly pine stand. Diameter distribution: 5 to 15 inches. Heights = 45 to 65 feet. 35% of the merchantable stems having limbs.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
The stems were processed into 5'3" pulpwood bolts.

PRODUCTION DATA:

Productivity of Can-Car Processor

Average minutes per cord to process = 9.95
Average minutes per pallet to off-load = 9.34
Average cords per pallet = 2.25
Average minutes to process and off-load = 31.73
Production = 4.25 cord/hour

(The above figures are at 100% availability)

OTHER COMMENTS: Visual stick length estimated.

CITATION: Folkema, M.P. 1982. EVALUATION OF THE TIMBERJACK 30 DELIMBER-SLASHER. FERIC. Technical Report No. TR-50.

MACHINE SYSTEM: Timberjack 30 delimber-slasher comprised of Husky 220 XL loader, Timberjack 230 (modified) skidder frame, and a Timberjack 30 delimber (with slasher saw).

OPERATOR RATING: Study I: operator had only 1 month of experience on the machine. Study II: 3 months experience. 5 years of log loader and slasher experience.

DESCRIPTION OF SYSTEM: Skidders → Slashers

DESCRIPTION OF OPERATION: Clearcut. The machine was observed delimbing and slashing full trees piled at roadside by delimbers. During the study, the machine was equipped to produce 3.8 meter lengths.

DESCRIPTION OF SITE: 140 km North of Maniwaki, Quebec. Terrain: Gently rolling. Road conditions were excellent during the study.

DESCRIPTION OF STAND: Main species harvested were black spruce and balsam fir. Merchantable tree length = 9.1 to 10.7 meters. About 50% of the stand, (all hardwoods, hemlock and eastern larch) remained standing.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Study I: 70% balsam fir, 30% black spruce. Volume/tree = 5.1 Ft^3.
Study II: 60% balsam fir, 40% black spruce. Volume/tree = 6.0 Ft^3.

PRODUCTION DATA:

	Study I	Study II
Date of study	June 1981	Aug. 1981
Study duration (hrs)	4.26	3.59
Extricate & load "full" trees (%)	55.4	56.5
Delimb (%)	20.6	15.1
Slash & pile on ground (%)	19.7	24.1
Moving (%)	2.2	3.5
Delays (%)	2.1	0.8
Volume/delimbing cycle (Ft^3)	5.6	8.0
Loading full trees (cycles/PMH)	50	49
Delimbing (cycles/PMH)	38	39
Trees processed/PMH	53	60
Production/PMH (cunits/PMH)	2.7	3.6

OTHER COMMENTS: The machine has limited usefulness for multi-product operations. Due to the swing room required for the Husky loader, it is difficult to have a second butt plate for 5.0 meter sawlogs.

CITATION: Heidersdorf, E. 1980. DEVELOPMENT OF GLFP/NESCO BOOM-MOUNTED FLAIL DELIMBER. FERIC. Technical Report No. TR-36.

MACHINE SYSTEM: Mark II Glfp/Nesco delimber consists of a small chain-flail with an integral tree topping device (66-cm circular topping saw). Mounted on the boom of a John Deere 743 carrier. Second prototype. Drott 40 feller-buncher, John Deere 640 grapple skidder.

OPERATOR RATING: Both flail operators had about 1-1/2 months experience.

DESCRIPTION OF SYSTEM: Drum speed averaged about 200-250 RPM.
Feller-buncher → Chain-flail delimber → Grapple skidder

DESCRIPTION OF OPERATION: The Drott feller-buncher placed the felled full trees in bunches with the butts directed toward the landing area and the tops angled to the flails direction of travel. The flail traveled down the strip limbing trees from the top end. After delimbing, a grapple skidder skidded the tree lengths to the landing.

DESCRIPTION OF SITE: Near Thunder Bay, Ontario. Terrain: Generally gently rolling or flat.

DESCRIPTION OF STAND: The area averaged approximately 80% spruce, and 20% jack pine.
Summer: 74% spruce, 26% jack pine. Trees per hectare = 1,550. Volume per hectare = 182 m^3.
Winter: 97% spruce, 3% jack pine. Trees per hectare = 640. Volume per hectare = 83 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Summer: Tree size = 0.11 m^3
Winter: Tree size = 0.13 m^3

PRODUCTION DATA:

Summary of Productivity of GLFP/NESCO Flail Delimber

	Summer	Winter
Study date	Aug. 1978	Feb. 1979
Principal chain configuration	4 "Axe-Heads" 10 regular	8 regular
Trees per bunch	8.3	5.6
Trees per set up (cycle)	10.8	5.2
Total cycle time, min.	3.46	2.23
Cycle per PMH	17	27
Trees per PMH	187	140
Production (m^3/PMH)	21.4	18.9

Shift Level Study - GLFP/NESCO Flail Delimber

Period (1978-1979)	Summer July 10 - Sept. 12	Winter Nov. 8 - March 31
Productive machine hours	219.5	392.0
Repair and service hours	98.5	207.0
Operational delays (hrs)	44.5	210.5
Mechanical availability (%)	69	65
Utilization (%)	61	49
Trees per PMH	148	139
Productivity (m^3/PMH)	23.1	17.5
Total Scheduled Time (hrs)	362.5	809.5

OTHER COMMENTS: Slopes over 10% presented side-hill stability problems for the delimber. The standing residuals sometimes obstructed boom swing, thereby decreasing limbing efficiency, and in fact, preventing delimbing of occasional bunches.

CITATION: Schuh, D., G. Bassler, and L. Kellogg. 1987. CHAIN-FLAIL DELIMBER-DEBARKERS: TECHNOLOGY FOR PULP-GRADE INWOODS CHIPPING OPERATIONS. College of Forestry, Oregon State University. Forest Research Laboratory Paper 2293-FE-357. 10p.

MACHINE SYSTEM: Gibson prototype delimber/debarker. This is an enlarged version of the Bigfoot with 4 chain-flail drums.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: 3 man crew. Hydraulic loader fed multiple-stem payloads into the delimber/debarker, from which they automatically entered the chipper. Chip vans were shuttled between the landing and a staging area.

DESCRIPTION OF OPERATION: Clearcut.

DESCRIPTION OF SITE: Near Heppner, Oregon.

DESCRIPTION OF STAND: Lodgepole pine. Stand stocking averaged 528 trees per acre. Volume per acre averaged 15.1 cunits (35.9 tons)

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

		Time Distribution	
Avg. piece size (Ft^3)	8.7	Productive (%)	36.5
Bone dry tons/SH	13.9	Repair (%)	10.9
Utilization (%)	36.5	Maintenance (%)	22.6
Bark content (%)	0.5	Disturbance (%)	30.0

OTHER COMMENTS: Van scheduling problems formed an additional source of delay. Since the prototype was only in it's 3rd month of operation, the machine still had some problems.

CITATION: Anderson, B. 1979. A NEW APPROACH TO CHAIN FLAIL DELIMBING. Pulp & Paper Canada. 80(12):76-78, 80.

MACHINE SYSTEM: (2) Prototype boom-mounted chain-flail delimbers with an integral topping saw. One was mounted on a Drott 40 tracked carrier. The other was mounted on JD 743 rubber-tired feller-buncher carrier.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-buncher → Flail Delimber → Grapple skidder

DESCRIPTION OF OPERATION: Clearcut. Feller-buncher felled and bunched trees with the tops slightly fanned. The bunched trees were angled sufficiently to create a clear strip between the rows of bunches. Grapple skidders then skidded the material to the landing.

DESCRIPTION OF SITE: Central Canada. Flat terrain.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average volume per tree = 4-6 Ft^3

PRODUCTION DATA:

Distribution of Scheduled Machine Hours

	Carrier	Flail Head
Scheduled time (%)	100	100
Available (%)	89	79
Active repair (%)	6	15
Service (%)	5	---
Wait mechanic and parts (%)	---	6

Machine Productivity, Trees/PMH

	July-Dec. 1978	Jan-Feb. 1979
Avg. from all shifts	159	173
Top 30% of all shifts	182	202

OTHER COMMENTS: Poorly piled bunches have a greater effect on productivity than do adverse terrain conditions.

CITATION: Folkema, M.P. and P. Giguere. 1979. DELIMBING WITH A CHAIN FLAIL AND A KNUCKLE-BOOM LOADER. FERIC. Technical Report No. TR-35.

MACHINE SYSTEM: Tanguay 14030 knuckle-boom loader. Hydro-Ax 500 chain-flail delimber. Trenche: Koehring feller-forwarder. Manouan: Cable skidders and feller-bunchers.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: The areas had been logged 8 months prior to processing.
Trenche: Feller-forward → Loader and delimber
Manouan: Feller-buncher → Cable skidders → Loader and delimber

DESCRIPTION OF OPERATION: Clearcut. The loader and delimber operated on haul roads. The loader placed a small bunch of full trees on the road. The delimber then made one (or more) passes on the pile.

DESCRIPTION OF SITE: Trenche, B.C. -5°C (1.5 Ft. of snow of the KFF piles)
Manouan, B.C. 10°C (light rain)

DESCRIPTION OF STAND: Trenche: 80% jack pine, 20% spruce/fir.
Manouan: 70% spruce/fir, 30% jack pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Trenche: Fresh KFF piles - 100% of branches remained at time of flailing. Trees per cunit = 25.
Manouan: 40% of branches remained at time of flailing. Trees per cunit = 20.

PRODUCTION DATA: Method A: On The Road

	Trenche	Manouan
Date of study	Jan. 31, 1979	May 28, 1979
Delimbing time/bunch (cmin.)	76	65
Wait for loader/bunch (cmin.)	31	14
Delays/bunch (cmin.)	27	13
Total time/bunch (cmin.)	134	92
No. of passes by hydro-ax/bunch	1.3	1.6
Trees/bunch	7.5	7.1
Volume/bunch (cunits)	0.30	0.37
Production (cunits/PMH)	13.5	24.2
Bunches/PMH	44.8	65.9

OTHER COMMENTS: The loader must handle each bunch of trees 2 times and must also swing the trees through a larger arc. The debris on the road produced a "dragging" or "damping" effect on the chains which reduced their effectiveness.

CITATION: Folkema, M.P. and P. Giguere. 1979. DELIMBING WITH A CHAIN-FLAIL AND A KNUCKLE-BOOM LOADER. FERIC. Technical Report No. TR-35.

MACHINE SYSTEM: Tanguay 14030 knuckle-boom loader (5 years old), and a Hydro-Ax 500 chain-flail delimber (4 years old).

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-buncher → cable skidder → loader/chain-flail delimber. The area was logged 8 months prior to processing.

DESCRIPTION OF OPERATION: Clearcutting. The loader was stationed on the road at the end of a whole-tree pile. The full trees were moved over about 10 feet. and were placed on the ground beside the full-tree pile. The Hydro-Ax delimbed the full trees by approaching them from the rear of the pile.

DESCRIPTION OF SITE: Manouan, B.C.

DESCRIPTION OF STAND: 60% spruce/fir, 40% jack pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Only 40% of the branches remained at time of flailing. Trees per cunit = 19.

PRODUCTION DATA: Method B: Beside The Pile

Date of study	May 29, 1979
Delimbing time/bunch (cmin.)	47
Wait for loader/bunch (cmin.)	12
Delays/bunch (cmin.)	16
Total time/bunch (cmin.)	75
No. of passes by Hydro-Ax/bunch	1.1
Trees/bunch	6.9
Volume/bunch (cunits)	0.37
Productivity (cunits/PMH)	29.7

OTHER COMMENTS: Topping with a chainsaw is only partially effective, especially for short stems underneath longer stems. More breakage results since the flail often drives over several "criss-crossed" trees.

CITATION: Schuh, D., G. Bassler, and L. Kellogg. 1987. CHAIN-FLAIL DELIMBER-DEBARKERS: TECHNOLOGY FOR PULP-GRADE INWOODS CHIPPING OPERATIONS. College of Forestry, Oregon State University. Forest Research Laboratory Paper 2293-FE-357. 10p.

MACHINE SYSTEM: A Hydro-Ax model 521 chain-flail delimber was used to preprocess stems. A Peterson prototype delimber/debarker was mounted on a Morbark 22 chipper. A Morbark Logger was used to maintain the landing.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: 3 man crew. Stems loaded into the debarker by the chipper boom.

DESCRIPTION OF OPERATION: Low thinning. Approximately 33 tons per acre were harvested, which consisted mainly of hemlock.

DESCRIPTION OF SITE: Near Port Gamble, Washington.

DESCRIPTION OF STAND: Douglas fir and western hemlock. The 35-40 year old stand averaged 700-1,500 stems per acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Production for Peterson delimber/debarker

Average piece size = 5.1 Ft^3
Bone dry tons per scheduled hour = 12.9
Utilization (%) = 45.3
Bark content (%) = 1.5

Time Distribution

Productive (%)	45.3
Disturbance (%)	37.3
Maintenance (%)	8.2
Repair (%)	9.2

OTHER COMMENTS: Many chip van-related delays.

CITATION: Richardson, R. 1986. EVALUATION OF BRUKS OFF-ROAD CHIPPERS. FERIC. Technical Report No. TR-71.

MACHINE SYSTEM: Two Bruks 1001 CT chippers, 1982 and 1984 models, with Deutz U-10 engines; the units were mounted on modified 1972 Kockums 875 forwarder equipped with Jonsered loaders (with hydraulic boom extensions) and Cranab grapples.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: (2) Bruks off-road chippers → (1) Mobile pulp loader → (1) Haul truck with (2) vans.

DESCRIPTION OF OPERATION: Clearcutting. Full trees were directionally felled at angles to the direction of chipper travel. Loading occured almost exclusively from the right side of the chipper except when chipping a new trail. The mobile pulp loader loaded chips from stock piles.

DESCRIPTION OF SITE: Cape Breton Island, N.S. The ground was unfrozen and ground-bearing capacity was poor. The machines were wallowing up to their axles in mud.

DESCRIPTION OF STAND: 50% fir and 50% hardwood. Hardwood largely composed of white birch and poplar.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Any hardwoods with diameters over 30 cm had 2.45-m bolts of pulpwood cut out.

PRODUCTION DATA: Study Period: 1st week of December 1985

Conditions and Performance During Full-Tree Chipping

Moisture content of biomass (%) net basis	41
Biomass density (ODT/HA)	73
Average extraction distance (m)	193
Travel speed, empty (m/min)	49
Travel speed, loaded (m/min)	41
Production (ODT/PMH)	4.1
(green tonnes/PMH)	7.0
Utilization (%)	68

Time Distribution

Element	% of Productive Time
Travel empty	13
Position and start motor	1
Chipping	50
Move between chipping	5
Chipper shutdown	2
Travel loaded	18
Position for unload	1
Unload	5
Position after unload	1
Delay	4
	100

OTHER COMMENTS: Power was the limiting factor for chipping hardwoods. The older machine processed 29% less than the 1984 model. This difference is mainly attributed to slower hydraulics and slightly higher downtime.

CITATION: Folkema, M.P. 1977. WHOLE-TREE CHIPPING WITH THE MORBARK MODEL 22 CHIPHARVESTOR. FERIC. Technical Note No. TN-16.

MACHINE SYSTEM: (2) Morbark model 22 (two-knife) Chiparvestors with no debris chute. Not self-propelled.

OPERATOR RATING: Most of the crew members, including the Chiparvestor operator, had several years of experience with the whole tree chipping operation.

DESCRIPTION OF SYSTEM: Feller-buncher → manual felling → skidders → chipper

DESCRIPTION OF OPERATION: Clearcutting. The crew operated on a cold logging basis, producing chips for a nearby pulpmill. The Chiparvestor would chip all the trees that could be reached with the grapple. Then a grapple skidder would move the Chiparvestor to the next deck using a fifth-wheel dolly.

DESCRIPTION OF SITE: Eastern Canada. Slopes were negligible. Muddy conditions resulted from rain which fell prior to and during the first day of the study. Chipping along roads. Temperature 0-5°C.

DESCRIPTION OF STAND: "Hard" hardwoods. 51% American beech, yellow birch, ash spp. sugar maple; 41% red maple, 8% spruce spp. and eastern hemlock.
For average DBH > 4 in.: Trees/acre = 460; cunits/acre = 16.1.
For average DBH > 1 in.: Trees/acre = 647; cunits/acre = 16.4.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume/tree = 3.5 Ft^3.
Conifers, comprising about 8% of the stand, were piled separately and were not chipped.

PRODUCTION DATA: Duration of study: 4 consecutive days in October 1976.

Time Classification

	% of SMH
Productive time (chipping)	48.3
Mechanical delays	22.5
Non-mechanical delays	29.2
Availability (%)	77
Utilization (%)	48

Production of Chiparvestor

Total green tons produced	516.84
Green tons per PMH	34.00
Green tons per SMH	16.41
Average load per van (green tons)	24.61
Number of vans loaded	21
Time required per van (hr) (based on PMH)	0.72
Time required per van (hr) (based on SMH)	1.50

OTHER COMMENTS: The frequent delays caused by moving the Chiparvestor and the vans proved to be a major cause of unproductive time on this operation.

CITATION: Folkema, M.P. 1977. WHOLE-TREE CHIPPING WITH THE MORBARK MODEL 22 CHIPARVESTOR. FERIC. Technical Note No. TN-16.

MACHINE SYSTEM: Morbark model 22 (2-knife) Chiparvestor with a debris chute.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-bunchers → cable skidder → bunk grapple skidder → Chiparvestor → chips.
Manual power saw → Cable skidder (larger trees) → Chiparvestor → sawlogs.

DESCRIPTION OF OPERATION: Clearcutting. Contractor operation producing whole-tree chips and sawlogs. Hot logging system. The contractor-owners often handled repairs, and acted as operator-supervisors on the operation.

DESCRIPTION OF SITE: Eastern Canada. Slope: negligible. Muddy ground conditions due to rain was common.

DESCRIPTION OF STAND: 23% "Hard" hardwoods (elm spp., cherry spp., and sugar maple); 77% "Soft" hardwoods (red maple, poplar spp.).
For average DBH > 4 in.: Trees/acre = 533; cunits/acre = 19.9.
For average DBH > 1 in.: Trees/acre = 850; cunits/acre = 20.4.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Sawlogs comprised of 5% of the total hardwood harvested.
Volume/tree (trees > 4 in. DBH) = 3.6 Ft^3.

PRODUCTION DATA: Duration of study: 4 consecutive days in July 1976.

Time Classification

	% of SMH
Productive time (chipping)	64.7
Mechanical delays	24.9
Non-mechanical delays	10.4
Availability (%)	75
Utilization (%)	65

Production of Chiparvestor

Total green tons produced	969.14
Green tons per PMH	45.41
Green tons per SMH	29.37
Average load per van (green tons)	26.19
Number of vans loaded	37
Time required per van (hr) (based on PMH)	0.58
Time required per van (hr) (based on SMH)	0.89

OTHER COMMENTS: Spare vans were used as back-up units at the Chiparvestor.

CITATION: Johnson, L.R. 1988. SUMMARY OF PRODUCTION AND TIME STUDIES OF MECHANIZED HARVESTING EQUIPMENT IN THE INTERMOUNTAIN WEST. Forest Products Department, University of Idaho (Unpublished).

MACHINE SYSTEM: A modified Morbark model 18. The infeed system and loading unit are the same as for model 18. The chipping head and outfeed system were redesigned for chunkwood.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Production was documented for the chipper working in 1) logging residue, where the material was pushed to roadside by a bulldozer, and 2) whole trees, where the material was felled, bunched and grapple skidded to the chipper.

DESCRIPTION OF OPERATION:

DESCRIPTION OF SITE:

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Material Characteristics

	Whole-tree	Logging Residue
Average moisture content (%)	46.4	15.5
Average diameter/piece (inches)	6.6	5.3
Average length/piece (feet)	55	10.3
Average weight/piece (green lbs.)	372.02	72.15
Average weight/piece (dry lbs.)	199.54	61
Number of pieces	3344	1490

PRODUCTION DATA:

Time Distribution

	Whole-Tree	Logging Residue
Chipping time (%)	25.1	13.3
Additional loading time (%)	3.3	22.2
Delays (%)	71.6	64.5
	100	100

Production Statistics

	Whole-Tree	Logging Residue
Utilization (%)	28.4	35.5
Pieces/productive hour	156.9	207.5
Pieces/scheduled hour	44.6	73.6
Green tons/productive hour	29.19	7.49
Green tons/scheduled hour	8.30	2.66
Dry tons/productive hour	15.66	6.33
Dry tons/scheduled hour	4.45	2.25
Minutes per delay (Avg.)	6.36	2.59
Pieces per load	21.30	70.95

Regression Equations

Logging Residue:
Greens tons/PMH = 10.09 - 1.956 (avg. residue diameter) + 0.108 (avg. piece size)
[$R^2 = 0.69$]

Whole trees:
Green tons/PMH = 6.79 + 0.0447 (avg. piece weight) + 0.0459 (pieces per load) x (avg. piece diameter)
[$R^2 = 0.22$]

OTHER COMMENTS: Chipped into a small dump truck. The average load was 5,118 lbs.

CITATION: Raymond K. 1990. PETERSON-PACIFIC DDC 5000 DELIMBER-DEBARKER-CHIPPER. FERIC. Field Note No. Processing-16.

MACHINE SYSTEM: Peterson-Pacific DDC 5000 combination flail delimber-debarker-loader-chipper unit. Comprises a Prentice 180C knuckleboom loader, a horizontal double drum flail (max. stem dia. 56 cm) and a Morbark model 23 chipper mounted on a tri-axle semi-trailer.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: → Peterson-Pacific DDC 5000

DESCRIPTION OF OPERATION: Delimbing, debarking, and chipping full trees from roadside piles.

DESCRIPTION OF SITE: Nova Scotia & Thunderbay, Canada.

DESCRIPTION OF STAND: Nova Scotia: (1) yellow birch (0.17 mgt/tree), sugar maple (0.15 mgt/tree); (2) Small softwood (0.11 mgt/tree); Thunderbay: (1) jack pine and spruce pine (0.18 mgt/tree).

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Mean (± 95% conf. int)	Aug. '89[1] (Sugar Maple)	Oct-Nov '89[1] (Yellow Birch)	Nov-Dec '89 (Small soft-wood)	Thunderbay[2] (Jack/Spruce Pine)
Tonnes/9 hr. shift	166.4 (± 27.5)	N/A	----	----
Tonnes/PMH	27.8 (± 2.0)	37.2 (± 3.7)	31.0	29.5
Trees/PMH	183 (± 19)	222 (± 53)	280	----
Average tree size (mgt)*	0.15	0.17	0.11	0.18

[1]Recovery of clean hardwood chips averaged 81.3% of total input material. Bark content for trial = 2.4%. Bark content for year to date average 1.1%.

[2]Flail utilization = 51% due to wait for wood delays (12%) and wait for chip vans (14.5%).

*Green tonnes

OTHER COMMENTS: Nova Scotia: Flail utilization increased from 67.6% to 78.7%, between August and December 1989 due to reduced operational delays.

CITATION: Giguere, P. 1979. EVALUATION OF TANGUAY CC-100 SLASHER. FERIC. Technical Note No. TN-29.

MACHINE SYSTEM: Tanguay CC-100 slasher. Koehring feller-forwarder equipped with a felling head. Koehring delimber, model KBL.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-forwarder → Delimber → Slasher

DESCRIPTION OF OPERATION: Clearcutting. Felling: two shifts/day basis.
Produced 2.5-m pulpwood and 3.7-m and 5.0-m logs.
Trees < 23 cm were felled with shears → pulpwood.
Trees > 23 cm were hand-felled → sawlogs.
Delimber and slasher: one shift/day basis.

DESCRIPTION OF SITE: Near Doaktown, New Brunswick. Temperature was around 3°C. Slasher operated along the roads.

DESCRIPTION OF STAND: Species harvested mostly were balsam fir and black spruce.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Pulpwood: merchantable length = 6.5 m, merchantable volume/tree = 0.07 m^3.
Sawlogs: merchantable length = 11.6 m, merchantable volume/tree = 0.42 m^3.

PRODUCTION DATA: A two day study. The total length of the timing was more than 4.5 hours.

Summary of Time Elements - Tanguay cc-100 Shaler

	Pulpwood Cycles (DSOB < 23 cm)		Sawlog Cycles (DSOB ≥ 23 cm)	
	Avg. Time Per Cycle (cmin.)	% of Productive Time	Avg. Time Per Cycle (cmin.)	% of Productive Time
Moving between piles	14	4	9	4
Loading tree lengths	60	16	50	22
Slashing 2.5-m	173	47	38	16
3.7-m and 5.0-m	0	0	45	18
Unloading	76	20	56	24
Cleaning debris	22	6	5	2
Delays	27	7	30	13
Total time/cycle	372	100	233	100

Productivity of Tanguay CC-100 Slasher

	Pulpwood (DSOB < 23 cm)	Sawlogs (DSOB ≥ 23 cm)
No. of trees/cycle	10.7	2.0
Volume/cycle (m^3)	0.79	0.80
Cycle/PMH	16.2	25.7
Trees/PMH	173	51
Volume/PMH (m^3)	13	21

DSOB = Diameter stump outside bark

OTHER COMMENTS: Before loading large trees, the operator must drag them as close as possible to the machine to increase the lifting capacity of the boom and to decrease the risk of overloading.

CITATION: Powell, L.H. 1981. INTERIOR LIMBING, BUCKING AND PROCESSING STUDY (EVALUATION OF BARKO 450 LOADER). FERIC. Technical Note No. TN-46.

MACHINE SYSTEM: Barko 450 hydraulic knuckle-boom loader. Mounted on a Chaptrac hydraulic undercarriage model 500 and equipped with a Weldco model XG-125 360° rotating grapple. 4.5 m3 capacity.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: (Hand felled) → Cable yarder → Loader → Off-highway trucks.

DESCRIPTION OF OPERATION: Clearcutting. Full trees had been piled along roadside.

DESCRIPTION OF SITE: West of Kelowna, B.C.

DESCRIPTION OF STAND: Spruce and balsam fir.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree size = 0.8 m^3

PRODUCTION DATA: Study Period: September to October 1980

Summary of Shift-level Monitoring

Machine availability (%)	97.3
Machine utilization (%)	78.8
No. of trucks loaded	115
Average truck load weight (kg)	49,003
Average truck volume (m^3)	62.6
Loader productivity (m^3/PMH)	73.6
- m^3/shift worked	654.0

Results from Detailed Timing Samples

Average time to load truck (min.)	50
No. of cycles to load truck	42
No. of logs per load (m^3)	63.4
Average piece size (m^3)	0.73
Average loading time per m^3 (min.)	0.79
Average load weight (kg)	48,854
Average loading rate (kg per minute)	970

OTHER COMMENTS:

CITATION: Powell, L.H. 1981. INTERIOR LIMBING, BUCKING AND PROCESSING STUDY (EVALUATION OF BARKO 450 LOADER) FERIC. Technical Note No. TN-46.

MACHINE SYSTEM: Barko 450 hydraulic knuckle-boom loader. Mounted on a Chaptrac hydraulic undercarriage model 500 and equipped with a Weldco model XG-125 360° rotating grapple. 4.5 m3 capacity. Feller-buncher, grapple skidder

OPERATOR RATING: Operator switched from Caterpillar 966C front-end loader to the Barko loader.

DESCRIPTION OF SYSTEM: Clearcutting. The logs were piled at roadside and loaded onto off-highway trucks.

DESCRIPTION OF OPERATION:
Feller-buncher → Grapple skidder → Loader → Off-highway trucks.

DESCRIPTION OF SITE: Near Peachland, interior B.C.

DESCRIPTION OF STAND: Major species harvested was lodgepole pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Piece size averaged = 0.31 m^3 per log.

PRODUCTION DATA:

Summary of Shift-level Monitoring (Sept. to Oct. 1980)	
Machine availability (%)	96.2
Machine utilization (%)	79.7
No. of trucks loaded	349
Average truck load weight (kg)	58,862
Average truck volume (m^3)	60.3
Loader productivity (m^3/PMH)	78.7
- m^3/shift worked	658.0

Results from Detailed Timing Samples	
Average time to load truck (min.)	32
No. of cycles to load truck	25
No. of logs per load	200
Average piece size (m^3)	62.6
Average loading time per m^3 (min.)	0.51
Average load weight (kg)	61,021
Average loading rate (kg per minute)	1,920

OTHER COMMENTS: The major disadvantage occurred when ground skidding to the landings. The slow travel speed between landings reduced available loading time per shift.

CITATION: MacDonald, A.J. 1990. A CASE STUDY OF ROADSIDE LOGGING IN NORTHERN INTERIOR OF BRITISH COLUMBIA. FERIC Technical Report No. TR-97.

MACHINE SYSTEM: Caterpillar LL229 hydraulic log loader equipped with a Harricana butt-and-top grapple.

OPERATOR RATING: Both fully experienced.

DESCRIPTION OF SYSTEM:
Cat FB 227 feller-buncher → (3) Cat 528 grapple skidders → (1) Lim-mit processor → Cat LL229 loader

DESCRIPTION OF OPERATION: Feller bunchers clearcut the trees, which were then grapple skidded to the roadside for limbing and topping. The trees were then loaded tree-length on off-highway trucks.

DESCRIPTION OF SITE: 75 km South of Houston, B.C. Terrain rolling with occasional guillies or steeper ground. Average slope = 8%. Road density = 58 m/ha.

DESCRIPTION OF STAND:

	Large wood area	Smallwood area
Average tree size (m^3)	0.86	0.24
Stems/ha merch.	388	976
unmerch.	77	13
Average tree diameter (cm)	35.8	10.7
Species distribution (%) Pine	32	97
Spruce	47	2
Balsam	21	1

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Butt diameter class (cm)	% Distribution by class	Tree volume (m^3)
10	4	0.08
20	56	0.21
30	30	0.52
40	9	1.07
50	1	2.04
ALL	100	0.41

PRODUCTION DATA:

Loading Summary

Volume (m^3)	35,839
Truck loads	577
Load average (m^3)	62.1
Loader productive hours (hr)	326.4
Loader scheduled hours (hr)	392.7
PMH/load	0.57
Loader shifts	31
Loads/shift	18.6
Average shift length (hr)	12.7
Loads/8 hr shift	11.7
Production/8 hr shift (m^3)	727

OTHER COMMENTS: The loader lost one shift when the roads were too soft for trucks to drive on, and two shifts when the smallwood area was harvested (i.e., when wood was not available for hauling).

CITATION: Stock, S. 1976. VOLVO SYSTEM MAKES THE MOST OF FIBER AT VALLEY FOREST. Pulp and Paper Canada. 77(6):32-37.

MACHINE SYSTEM:
(1) Drott 40 feller-buncher → (1) Volvo 980 processor → (1) Volvo 868 forwarder (all machines are about 6 months old).

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller buncher → Grapple processor → Forwarder

DESCRIPTION OF OPERATION: Clearcutting. System works mainly in softwood stands producing sawlogs and 8 ft. pulpwood. Feller-buncher does not bunch, rather it lays the stems in a fan shape for the processor. Processor follows the feller by one week. The forwarder then forwards the material to a piling yard.

DESCRIPTION OF SITE: St. Anne - Nackawic, Canada.

DESCRIPTION OF STAND: Average softwood butt diameter = 8 inches; the average DBH is 6 inches.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree size = 5.2 Ft^3

PRODUCTION DATA:

	Drott 40 Feller-Buncher	Volvo 980 Processor	Volvo 868 Forwarder
Production (trees/PMH)	110	100	---
Production (cunits/PMH)	---	---	3.2
Availability (%)	82	---	---
Utilization (%)	---	66	---

OTHER COMMENTS:

CITATION: Chisholm, B.S. 1979. HOT-LOGGING FULL TREE CHIPS: VFP'S KFF-MORBARK EXPERIENCE. Pulp and Paper Canada. 8(10):70-72, 74, 75.

MACHINE SYSTEM:
(1) Koehring feller-forwarder, (2) cable skidders, (1) Morbark Chiparvestor
(1) shunt truck, (2) trucks, (3) vans.

OPERATOR RATING: The feller-forwarder operator had one week of experience.

DESCRIPTION OF SYSTEM: The feller-forwarder cuts and forwards wood to the chipper. A two man crew and a one man crew use the skidders to log areas too steep for the KFF, and harvest trees too large for the KFF.

DESCRIPTION OF OPERATION: Clearcutting. Forwarding maximum of 600 to 1,500 feet.

DESCRIPTION OF SITE: St. Anne, Quebec. Well drained hardwood ridges with slopes averaging 10 to 15%.

DESCRIPTION OF STAND: 60% softwood, 40% hardwood.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Study Period: April 1977 to January 1979

	KFF	Morbark
Utilization (%)	73.6	50.5
Mechanical availability (%)	79.1	85.6
Trees/PMH	95.5	---
Cunits/PMH	6.44	10.76
Average load (cunits)	7.39	11.96

OTHER COMMENTS:

CITATION: Clemence, B.R. 1979. TREE-LENGTH DELIMBING WITH THE FELL-DEL HARVESTER. Pulp and Paper Canada. 76(6):84-87.

MACHINE SYSTEM: (3) Timmins heads (16 inch shear) mounted on (1) Poclain LC80, (1) Liebherr 925 and (1) Drott 50 tracked carrier → (1) Lokomo wheeled forwarder → (1) FMC 200 BG forwarder

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Trees are felled, delimbed and bunched by the Fel-Del harvesters and then forwarded by the Lokomo and FMC.

DESCRIPTION OF OPERATION: Clearcutting. Tree length material.

DESCRIPTION OF SITE: Iroquis Falls, Ontario. Muskeg up to 3 foot deep.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: (Long term study)

Productivity Information on Fel-Del Harvester

Carrier	Poclain	Liebherr	Drott
Trees/PMH	38	40	42
Cunits/PMH	1.9	2.0	2.1
Availability (%)	48	46	50

Productivity Information on Forwarders

Forwarder	FMC	Lokomo
Trees/PMH	44	46
Cunits/PMH	22	23
Availability (%)	72	69

OTHER COMMENTS:

CITATION: Johnson, L.R. 1981. SMALL TREE HANDLING SYSTEMS IN THE INTER-MOUNTAIN REGION. *IN* Proceedings: "Harvesting Small Timber: Waste Not, Want Not." Forest Products Research Society. Portland, OR. April 28-30, 1981. pp. 52-58.

MACHINE SYSTEM: Model 1075 Melroe Bobcat feller-buncher (2nd stage) farm tractors and wheeled skidders equipped with shopbuilt grapples (heeling mechanism) Morbark 22 chipper with modified infeed mechanism Morbark 12 chipper.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
1st stage: Hand felling → grapple skidders → chippers (Morbark) (< 6 inches) → manual processing.
2nd stage: Feller-buncher → grapple skidders → chippers (Morbark) (< 6 inches) → manual processing.
3rd stage: Hand felling → grapple skidders → chippers (Morbark) (< 6 inches) → manual processing.

DESCRIPTION OF OPERATION: Salvage of beetle-killed ponderosa pine. 1st stage: trees < 5 inches DBH were hand felled and piled in bunches for grapple skidding. 2nd stage: mechanical felling and bunching of stems in the 6 to 14 inch class. 3rd stage: hand felling of the larger timber.

DESCRIPTION OF SITE: Western Montana. Terrain was moderate, with slopes under 25%.

DESCRIPTION OF STAND: Beetle-killed ponderosa pine. Diameter class from 4 to 16 inches.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Produced both saw logs and whole tree chips.
Anything 6 inches in diameter (and larger) & 16 feet long → saw logs.
The rest of the material was chipped.

PRODUCTION DATA:

Productivity

1st stage felling and stacking	800 stems/7 hour shift (range of 31-56 trees/hour/individual)
Feller-buncher	50 stems/hour
Skidder	10 bunches or 200 stems/hour
Morbark 22 chipper: < 5 inches	4.04 minutes/ton
> 5 inches	3.7 minutes/ton
Morbark 18 chipper < 5 inches	5.75 minutes/ton
> 5 inches	4.13 minutes/ton

OTHER COMMENTS:

CITATION: Huyler, Neil K. 1982. THE COST OF THINNING WITH A WHOLE-TREE CHIP HARVESTING SYSTEM. Northern Logger and Timber Processor. July 1982. pp. 8, 9, 14, 28-29.

MACHINE SYSTEM: John Deere 644B loader with Morbark 20 inch shear. JD 640 grapple skidder. JD 749 grapple skidder. 22 inch Morbark Chiparvester. 2 tractor trailers.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-buncher → grapple skidder → chipper → tractor trailer.

DESCRIPTION OF OPERATION: Clearcutting overstocked northern hardwood stands for energy chips.

DESCRIPTION OF SITE: Slopes ranging from 8-10%. Vermont.

DESCRIPTION OF STAND: Northern hardwood with 265 trees per acre. Average DBH = 9.2 inches.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

<u>Total System Productivity</u> - 126.2 green tons/day or 308.9 stems/day

<u>Feller Buncher Productivity</u>
- Trees/bunch = 9.5. (4.29 tons/bunch)
- 42.45 trees/sched. hour
- 61.50 trees/productive hour
- Utilization = 69%

<u>Graple Skidder Productivity</u>

	JD 640	JD 740
Average skid distance (feet)	2,657	2,657
Average cycle time (min.)	30.84	34.84
Average cycle time w/o delay (min.)	19.48	22.32
Average turns/day	17.6	16
Average trees/turn	9.5	9.5
Average tons/turn	4.29	4.29

<u>Chipper Productivity</u>
36.5 tons/hour with no delay
15.3 tons/hour with delay

OTHER COMMENTS: Biomass/energy wood type of harvesting system.

CITATION: Smith, G.D. 1973. TREE-LENGTH HARVESTING WITH THE DROTT FELLER-BUNCHER AND THE MORIN DELIMBER. Pulp and Paper Magazine of Canada. 74(12):60-62.

MACHINE SYSTEM:
(3) Drott 35 feller-bunchers with 18" shears
(1) Timberjack 230 line skidder
(1) Morin delimber mounted on a Log-All feller-skidder

OPERATOR RATING:

DESCRIPTION OF SYSTEM: (3) Feller-buncher → Line skidder → Delimber → Line skidder → Roadside slasher.

DESCRIPTION OF OPERATION: Clearcut. After felling, the prebunched trees are choked and then skidded with Timberjack 230. The trees are then delimbed and topped by the Morin delimber.

DESCRIPTION OF SITE: Ontario, Canada. Operation on a variety of ground conditions involving slopes of 10-15% grades.

DESCRIPTION OF STAND: Black spruce, balsam fir, and jack pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: 8 foot pulpwood.

PRODUCTION DATA:

1972 Productivity Information

Machine	Cunits/PMH	Trees/PMH	Utilization
Drott 35	5.66	88	---
Timberjack 230	2.26	35	---
Morin delimber	14.55	225	81%

OTHER COMMENTS:

CITATION: Hedin, I.B. 1980. COMPARISON OF TWO LOGGING SYSTEMS IN INTERIOR BRITISH COLUMBIA: CENTRAL PROCESSING YARD (CPY) VS CONVENTIONAL. FERIC. Technical Report No. TR-45.

MACHINE SYSTEM:

Feller bunchers	**2**	**Buckermen**	**3**	**Highway trucks: variable**
Grapple skidders	**3**	**Bulldozer**	**1**	
Loaders-bush	**2**	**Flail**	**--**	

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller buncher → Grapple skidders → Loaders → Manual bucking

DESCRIPTION OF OPERATION: Clearcutting. Trees were mechanically felled and skidded to the landing with grapple skidders. At the landing, the trees were manually topped, delimbed, bucked and then loaded log-length onto highway tracks.

DESCRIPTION OF SITE: Peachland, B.C. Winter: 0 to 15% slope.

DESCRIPTION OF STAND: Winter: Lodgepole pine, occasional spruce.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: Winter: 3 landings.

PRODUCTION DATA: Study Date: January 23-31, 1979

Production of the System

	Winter
Average volume/day (m^3 - bush)	820
Total volume (m^3 - highway)	4,198
No. of loads (total)	118
Man and machine hours (loading, unloading and processing)	252.8
Skidding productivity (m^3/prod. hr)	32.0
Skidding utilization (%)	87.4
Buckermen production (m^3/hr)	28.1

OTHER COMMENTS:

CITATION: Gingras, J.F. 1988. THE FELLER-BUNCHER/GRAPPLE SKIDDER SYSTEM: OPTIMIZING BUNCH SIZE. Canadian Forest Industries. September 1988. pp. 56-58, 60.

MACHINE SYSTEM: Feller-buncher - saw head (105 kW). Grapple skidder (125 kW).

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-buncher/grapple skidder system.

DESCRIPTION OF OPERATION: Clearcut. The operator was instructed to make bigger bunches by increasing the number of trees in his pile at times when stand conditions were not different from the rest of the area.

DESCRIPTION OF SITE: Eastern Canada.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Productivity of Feller-Buncher and Grapple Skidder (Normal vs Large Bunches)

	Feller-Buncher		Grapple Skidder		
	Normal Bunch	Large Bunch	1 Normal Bunch/Load (2.8m3/load)	1 Large Bunch/Load (4.3m3/load)	*2-5 Normal Bunch/Load (4.4m3/load)
Productivity (m^3/PMH)	37.4	35.7	22.0	27.5	36.7
Utilization PMH/SMH (%)	-----	80	-----	85	-----
Net system savings (%)	-----	-----	-----	10	23

* Avg. bunches/load = 2.4

OTHER COMMENTS: Bunch size was shown to be a critical productivity parameter of this system since it influences the performance of both machines.

CITATION: Ford III, E.C. 1981. PREHARVESTING NON-MERCHANTABLE STEMS IN NATURAL PINE STANDS FOR FUEL. *IN* Proceedings: "Harvesting Small Timber: Waste Not, Want Not." Forest Products Research Society. Portland, OR. April 28-30, 1981. pp. 59-62.

MACHINE SYSTEM: John Deere 444 Feller-buncher equipped with a high speed cutting head. A John Deere 440-C grapple skidder, and a Morbark model 12 whole tree chipper equipped with a dirt and bark separator. Truck tractors and chip vans. Cutting head was a demonstrator unit.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-buncher → Grapple skidder → Chipper

DESCRIPTION OF OPERATION: Preharvesting unmerchantable pine and hardwood stems in natural pine stands for use as boiler fuel. Feller-buncher, grapple skidder and chipper were leased new.

DESCRIPTION OF SITE: Georgetown County, South Carolina.

DESCRIPTION OF STAND: Stand comprised of primarily Loblolly and pond pine. Area A (one acre plot): 614 stems/acre; basal area = 122.35 ft^2; avg. DBH = 5.52 inches; basal area of merchantable stems = 88.68 ft^2; residual basal area = 80.36 ft^2.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: The fuel harvesting job removed 306 stems/acre or 41.99 ft^2 of basal area/acre with an average DBH of 5.94 inches.

PRODUCTION DATA:

Productivity

Feller-buncher	
No. of bunches	62
No. of bundles	15
Avg. basal area/bunch (Ft^2)	0.68
Productivity (tons/PMH)	12.63
Availability (%)	81
Chipper	
Fuel material lost due to the dirt and bark separator (%)	3-5
Availability (%)	79
Productivity (tons/PMH)	13.48

Grapple Skidder Productivity

Avg. bundle size basal area (Ft^2)	0.28
Availability (%)	91

Skidding Distance in chains	Productivity in tons per hour
2	78.80
4	54.94
6	42.15
8	34.20
10	28.78
12	24.83
14	21.85

OTHER COMMENTS: The mechanical availability of the feller-buncher was 92%; however, the shear, being a old demonstrator unit, caused the overall availability for the feller-buncher to be only 81%.

CITATION: Gingras, J.F. 1988. THE FELLER-BUNCHER/GRAPPLE SKIDDER: OPTIMIZING BUNCH SIZE. FERIC. Technical Report No. TR-81.

MACHINE SYSTEM: Caterpillar 227 feller-buncher with a Harricana felling head. John Deere 648 grapple skidder. Timberjack 450 grapple skidder.

OPERATOR RATING: The feller-buncher operator was instructed to create larger bunches at specific times (e.g. during one-half of a shift) during the study.

DESCRIPTION OF SYSTEM: Feller-buncher → Grapple skidder

DESCRIPTION OF OPERATION: Clearcut.
The normal felling practice was to work to one side of the machine. The normal skidding practice was to skid only one bunch per turn.

DESCRIPTION OF SITE: Near Ramsay, Ontario.
Area 1: Rolling but firm terrain.
Area 2: Flat and firm.

DESCRIPTION OF STAND:
Area 1: 1/2 of the area consisted of mature jack pine and spruce. 20% hardwood. Merchantable stems/ha = 820. Avg. DBH = 17 cm. Avg. m^3/ha = 160.
Area 2: Immature jack pine and spruce stand. Merchantable stems/ha = 1,400. Avg. DBH = 15 cm. Avg. m^3/ha = 190.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Area 1: Avg. m^3/tree = 0.28
Area 2: Avg. m^3/tree = 0.19

PRODUCTION DATA: Study Date: June 1985

Felling Summary

Machine	Cat 227
No. of bunches	86
Avg. no. trees/bunch	11.0
Avg. volume/bunch (m^3)	2.8
Total cycle time (min)	6.00
Bunches/PMH	10.0
Trees/PMH	110
m^3/PMH	28.0

Skidding Summary

Machine	TJ450/JD648
No. of turns	94
Avg. skid distance (m)	142
Avg. vol./turn (m^3)	2.8
Avg. no. of bunches/turn	1.1
Total cycle time (min.)	7.73
Turns/PMH	7.8
Productivity (m^3/PMH)	21.8

Effect of Bunch Volume on Feller-Buncher Productivity			
Volume/bunch (m^3)	0 - 2.0	2.1 - 3.0	3.1 +
Area 1 (m^3/PMH)	--	27.1	34.6
Effect of Bunch Volume on Skidder Productivity			
Volume/bunch (m^3)	0 - 2.0	2.1 - 3.0	3.1 +
Area 1 (m^3/PMH)	16.6	19.9	25.9

OTHER COMMENTS: Mechanical problems with the felling head limited the accumulation capacity to two trees.

CITATION: Gingras, J.F. 1988. THE FELLER-BUNCHER/GRAPPLE SKIDDER SYSTEM: OPTIMIZING BUNCH SIZE. FERIC. Technical Report No. TR-81.

MACHINE SYSTEM: Timbco 2518 feller-buncher with shear and accumulator. Timberjack 450 skidder with a dual arch grapple equipped with high flotation tires.

OPERATOR RATING: Feller-buncher operator's decision regarding bunch size.

DESCRIPTION OF SYSTEM: Feller-buncher → Grapple skidder

DESCRIPTION OF OPERATION: Clearcut. The cutting pattern of the feller-buncher was highly irregular. The trees were skidded to two roadside landings. Only one bunch per turn was forwarded by the skidder.

DESCRIPTION OF SITE: About 20 km northeast of Longlac, Ontario. Terrain = fairly flat, swampy.

DESCRIPTION OF STAND: Mature, low-volume black spruce stands. Merchantable stems/ha = 1,900. Avg. DBH = 12 cm. Avg. m^3/ha = 130.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: Avg. m^3/tree = 0.15

PRODUCTION DATA: Study Period: A week in June 1986.

Felling Summary	
No. of bunches	60
Avg. no. trees/bunch	15.0
Avg. volume/bunch (m^3)	3.2
Total cycle time (min.)	6.35
Bunches/PMH	9.4
Trees/PMH	141
m^3/PMH	30.1

Skidding Summary	
No. of turns	110
Avg. skid distance (m)	293
Avg. volume/turn (m^3)	3.1
Avg. no. of bunches/turn	1.0
Total cycle time (min.)	6.04
Turns/PMH	9.9
Productivity (m^3/PMH)	30.7

Effect of Bunch Volume on Feller-Buncher Productivity			
Volume/bunch (m^3)	0 - 2.0	2.1 - 3.0	3.1 +
Area 2 (m^3/PMH)	19.7	24.8	33.1
Effect of Bunch Volume on Skidder Productivity			
Volume/bunch (m^3)	0 - 2.0	2.1 - 3.0	3.1 +
Area 2 (m^3/PMH)	15.2	24.6	38.6

OTHER COMMENTS: Feller operator waited for the more favorable patches of bigger or better-stocked wood to make larger bunches.

CITATION: Gingras, J.F. 1988. THE FELLER-BUNCHER/GRAPPLE SKIDDER SYSTEM: OPTIMIZING BUNCH SIZE. FERIC. Technical Report No. TR-81.

MACHINE SYSTEM: Five John Deere 693 feller-bunchers. Five Timberjack 520 grapple skidders. One feller-buncher with a Harricana shear head and one skidder were studied.

OPERATOR RATING: Feller-buncher operator's decision regarding bunch size.

DESCRIPTION OF SYSTEM: Feller-buncher → Grapple skidder

DESCRIPTION OF OPERATION: Clearcut. The feller-buncher worked in a systematic up-and-down pattern. Bunches were piled with the butt ends facing the road. The skidders usually pulled only one bunch per turn.

DESCRIPTION OF SITE: 80 km southwest of Grande Prairie, Alberta.

DESCRIPTION OF STAND: High volume stands of Lodgepole pine and white spruce. Merchantable stems/ha = 950. Avg. DBH = 24 cm. Avg. m^3/ha = 380.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Avg. m^3/tree = 0.4 m^3

PRODUCTION DATA: Study Period: 1 week in July 1986.

Felling Summary

No. of bunches	181
Avg. no. trees/bunch	8.6
Avg. volume/bunch (m^3)	3.5
Total cycle time (min.)	2.94
Bunches/PMH	20.4
Trees/PMH	175
m^3/PMH	71.4

Skidding Summary

No. of turns	67
Avg. skid distance (m)	68
Avg. volume/turn (m^3)	3.7
Avg. no. of bunches/turn	1.0
Total cycle time (min.)	3.95
Turns/PMH	15.2
Productivity (m^3/PMH)	56.2

Effect of Bunch Volume on Feller-Buncher Productivity			
Volume/bunch (m^3)	0 - 2.0	2.1 - 3.0	3.1 +
Area 3 (m^3/PMH)	48.5	57.8	80.1
Effect of Bunch Volume on Skidder Productivity			
Volume/bunch (m^3)	0 - 2.0	2.1 - 3.0	3.1 +
Area 3 (m^3/PMH)	19.8	38.6	65.4

OTHER COMMENTS:

CITATION: Gingras, J.F. 1988. THE FELLER-BUNCHER/GRAPPLE SKIDDER SYSTEM: OPTIMIZING BUNCH SIZE. FERIC. Technical Report No. TR-81.

MACHINE SYSTEM: John Deere 693B feller-buncher equipped with a Harricana circular saw head. John Deere 740 grapple skidder and John Deere 740 cable skidder. Feller-buncher operator was instructed to create larger bunches at specific times (e.g. during one-half of a shift) during the study.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-buncher → Grapple skidder → Cable skidder

DESCRIPTION OF OPERATION: Clearcut. The cable skidder was working in the wetter areas and the longer skids. The normal skidding practice was to take two or more bunches per turn and sometime up to 5. Skidding was performed straight uphill to roadside.

DESCRIPTION OF SITE: 50 km northeast of Deersdale, New Brunswick. The site varied from a uniform slope of about 8% to a more undulating terrain, with short pitches reaching 15-20%.

DESCRIPTION OF STAND: Even-aged stands of spruce/fir, 70-90 years old. Merchantable stems/ha = 1,900. Avg. DBH = 18 cm. Avg. m^3/ha = 340.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Avg. m^3/tree = 0.21

PRODUCTION DATA: Study Period: October 1986

Felling Summary	
No. of bunches	164
Avg. no. trees/bunch	11.3
Avg. volume/bunch (m^3)	2.3
Total cycle time (min.)	3.52
Bunches/PMH	17.0
Trees/PMH	192
m^3/PMH	39.1

Skidding Summary	
No. of turns	125
Avg. skid distance (m)	80
Avg. volume/turn (m^3)	4.1
Avg. no. of bunches/turn	2.1
Total cycle time (min.)	7.26
Turns/PMH	8.3
Productivity (m^3/PMH)	34.0

Effect of Bunch Volume on Feller-Buncher Productivity			
Volume/bunch (m^3)	0 - 2.0	2.1 - 3.0	3.1 +
Area 4 (m^3/PMH)	---	37.4	35.7
Effect of Bunch Volume on Skidder Productivity			
Volume/bunch (m^3)	0 - 2.0	2.1 - 3.0	3.1 +
Area 4 (m^3/PMH)	---	22.0	27.5

Effect of taking 2 to 5 normal-sized bunches on skidder productivity (skid distance adjusted to 150 m; Study 4)

No. of Bunches Per Turn	1	2 - 5
Avg. bunch volume (m^3)	2.8	1.9
Avg. turn volume (m^3)	2.8	4.6
Avg. loading time (min.)	0.61	1.48
Productivity (m^3/PMH)	22.0	36.7

OTHER COMMENTS: Always making larger bunches may lead to a lowering of the felling productivity especially in less than ideal stand conditions (i.e. poor stocking, poor trees).

CITATION: Bouchard, R. 1988. TRIAL OF A DEBARKING-CHIPPING OPERATION AT CIP INC., LA TUQUE, QUEBEC. Canadian Forest Industries. September 1988. pp. 62-64, 66, 67.

MACHINE SYSTEM: Rocket stroke-delimber/topper on a Drott 40 carrier → Kockums Cambio debarker (5 knife) → Morbark model 22 total Chiparvester.

OPERATOR RATING: Experienced workers.

DESCRIPTION OF SYSTEM:
Feller-buncher → Skidders → Delimber → Debarker → Chipper (Grapple skidder maintained deck) → Chip van

DESCRIPTION OF OPERATION: Clearcut producing whole tree chips. Trees were felled and bunched by the feller-buncher. The bunches were skidded to the landing by (2) line skidders and deposited 60 meters from the delimber. A grapple skidder then carried the material to the delimber/debarker and chipper.

DESCRIPTION OF SITE: La Tuque, Quebec. Flat, sandy soil.

DESCRIPTION OF STAND: Even-aged jack pine with some hardwoods.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Time Distribution based on 22.5 hours

Element	Delimber	Debarker	Chipper
Normal production (%)	91	88	87
Move chip vans (%)	0	5	8
No wood to process (%)	2	1	2
Operating delays (%)	2	3	0
Mechanical delays (%)	5	3	3

Hourly Productivity of Debarker

	1st Week	2nd Week
Loads	13	13
Dry tons/load (metric tn)	17.67	17.80
Volume/load (m^3)	44.09	44.17
Trees/load	278	226
Avg. vol/tree (m^3)	0.158	0.195
Total time/load (min.)	100	83

OTHER COMMENTS:

CITATION: Gingras, J.F. 1988. THE EFFECT OF SITE AND STAND FACTORS ON FELLER-BUNCHER PERFORMANCE. FERIC. Technical Report No. TR-84.

MACHINE SYSTEM:
#1: John Deere 693 with a Harricana shear felling head.
#2: Timbco 2518 with a Tenco LDC-206 shear felling head.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE:
#1: Eastern Canada - favorable terrain with few slopes.
#2: Eastern Canada - wet pockets, steep slopes, rocky outcrops.

DESCRIPTION OF STAND:
#1: Mature jack pine; average of 1,240 stems/ha; average DBH = 18.0 cm.
#2: Spruce, birch, and jack pine; average of 1,310 stems/ha; average DBH = 16.6 cm.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

<u>Machine 1</u>

Trees/PMH = 214.7 - 0.0134 (stand density) - 5.31 (unmerch/merch) - 4.2 (average DBH) + 29.7 (trees/cycle) [$R^2 = 0.81$]

<u>Machine 2</u>

m^3/PMH = - 29.8 - 10.0 (unmerch/merch) + 2.90 (average DBH) + 3.77 (trees/cycle) [$R^2 = 0.75$]

(Regression equations exclude the effect of slope)

<u>Variables Used in Regression</u>

	Machine 1			Machine 2		
Variable	Min.	Avg.	Max.	Min.	Avg.	Max.
Stand density (trees/ha)	240	1,240	2,400	305	1,310	2,990
Unmerch. (trees/ha)	0	200	750	0	370	1,450
DBH (cm)	13.5	18.0	30.3	12.5	16.6	23.6
Trees/cycle	--	2.1	--	--	4.5	--

Slope Corrections for Regression Equations

Machine 1	% Slope	Productivity Correction	Machine 2	% Slope	Productivity Correction
Trees/PMH	0-5	0	Trees/PMH	0-15	0
	6-10	-11		16-25	-10
	11-15	-17		26-35	-17
	16-20	-36		36-40	-41
m^3/PMH	0-10	0	m^3/PMH	0-15	0
	11.20	-5.2		16-35	-2.4
				36-40	-8.5

Overall Productivity	Machine 1	Machine 2
Study period (hours)	13.4	11.4

	Cycle #1	Cycle #2
Move to cut (%)	13	21
Brush (%)	4	3
Position (%)	36	36
Fell (%)	15	12
Bunch (%)	26	19
Move to bunch (%)	3	7
Delays (%)	3	2
	100	100
Average felling cycle (min.)	0.74	1.27
Cycle/PMH	81.4	46.5
Trees/cycle	2.1	4.5
Volume/tree (m^3)	0.19	0.15
Trees/PMH	170	210
Volume/PMH (m^3)	32	31

OTHER COMMENTS:

CITATION: Jolley, J.D. 1986. KOEHRING K3FF FELLER-FORWARDER. Non-Published Paper Presented at 1986 IUFRO World Congress in Yugoslavia. September 1986.

MACHINE SYSTEM: Koehring K3FF feller-forwarder

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Koehring K3FF feller-forwarder → John Deere 743 delimber → Bucyrus - Erie 32S loader

DESCRIPTION OF OPERATION: Clearcutting. Feller-forwarder felled and forwarded all pine from 13 to 44 cm DBH to decks at roadside where a JD 743 delimber processed them and a Bucyrus-Erie 325 log loader loaded them onto trucks.

DESCRIPTION OF SITE: Southeastern Oklahoma. Sites were described as containing hard, rocky soils with slopes of less than 30%.

DESCRIPTION OF STAND: Natural mixed species stands containing 76 m^3/ha of pine and 14 m^3/ha of hardwoods. The average pine was 25 cm DBH and 15 m tall.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Long term data over 12,873 scheduled hours.
- Mechanical availability = 78%
- Machine utilization = 85% (estimate)
- Average productivity of 23.6 m^3 per scheduled hour or 110 trees per productive hour.

OTHER COMMENTS: Maximum tree height which could be forwarded was 24 meters. Machine had problems when operating in short slopes with steep pitches.

CITATION: Powell, L.H. and G. St. Jean. 1979. TRIAL OF OSA 670 FELLER BUNCHER AND OSA 705 PROCESSOR IN BRITISH COLUMBIA. FERIC. Technical Report No. TR-31.

MACHINE SYSTEM: OSA 705 processor mounted on an OSA 260 forwarder. Machine was equipped with a 48 inch circular slashing saw and a 25 inch chainsaw topping saw. Modifications included a longer feed tray and a larger capacity topping shear.

OPERATOR RATING: Experienced.

DESCRIPTION OF SYSTEM: Skidders → OSA 705 processor

DESCRIPTION OF OPERATION: Clearcutting. A trial operation. The processor worked on the landing.

DESCRIPTION OF SITE: British Columbia.
Range of slopes: 0-61%

DESCRIPTION OF STAND:

Species: Lodgepole pine
Alpine fir
Engelmann spruce
Volume/acre: 15-50 cunits
Average height: 85 feet

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume/tree: 15.0 Ft^3

PRODUCTION DATA:

Production Summary for the OSA 705

Availability (%)	81.5
Utilization (%)	59.1
Average piece size (ft^3)	26.8
Trees/PMH	81
Cunits/PMH	21.8
No. shifts studied	63

Time Distribution

Productive time (%)	59
Mechanical delay (%)	23
Non-mechanical delay (%)	18

OTHER COMMENTS: Major cause of low utilization was an inadequate supply of material at the landing.

CITATION: Richardson, R. 1989. EVALUATION OF FIVE PROCESSORS AND HARVESTERS. FERIC. Technical Report No. TR-94.

MACHINE SYSTEM: Rottne Rapid 860 two-grip processor.

OPERATOR RATING: Good.

DESCRIPTION OF SYSTEM:
Site 1/Site 2: Manual felling → Rottne Rapid 860 processor
Site 3: Feller-buncher → Rottne Rapid 860 processor

DESCRIPTION OF OPERATION: Produced shortwood in cutover.

DESCRIPTION OF SITE: Site 1: Steep slopes to 48%, rough ground conditions. Site 2: Slopes to 20%, ground conditions fair to soft. Site 3: Flat, frozen ground with 30- 45 cm of snow.

DESCRIPTION OF STAND: Site 1: Spruce/hardwood, small trees (0.11 m^3/tree). Site 2: Spruce/hardwood, larger trees (0.14 m^3/tree). Site 3: Spruce/fir, tree size = 0.16 m^3/tree.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

	Manually felled trees		Feller-bunched trees
	Site 1	Site 2	Site 3
No. of shifts	27	17	15
Trees/PMH	68	67	82
m^3/PMH	7.4	9.0	13.1
Utilisation (%)	78	80	73
Mechanical availability (%)	83	84	77

There is a 20% increase in processor productivity (from 68 to 82 trees/PMH) when working after a feller-buncher.

OTHER COMMENTS: Rigid preventative maintenance program resulted in little downtime related to repairs (7% of SMH).

CITATION: Moore, T. 1989. THE DENIS STROKE DELIMBER IN RADIATA WINDTHROW. Logging Industry Research Association, New Zealand. Vol. 14, No. 10.

MACHINE SYSTEM: Denis stroke-delimber mounted on a Komatsu PC 200 LC tracked excavator.

OPERATOR RATING: Experienced.

DESCRIPTION OF SYSTEM:
Motor manual felling → Bell Logger → Cat 518 grapple skidder → Denis delimber

DESCRIPTION OF OPERATION: Windthrow salvage clearcut. Whole trees were bunched by Bell logger, and extracted to windrows by the grapple skidder. The delimber walked across the cutover, delimbed the rows and stacked for load out.

DESCRIPTION OF SITE: Central Plateau, New Zealand. Moderate terrain and pumice soils good for both tracked and rubber tired machines.

DESCRIPTION OF STAND: Radiata pine windthrow, 15 years old. Stocking = 270 trees/ha.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Mean merch. volume = 0.22 m^3, mean length = 10 m.
Mean LED = 28 cm, mean SED = 12 cm.

PRODUCTION DATA:

Element	No. of Occasions	Mean per cycle (min)	% of Total Cycle
Pickup	314	0.172	26.5
Process	314	0.304	46.8
Sort and stack	18	0.057	8.7
Clear slash	55	0.064	9.9
Move	31	0.036	5.6
Operational Delay	7	0.016	2.5
Total Cycle		0.649	100.0

Productivity: 314 trees in 204 min = 92 trees/PMH
@ 0.22 m^3 piece size = 20 m^3/PMH

OTHER COMMENTS: Delimb time did not vary for piece sizes from 0.11 to 0.3 m^3. The availability of two operators was seen as a major factor, by reducing operator fatigue and having someone to manually delimb malformed and heavily branched stems.

CITATION: Gonsior, M.J. and Mandzak, J.M. 1986. MECHANIZED SYSTEMS FOR HARVESTING SMALL TREES IN MOUNTAINOUS TERRAIN. Unpublished manuscript. USDA Forest Service.

MACHINE SYSTEM: Timbco Feller-buncher → Skidder → Hahn harvester → Morbark model 18 chipper.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: (see above)

DESCRIPTION OF OPERATION: Seed tree operation which resembled a clearcut.

DESCRIPTION OF SITE:
Site A: Slopes ranged from 10-30%.
Site B: Slopes ranged from 10-20%.

DESCRIPTION OF STAND:

	Average Diam.	Stems/Acre	BF/Acre	Dominant Species
Stand A	5.9"	484.6	6,147	lodgepole pine, western larch
Stand B	6.1"	246.4	3,104	lodgepole pine, western larch

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Timbco Feller-Buncher		
Time Distribution	Stand A	Stand B
Fell & bunch (%)	48.1	58.0
Unscheduled down time (%)	19.6	15.4
Scheduled down time (%)	5.0	5.8
Travel & cut while travelling (%)	22.3	17.7
Other non-productive (%)	5.0	3.1
Avg. felling & bunching time/tree	17.9 sec.	20.9 sec.
Avg. productivity per sched. hour	124.5 trees	111 trees

Hahn Harvester	
Time Distribution	Stands A & B Combined
Process (%) Unscheduled down time (%) Slash clearing (%) Maintenance (%) Wait for wood (%)	52.0 23.4 13.3 3.1 8.2
Avg. processing time per tree	15.65 seconds
Trees/PMH	230
Trees/SMH	120

Chipper Time Distribution

Chipping (%)	45.4
Unscheduled down time (%)	12.2
Scheduled down time (%)	11.5
Other non productive (%)	11.3
Wait van (%)	4.8
Wait wood (%)	14.8

Productivity

1 van load = 24.8 green tons or 11.44 bone dry units
1 van load chipped per SMH
38.5 productive minutes for 1 van load

OTHER COMMENTS: No study was performed on the skidders.

CITATION: Hedin, I.B. 1980. COMPARISON OF TWO LOGGING SYSTEMS IN INTERIOR BRITISH COLUMBIA: CENTRAL PROCESSING YARD (PY) VS. CONVENTIONAL. FERIC. Technical Report No. TR-45.

MACHINE SYSTEM:

Feller-bunchers	**1**	**Buckermen**	**3**
Grapple skidders	**3**	**Bulldozer**	**1**
Loaders-bush	**2**	**Flail**	**1**

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-bunchers → Grapple skidders → Loaders → Manual bucking → Chain-flail (summer only)

DESCRIPTION OF OPERATION: Clearcutting. Trees were mechanically felled, and skidded to the landing with grapple skidders. At the landing, the trees were manually topped, delimbed and bucked and then loaded log length onto highway trucks.

DESCRIPTION OF SITE: Peachland, B.C. 0 to 45% slopes, occasional pitches exceeding 100%.

DESCRIPTION OF STAND: Lodgepole pine and aspen, with occasional spruce, balsam fir, and Douglas fir.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Summer: 4 landings

PRODUCTION DATA: Study Period: June 21 - July 5, 1979

Production of the System

Average volume/day (m^3 - bush)	630
Total volume (m^3 - highway)	3,993
No. of loads (total)	114
Man and machine hours (loading, unloading and processing)	391.0
Skidding productivity (m^3/prod. hr.)	22.4
Skidding utilization (%)	84.8
Buckermen production (m^3/hour)	18.0
Flail production (m^3/hour)	76.1

OTHER COMMENTS:

CITATION: Peterson, J.T. 1987. HARVESTING ECONOMICS: GRAPPLE YARDING SECOND-GROWTH TIMBER. FERIC. Technical Report No. TR-75.

MACHINE SYSTEM: 1982 Madill 084 swing yarder with a GM 12U71 engine. M10 tank undercarriage. 15.2 meter high A-frame tower. 1978 Hitachi UH14 mobile backspar.

OPERATOR RATING: Regular operator was above average in skill and efficiency. A relief operator had little prior experience and was considered to be in training.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION:
Handfelled Area: All trees were handfelled parallel to the haul road. Trees under 60 cm butt diameter were yarded as full trees. Selective bucking was performed on trees ≥ 60 cm butt diam.
Bunched area: Trees under 50 cm in butt diameter were mechanically felled and bunched at 45° to the haul road with butts facing the road. Oversize trees were manually felled and partially bucked at the stump. The pieces were grapple yarded to roadside, decked in windrows, and then processed.

DESCRIPTION OF SITE: 5.3 km West of Buckley Bay, B.C.
Bunched area: Average slope = 18%. Rolling terrain, light underbrush and some windfalls.
Handfelled area: Average slope = 23%. Rolling terrain, light underbrush, and some windfalls.

DESCRIPTION OF STAND: 60% Douglas-fir, 21% western hemlock, 16% western red cedar, and 3% deciduous species.
Bunched area: 939 stems/ha. Gross vol/ha = 566 m^3.
Handfelled area: 778 stems/ha. Gross vol/ha = 713 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Bunched area: Net volume/ha = 518 m^3, gross volume/piece = 0.59 m^3.
Handfelled area: Net volume/ha = 665 m^3, gross volume/piece = 0.91 m^3.
3% of the stems (13% of the volume) were greater than 50 cm in diameter.
5% of the trees required hand bucking (those >60 cm butt diam).

PRODUCTION DATA: Study Duration: 7 months

Productivity - Actual Results

	Bunched-wood Area	Handfelled Area
Avg. no. pieces/turn	2.2	1.4
Pieces/PMH	107.9	68.8
Pieces/SMH	82.8	53.2
No. turns/PMH	49.5	48.4
No. turns/SMH	38.0	37.5
m^3/PMH	63.7	62.6
m^3/SMH	48.9	48.4

Timing Summary

	Bunched-wood Area	Handfelled Area
Productive machine hours (%)	77	77
Non-productive (%)	15	16
Delays (%)	8	7
Total hours	52.9	85.3
Average time/turn (min.)	1.20	1.24
Average piece size (m^3)	0.59	0.91
Average yarding distance (m)	70.7	76.6
Average move time (min.)	3.2	6.5
Number of moves/PMH	3.6	1.7

The following equations can be used to predict the yarding cycle times per turn for bunched and handfelled wood:

A. Bunch wood:

Outhaul time (min) = 0.0296 + 0.0027 x distance
Inhaul time (min) = 0.0044 x distance
Fixed time (excluding delays) per turn is estimated at 0.69 min.

B. Handfelled wood:

Outhaul time (min) = 0.0323 + 0.0026 x distance
Inhaul time (min) = 0.0247 + 0.0035 x distance
Fixed time (excluding delays) per turn is estimated at 0.74 min.

OTHER COMMENTS: Hang-ups often occurred if more than one piece was grappled in the handfelled area.

CITATION: Deal, E.L. 1982. STEEP SLOPE FELLING AND BUNCHING IN SMALL TIMBER. *IN* Proceedings: "The Small Tree Resource: A Materials Handling Challenge." Forest Products Research Society. Portland, Oregon. April 19-21, 1982. pp. 111-128.

MACHINE SYSTEM: Menzi-Muck feller-buncher with a prototype 14 inch felling head.

OPERATOR RATING: Operator's first experience in timber harvesting.

DESCRIPTION OF SYSTEM:
Feller-buncher → A rubber-tired skidder equipped with a "homemade" skyline system using a cristy carriage.

DESCRIPTION OF OPERATION: Clearcutting. Side line corridors from the skyline corridor were flagged and cut by the Menzi-Muck in a herring bone pattern.

DESCRIPTION OF SITE: North Carolina. Slopes: 40 - 100% with one portion containing a boulder field.

DESCRIPTION OF STAND: Hard hardwoods with diameters ranging from 4 to 20 inches (DBH) and heights of 30 to 100 feet. Much of the area was covered with dense stands of rhododendron brush up to 12 feet in height.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Productivity - Menzi-Muck Feller-Buncher

DBH Class	Vol/ Tree (lbs.)	Trees per Ton	Time/ Tree (min.)	Total Time/ Ton	Production[1] Per Hour (tons)
2	19.72	101.40	.48	48.67	.73
4	107.80	18.55	.64	11.87	3.03
6	245.87	8.13	.80	6.50	5.54
8	475.00	4.21	.96	4.04	8.91
10	1,088.71	1.84	1.12	2.06	17.48
12	1,747.02	1.15	1.28	1.47	24.49
14	2,390.18	.83	1.44	1.20	30.00
16	3,242.96	.62	1.60	.99	36.36

[1] Assumes Menzi-Muck spends 60% of total time performing productive work.

OTHER COMMENTS: Production was limited due to the feller-buncher head's relatively light construction and inability to quickly shear hard hardwoods. Communications were hindered because the operator did not speak English and all instructions were given through an interpreter.

CITATION: Arola, R.A. et al. FELLING AND BUNCHING SMALL TIMBER ON STEEP SLOPES. USDA Forest Service Engineering Project, Houghton, Michigan.

MACHINE SYSTEM: Menzi-Muck excavator (model 3000 EHA) modified by mounting a prototype 12 inch shear (without an accumulator) at the end of the boom.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Machine was studied working in 2 stands. One stand consisted of poles and the other consisted of saplings.

DESCRIPTION OF OPERATION: Clearcutting. Pole stand: Machine worked parallel to slope. Sapling stand: Strips were cut at right angles to the contours. The machine worked straight up and down the slope and was winch assisted.

DESCRIPTION OF SITE: Upper peninsula of Michigan. Study was performed in the winter, with 1-5 inches of snow on the ground. Pole stand: sandy soil, 35-85% slopes. Sapling stand: sandy soil, 80% slopes.

DESCRIPTION OF STAND:

Stand	Species	DBH	Trees per acre	Volume per acre
Pole	W. Birch, R. Maple	4 -14 inches	556 (≥4" DBH)	30 cords (≥6" DBH)
Sapling	W. Birch	1-9 inches	3100 (≥1" DBH)	3.5 cords (≥6" DBH)

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

	Pole		Sapling	
	Avg.	SD	Avg.	SD
Butt diameter/bunch (in.)	7.14	2.84	4.31	1.76
Trees/bunch	6.93	4.46	20.06	8.44
Weight/tree (gr tons)	0.28	0.24	0.07	0.08
Trees/bunch (gr tons)	1.94	1.15	1.50	0.71

PRODUCTION DATA:

	Pole	Sapling
Trees cut	967	1,081
SH (hours)	19.5	12.2
PH (hours)	16.4	10.7
U (%)	84	87
Trees/SH	49.7	88.3
Tons/SH	13.9	6.2
Trees/PH	58.9	100.9
Tons/PH	16.5	7.1
Felling cycles	924	909
Trees/cycle	1.05	1.19
Average time/cycle (min.)	1.27	0.81
Average delay/cycle (min.)	0.20	0.10

OTHER COMMENTS:

CITATION: Schiess, P., D. Schuh, E.S. Miyata and C.N. Mann. 1983. TIMBER HARVESTING IN THE CENTRAL ROCKIES. Regional Technical Conference, Colorado State University. January 4-6, 1983. Publication No. XCM-87. pp. 166-212.

MACHINE SYSTEM: Kaiser X5M "Spyder" walking feller-buncher. Telescoping (20 ft. reach) boom with a 13-inch Morbark shearhead and accumulator. Hydraulic-driven rear wheels. Highly modified prototype.

OPERATOR RATING: Had about one or two weeks of experience.

DESCRIPTION OF SYSTEM: Felled and bunched trees.

DESCRIPTION OF OPERATION: A 0.9 acre red alder stand was clearcut. Each clearcut swath was about 44 feet wide. The direction of movement on this swath was downhill.

DESCRIPTION OF SITE: Near Eatonville, Washington. The general terrain was convex and ranged from 30 to 60 percent slope.

DESCRIPTION OF STAND: Over 90% red alder, the remainder was mixed hardwoods and conifers. Stocking = 301 trees/acre. Average tree height = 52 feet. Total basal area = 100 Ft^2/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Average Work Element Time Per Cycle

Work Element	Time (min)	% of Subtotal	% of Total
Reach and position	0.43	52	
Shear	0.08	10	
Lift and swing	0.22	26	
Bunch	0.10	12	
Subtotal			
Felling-bunching cycle	0.83	100	51
Move time	0.69		42
Brushing delays	0.12		7
Total cycle time	1.64		100

Productivity

Slope Class (%)	Production (trees/hr)
30-45	41
45-60	34
Average	37

OTHER COMMENTS: The machine was also tested in slash clearing and piling at Wrangell Island, Alaska.

CITATION: Arola, R.A. 1983. STEEP SLOPE FELLING AND BUNCHING - THE MENZI MUCK, TIMBER HARVESTING IN THE CENTRAL ROCKIES. Regional Technical Conference, Colorado State University. January 4-6, 1983. Publication No. XCM-87. pp. 155-165.

MACHINE SYSTEM: Menzi Muck 3000 EH, semiwalking-type machine was adapted as a small-tree, steep slope feller-buncher. Compact 12-inch tree shear, outfitted shear head with a heavy protective bottom plate and serrated edge to prevent damage and facilitate machine movement.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: The machine felled and bunched trees.

DESCRIPTION OF OPERATION: Field tested.
Site 1: The machine was operated by travelling parallel to the contour.
Site 2: The machine was operated straight up and down slopes.

DESCRIPTION OF SITE: Upper peninsula of Michigan.
Site 1: Pole-size hardwood stand. Sandy soil. Slope was 35 to 85%
Site 2: Sapling-size stand of hardwoods. Sandy soil. 80% slope.
Both sites: Had a thick layer of snow covered leaf litter.

DESCRIPTION OF STAND:
Site 1: Predominantly white birch. DBH = 4-14 in. Basal area of trees ≥ 4 inches = 156 Ft^2/acre. 566 trees/acre (≥ 4 in. DBH).
Site 2: Predominantly white birch. DBH = 1-9 in. Basal area (≥ 4 in.) = 78 Ft^2/acre. 3,100 trees/acre (≥ 1 in. DBH).

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Site 1: Merchantable volume, ≥ 6 inches DBH = 30 cords/acre.
Site 2: Merchantable volume, ≥ 6 inches DBH = 35 cords/acre.

PRODUCTION DATA: Tested: Winter 1979

Productivity of Menzi-Muck Feller-Buncher

	Site 1	Site 2
Scheduled hours	19.5	12.2
Productive hours	16.4	10.7
Average butt diameter (inches)	7	4.5
Trees/bunch	7	20
Weight/bunch (green tons)	2	1.5
Average no. of trees accessed/setting	2.8	5.4
Productivity (tons/productive hour)	16.5	7.1
(trees/productive hour)	60	100

OTHER COMMENTS:

CITATION: Cottell, P.L., B.A. McMorland and G.V. Wellburn. 1976. EVALUATION OF CABLE LOGGING SYSTEMS IN INTERIOR B.C. AND ALBERTA. FERIC. Technical Report No. TR-8.

MACHINE SYSTEM: Skagit GT3 grapple yarder, equipped with a track undercarriage, 44-ft tower, and 4 winches. The mobile tail-hold was a tractor. Also used a skidder and a front-end loader.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Yarding was usually downhill, bringing tree-lengths to roadside decks. Skidder was used to swing wood to the landings for bucking.

DESCRIPTION OF OPERATION: Clearcut. Year round operation, company-owned operation. Yarding roads offset as much as 30° to the contour. Three-man crew: operator, spotter and landing helper. Winter felling usually occurred 2 days ahead of yarding.

DESCRIPTION OF SITE: Cariboo, B.C. Slopes varied from level to 60%. 6 feet of snow and -29°C.

DESCRIPTION OF STAND: 73% spruce, 25% balsam fir and 2% other species. Average butt diameter = 12 in. Maximum butt diameter = 39 in.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Percent Distribution of Scheduled Time: Skagit GT3	
Productive (%)	60
Repair and service (%)	14
Non-productive (%)	17
Delays (%)	9
Mechanical availability (%)	85
Machine utilization (%)	70

Production Summary: Skagit GR3 Grapple Yarder	
Scheduled time (hours/shift)	9.4
Avg. piece size, all landing (Ft^3)	30
Piece count per shift	263
Gross volume per shift (cunits)	80
Productivity:	
cunits/scheduled machine hour	8.47
cunits/productive machine hour	11.44

OTHER COMMENTS: When yarding bucked logs, chokers had to be set on 20% of the pieces. During tree-length yarding, only 5% of pieces required choking.

CITATION: Folkema, M.P. 1979. THE DROTT ROTARY CUTTER FELLER BUNCHER: LONGER-TERM DATA COLLECTION FROM TWO OPERATIONS. FERIC. Technical Note No. TN-28.

MACHINE SYSTEM: Drott 40 feller-buncher equipped with 24 in. rotary cutter (or auger) head.

OPERATOR RATING: The operator had about 4 months of experience on the auger at the start of FERIC's study. A well-motivated employee.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. 8-hour shift, 5 days/week. Operator carried out all the service and most of the repairs.

DESCRIPTION OF SITE: South of Vanderhoof, B.C. Terrain: rolling or hilly terrain with slopes up to 20%.

DESCRIPTION OF STAND: Species harvested: Lodgepole pine, spruce and balsam fir. Merchantable volume = 40 cunits/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average volume/tree = 21.2 Ft^3

PRODUCTION DATA: Study Duration: 1.5 months

Time Distribution
% of Total Time

Productive (PMH) (%)	53.1
Repair & maintenance (%)	36.7
Delays (%)	10.2

Productivity Summary

Trees per PMH	70
Productivity (cunit) per PMH	14.7
CPPA availability (%)	64

Breakdown Information

Total no. of repairs	59
Mean time to repair (hr)	1.3
Mean time between repairs (hr) (based on PMH)	2.7

OTHER COMMENTS: FERIC test data from the cutting of poplar logs showed that a 13 in. log required 8 cmin, while a 18 in. log required 15 cmin.

CITATION: McMorland, B. 1986. PRODUCTION AND PERFORMANCE OF MECHANICAL FELLING EQUIPMENT IN INTERIOR B.C.: TIMBCO FELLER-BUNCHER WITH ROTOSAW HEAD. Technical Report No. TR-67.

MACHINE SYSTEM: Timberjack Timbco model 2520 feller-buncher with a 56 cm rotosaw felling head. Crawler tractor with rotosaw director. 1 rubber-tired grapple skidder, 3 rubber-tired line skidders, 1 crawler tractor and 2 front-end loaders.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-buncher → Grapple skidder → Landing buckers and front-end loaders
Handfaller → Line skidders → Landing buckers and front-end loaders

DESCRIPTION OF OPERATION: Clearcut.

DESCRIPTION OF SITE: 60 km northeast of Smithers, B.C. 95% of area = 0-30% slopes; 4% of area = 30-40% slopes; and 1% of area > 40% slopes.

DESCRIPTION OF STAND: 80% spruce, 15% balsam fir, and 5% pine. Avg. DBH = 33-35 cm. Winter snow level = 0.5 to 1.0 m.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Three sorts were required on the landings: balsam fir, short logs (all species) and spruce/pine sawlogs. Avg. tree size = 0.86 m^3.

PRODUCTION DATA:

Time and Production Summary

	Day	Afternoon	Both		Day	Afternoon	Both
Study Periods	Nov. 26, 1984 to March 6, 1985	Dec. 4, 1984 to Jan. 6, 1985	--	PMH (%)	68.1	63.1	67.4
				Availability (%)	73.0	67.8	72.3
				Avg. tree size (m^3)	0.86	0.86	0.86
				Volume/PMH (m^3)	60.2	59.4	60.1
Shifts	63	12	75	Trees/PMH	70.0	69.1	69.9
Shift length (hours)	9.6	7.9	9.3				
PMH	67.7%	62.8%	67.7%				
Repair/service	18.8%	25.7%	20.4%				
Non-mechan. delays	8.3%	6.4%	8.6%				
Other delays	5.2%	5.1%	5.4%				

OTHER COMMENTS: The operation produced 13-20 highway loads per day.

CITATION: Stokes, B.J. and Lanford, B.L. 1985. THE ALBRIGHT FELLING SAW IN SAW TIMBER STANDS. Transactions of the ASAE. ASAE Paper No. 83-1600.

MACHINE SYSTEM: 3 Albright felling saws mounted on carriers.
1) Felling saw mounted on a Hydro-Ax 411 carrier
2) Felling saw mounted on a Caterpillar 930 wheel loader
3) Felling saw mounted on a Caterpillar 930 wheel loader

OPERATOR RATING:

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. Only the felling saw and carriers were studied.

DESCRIPTION OF SITE: Alabama. Mixed pine and hardwood stand. Slopes ranged from 0-25% and averaged 8.7%.

DESCRIPTION OF STAND: Mixed pine and hardwood, averaging 295 trees per acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Data of Harvested trees	Average	Min.	Max.
Merch. trees/hectare	272	59	627
DBH (cm)	36.1	10.2	67.0
Total height (m)	22.0	10	27
Volume/tree (m^3)	1.0	0.1	2.4

PRODUCTION DATA:

Movetime = $5.2758 \times (TPH)^{-1/2} + 0.1088 \times (THP)^{-1/2} \times S$
where: movetime is in minutes
TPH = merch trees/hectare
S = slope in percent

Position and Sawtime (min.) =
Machine 1 and softwoods = $0.4291 + 0.000085 \times (DBH)^2$
Machine 1 and hardwoods = $0.4868 + 0.000085 \times (DBH)^2$
Machines 2 & 3 and softwoods = $0.8250 + 0.000085 \times (DBH)^2$
Machines 2 & 3 and hardwoods = $0.8827 + 0.000085 \times (DBH)^2$
Where: DBH = DBH in centimeters

Production Summary (min)		Mach. 1	Mach. 2.	Mach. 3
Movetime	Mean Range	0.502 0.13-1.00	0.202 0.08-0.56	0.416 0.09-0.99
Position and Saw	Mean Range	0.527 0.12-0.92	0.952 0.80-1.23	1.060 0.27-1.99
Total		1.029	1.154	1.476

OTHER COMMENTS:

CITATION: McMorland, B. 1980. NON-SHEARING FELLING HEADS. FERIC. Tecnical Note No. TN-34.

MACHINE SYSTEM: Dika buncher, 28 inch capacity. A Caterpillar 225 was used as the carrier for the Dika buncher head. Between summer and winter tests the Dika buncher head was remounted on a Caterpillar 235 and the chain was changed from 1-1/4-in. kerf to the larger 2-1/4-in. type kerf.

OPERATOR RATING:
Summer: The operator was experienced on feller-buncher.
Winter: The same operator was now considered well-experienced.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: Takla Lake, B.C.
Summer: Terrain ranged from swampy to 15% to 20% slopes.
Winter: Temperature = -10°C to -20°C. Granular snow was on the ground to a depth of 2 to 3 feet. The trees were heavily snow-laden.

DESCRIPTION OF STAND: Summer: Primarily spruce and balsam fir. Avg. DBH = 13.0 in. Merchantable stems/acre = 189. Unmerchantable stems/acre = 67. Cunits/acre = 58. Winter: Composed of pine, spruce and balsam fir. Avg. DBH = 12.3 in. Merchantable stems/acre = 250. Unmerchantable stems/acre = 106. Cunits/acre = 91.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Summer: Volume/tree = 31 Ft^3.
Winter: Volume/tree = 36 Ft^3.

PRODUCTION DATA:

Detailed Time Study Results and Productivity

	Summer	Winter
Felling cycle (%)	73	83
Brushing (%)	16	5
Delays (%)	11	12
Felling cycle (minutes)	1.09	0.78
Average trees/bunch	4.3	7.0
Trees/PMH	55.0	76.9
Volume/PMH (cunits)	17.1	27.7

Shift-Level Study Results
Production, Productivity and Mechanical Downtime

	Summer	Winter
Average volume/tree (Ft^3)	28.9	36.4
Trees/PMH	45.3	43.9
Volume/PMH (cunits)	13.1	16.0
Average PMH/shift worked (hours)	8.2	7.7
Trees/shift worked	373	338
Volume/shift worked (cunits)	107.9	122.9
Repair and service hours/ 100 PMH	17.4	27.5

OTHER COMMENTS: The large chain was difficult to handle and often required a pickup truck or other vehicle to pull it into position in the head. This necessitated moving the machine to a road or landing to change the chain.

CITATION: Johnson, L.R. 1988. SUMMARY OF PRODUCTION AND TIME STUDIES OF MECHANIZED HARVESTING EQUIPMENT IN THE INTERMOUNTAIN WEST. Forest Products Department, University of Idaho (Unpublished).

MACHINE SYSTEM: Koehring Feller-buncher with Koehring saw.

OPERATOR RATING: Inexperienced.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. The machine operated in a random harvest pattern.

DESCRIPTION OF SITE: Slopes averaged 7.8%.

DESCRIPTION OF STAND: Dense, relatively large timber. Average diameter = 12.771 inches, SD = 4.146 inches..

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Inches	Freq.	Inches	Freq.	Inches	Freq.	Inches	Freq.	Inches	Freq	Inches	Freq.
6	7	10	101	14	85	19	2	24	5	29+	3
7	20	11	105	15	44	20	17	25	5		
8	50	12	139	16	28	21	5	26	8		
9	67	13	113	17	13	22	6	27	5		
				18	17	23	6	28	8		

PRODUCTION DATA:

Time Distribution	
Swing and move (%)	60.1
Saw and bunch (%)	22.5
Extra moves (%)	5.7
Delays (%)	11.6
Utilization (%)	88.4

Production Statistics	Avg.	SD
Trees/productive hour	107.1	---
Trees/scheduled hour	94.7	---
Trees/turn	1.013	0.112
Distance moved (ft)	17.464	13.860

No regression equation.

OTHER COMMENTS: Production was affected by excessive stand density and random felling pattern.

CITATION: Ashmore, C., Stokes, B.J. and B.L. Lanford. 1987. PERFORMANCE AND COST OF THE BOREAL 20-INCH CIRCULAR SAW. USDA Forest Service, Southern Forest Experiment Station. Research Paper SO-238.

MACHINE SYSTEM: Boreal double decker 20-inch circular saw mounted on a Hydro-Ax 611.

OPERATOR RATING: 1-1/5 year experience.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: S.W. Alabama.

DESCRIPTION OF STAND: Mature, natural southern yellow pine with an average of 93 trees per acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

	Avg.	SD	Range
DBH (in.)	13	3.4	6.8-20.4
DGL (in.)	15.8	4.2	8.4-27.6
Tree ht. (Ft)	85.7	9.6	62-106
Vol/tree (Ft^3)	33.8	19.4	7.2-88.6

PRODUCTION DATA:

Element	Avg.	SD	Range	Number of Observations
Position saw (min.)	0.216	0.087	0.082-0.585	202
Move and dump (min.)	0.35	0.211	0.097-1.437	197

Position and Saw Time in minutes = $0.096 + 0.00067\,(DBH)^2$ $[R^2 = 0.48]$

Average minutes/tree	0.572
Average trees/PMH	105
Average cunits/PMH	35.5

OTHER COMMENTS:

CITATION: Greene, W.D. and J.F. McNeel. 1987. PRODUCTIVITY, COSTS, AND LEVELS OF BUTT DAMAGE WITH A BELL MODEL T FELLER-BUNCHER. Forest Products Journal. 37(11/12):70-74.

MACHINE SYSTEM: Bell model T feller-buncher using a 24 inch capacity chainsaw felling head. Machine was 3 months old at the time of the study.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcut. Slopes were less than 5%.

DESCRIPTION OF SITE: Lower coastal plain of Virginia. Slopes were less than 5%, little understory.

DESCRIPTION OF STAND: Southern pine stand containing 100 trees/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

	N	Mean	SD	Minimum	Maximum
DBH (in.)	320	13.28	3.29	4	22
Stump diameter (in.)	320	17.02	4.14	5	28
Total height (ft)	320	71.48	6.43	53	88
Vol/tree (Ft^3,OB)	320	33.93	18.25	1	96

PRODUCTION DATA:

Summary Statistics

Variable (all min.)	N	Mean	SD	Minimum	Maximum
Position and sever	322	0.159	0.083	0.051	1.123
Move to tree	322	0.255	0.178	0.043	1.228
Bunching	320	0.124	0.124	0.033	0.652
Bunch maintenance*	21	0.313	0.158	0.123	0.625
Average cycle time		0.558			

Hourly productivity averaged 40 cords/PMH.

Bunch maintenance was 0.313 min. per occurance, 0.020 min. per tree.

	N	Mean	SD	Min.	Max.
Distance between felled trees (ft)	269	35.07	25.25	1	170

Move to tree time

MT = 0.1409 + 0.003196 x Distance [$R^2 = 0.188$]
Where MT = Move to tree time (min/tree)
Distance = Distance between felled trees (ft)

Position and Sever

PS = 0.07704 + 0.005860 x DBH [$R^2 = 0.116$]
PS = Position and sever time (min.)
DBH = Diameter at breast height (in.)

Cycle Time

Cycle = 0.3603 + 0.002947 x Distance + 0.009608 x DBH [$R^2 = 0.108$]
Cycle = Total cycle time (min/tree)
DBH = Diameter at breast height (in.)
Distance = Distance between felled trees (ft)

OTHER COMMENTS:

CITATION: Anon. 1976. CLARK BOBCAT FELLER BUNCHER. Machinery Evaluation. Logging Industry Research Association, New Zealand. Vol. 1, No. 2.

MACHINE SYSTEM: Clark Bobcat 1075 feller-buncher equipped with a 38 cm shear.

OPERATOR RATING: Inexperienced.

DESCRIPTION OF SYSTEM:
Feller-buncher → Manual limbing → Grapple skidder

DESCRIPTION OF OPERATION: Clearcutting. The bobcat felled along a row, laying out bunches of 4-12 stems for manual delimbing and subsequent grapple skidding.

DESCRIPTION OF SITE: Flat.

DESCRIPTION OF STAND:
Stand 1: Ponderosa pine
Stand 2: Ponderosa pine
Stand 3: P. nigra

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Stand	1	2	3
Average height (m)	13.4	13.4	16.8
Average butt diameter (cm)	24.9	31.8	31.0
Average volume (m^3)	0.13	0.26	0.57

PRODUCTION DATA:

Stand	1	2	3
Shear (min./tree)	0.15	0.19	0.16
Bunch (min./tree)	0.13	0.22	0.21
Re-position (min./tree)	0.10	0.18	0.18
Production (stems/hr)	158	101	109
Utilization	--------- 82% --------		

OTHER COMMENTS: Short duration study.

CITATION: Moulson, D.C. 1981. DEVELOPMENT OF 36-INCH FELLER-DIRECTOR. FERIC. Technical Report No. TR-48.

MACHINE SYSTEM: Mark I: 36-inch saw feller-director head. Cranab FK9060 boom and swing assembly carrying the head. The whole unit was mounted on a used FMC 200 series track skidder. Mark II: A new head, modified Drott 40 upperworks.

OPERATOR RATING: Winter: Not a production operator. Summer: Production operator.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcut. Field testing of prototype feller-director heads.

DESCRIPTION OF SITE: Winter: McGregor, B.C. Slopes = -7 to + 11%. Summer: Prince George, B.C. Slopes = +8 to +20%.

DESCRIPTION OF STAND: Winter: Average DBH = 15.8 in. Merchantable stems per acre = 149. Unmerchantable stems per acre = 25. Average stump diameter = 19.3 in. Summer: Average DBH = 13.7 in. Merchantable stems/Acre = 135. Unmerchantable stems/acre = 81. Average stump diameter = 18.3 in.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Mark I - March 1979, Mark II - September 1980.

Detailed Time Study Results

	Mark I Winter	Mark II Summer
Total time/tree (min.)	1.04	1.34
Volume per tree (Ft^3)	66	52.3
Cunits per acre	98	67.6
Trees/PMH	57.7	44.8
Volume/PMH (cunits)	38.1	23.5

OTHER COMMENTS: Carrier terrain capacity = 35% slope.

CITATION: McMorland, B. 1980. NON-SHEARING FELLING HEADS. FERIC. Technical Note No. TN-34.

MACHINE SYSTEM: Albright director. This Albright head (36 in. capacity) was mounted on a Caterpillar D7G bulldozer. The manufacturer was still modifying it for snow conditions when tested.

OPERATOR RATING: The operator was experienced on bulldozers but had no felling experience.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. Only winter data is available.

DESCRIPTION OF SITE: Fort St. James, B.C. Level ground. Temperature during the test was -20°C and there was 4 to 6 feet of loose snow on the ground.

DESCRIPTION OF STAND: Mainly balsam fir with some large spruce. Average DBH = 13.9 in. Merchantable stems/acre = 178. Unmerchantable stems/acre = 34. Cunits/acre = 87.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume per tree = 49 Ft^3

PRODUCTION DATA:

Detailed Time Study Results and Productivity

Felling cycle (%)	89
Brushing (%)	5
Delays (%)	6
Total time/tree (minutes)	1.10
Trees/PMH	54.5
Volume/PMH (cunits)	26.7

Shift-Level Study Results
Production, Productivity and Mechanical Downtime

Average volume/tree (Ft^3)	27.8
Trees/PMH	43.8
Volume/PMH (cunits)	12.2
Average PMH/shift worked (hours)	2.9
Trees/shift worked	126
Volume/shift worked (cunits)	35.0
Repair and service hours/100 PMH	262.9

OTHER COMMENTS: The Albright director head was developed primarily for mounting on tracked machines and is too heavy for most other types of carriers. Even when mounted on the D7 bulldozer, the weight was concentrated on the front of the tracks, thus reducing traction.

CITATION: McMorland, B. 1980. NON-SHEARING FELLING HEADS. FERIC. Technical Note No. TN-34.

MACHINE SYSTEM: Dika director (36 inch capacity) mounted on a Caterpillar D8.

OPERATOR RATING: The operator was experienced with Dika directors and had been with this particular machine for 5 weeks.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. Only winter data is available.

DESCRIPTION OF SITE: Prince George area, B.C. Slopes = +1 to +5%. Scattered windfalls sometimes impeded the machine's progress. Snow depth was between 4 and 5 feet. Temperature averaged -15°C.

DESCRIPTION OF STAND: Stand predominantly spruce with small quantities of balsam fir and pine. Average DBH = 12.9 in. Merchantable stems/acre = 163. Unmerchantable stems/acre = 26. Cunits/acre = 65.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume/tree = 40 cunits

PRODUCTION DATA:

Detailed Time Study Results and Productivity

Felling cycle (%)	87
Brushing (%)	1
Delays (%)	12
Total time/tree (minutes)	1.19
Trees/PMH	50.4
Volume/PMH	20.2

Shift-Level Study Results
Production, Productivity and Mechanical Downtime

Average volume/tree (Ft^3)	35.7
Trees/PMH	35.9
Volume/PMH (cunits)	12.8
Average PMH/shift worked (hours)	4.6
Trees/shift worked	165
Volume/shift worked (cunits)	58.8
Repair and service hours/100 PMH	106.7

OTHER COMMENTS:

CITATION: McMorland, B. 1980. NON-SHEARING FELLING HEADS. FERIC. Technical Note No. TN-34.

MACHINE SYSTEM: Northwood/FERIC director (36 in. capacity) was boom-mounted on a modified FMC carrier. The director, which was a second prototype, had been on site since January 1979.

OPERATOR RATING: At the test time no regular operator had been assigned to the machine.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. Summer or shift study data is not available.

DESCRIPTION OF SITE: Prince George area, B.C. Slopes = -7 to +11%. Temperature = -5°C to +10°C. Loose snow (6 to 7 feet) to 5 Ft. of dense snow.

DESCRIPTION OF STAND: Stand consisted of widely-spaced spruce and balsam fir. Average DBH = 15.8 in. Merchantable stems/acre = 149. Unmerchantable stems/acre = 25. Cunits/acre = 98.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Volume/tree = 66 Ft^3

PRODUCTION DATA:

Detailed Time Study Results and Productivity

Felling cycle (%)	78
Brushing (%)	1
Delays (%)	21
Total time/tree (minutes)	1.04
Trees/PMH	57.7
Volume/PMH	38.1

OTHER COMMENTS: Occasionally, the push arm does not have sufficient power to push trees with excessive lean or wind load. In this case, the chain is stopped and maximum push is applied.

CITATION: McMorland, B. 1980. NON-SHEARING FELLING HEADS. FERIC. Technical Note No. TN-34.

MACHINE SYSTEM: Albright director (28 in. capacity) mounted on a Komatsu D65S (loader-type) tracked-carrier.

OPERATOR RATING: The operator had worked with the machine for about 4 months and had been involved in much of its development.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. Only winter shift-level study available. Owner-operator operation.

DESCRIPTION OF SITE: Grande Prairie, Alberta. 2 feet of powder snow, and an average temperature of -20°C.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Shift-Level Study Results
Production, Productivity and Mechanical Downtime

Average volume/tree (Ft^3)	29.1
Trees/PMH	67.5
Volume/PMH (cunits)	19.6
Average PMH/shift worked (hours)	3.7
Trees/shift worked	249
Volume/shift worked (cunits)	72.4
Repair and service hours/100 PMH	91.5

OTHER COMMENTS: The head could not be lowered below the bottom track level of the carrier, and this caused some head-placement restrictions.

CITATION: Peterson, J.T. 1988. EVALUATION OF THE RANGER-KOCKUMS FELLER-SKIDDER. FERIC. Technical Note No. TN-117.

MACHINE SYSTEM: (2) Model 85-35 Ranger-Kockums feller-skidders equipped with modified model 60 Hultoins feller-director heads. Both feller-skidder had double-bogey rear sections fitted with flex-trac. Cutting capacity = 70 cm. Jonsered model 150B loader; lifting capacity = 2300 kg.

OPERATOR RATING: Regular operator and a trainee operator.

DESCRIPTION OF SYSTEM: Feller-skidder → Processor

DESCRIPTION OF OPERATION: Clearcutting. After felling, the trees were placed in the clambunk and skidded to the road. Trees were then mechanically processed at roadside and hauled off-highway to the unloading point. Large trees were manually felled.

DESCRIPTION OF SITE: Four study sites, 39 km southwest of Campbell River, B.C. The sites were close together. Average slope = 10%, rolling terrain.

DESCRIPTION OF STAND: Oldgrowth. 54% balsam fir, 37% western hemlock, 4% cypress, 3% western white pine, and 2% Douglas fir. Stand averaged 595 stems/ha.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average gross volume/tree = 1.4 m^3. Average net volume/tree = 1.1 m^3.

PRODUCTION DATA: Detailed study: 5 days in September 1987.

Time and Production Summary -- Detailed - Timing Study

Productive machine time (%)	72.7
Mechanical delays (%)	26.2
Non-mechanical (%)	1.1
Total scheduled machine time (hours)	27.5
No. of trees skidded/turn	10.4
No. of trees skidded/PMH	19.2
No. of trees skidded/SMH	13.9
Average net volume/tree (m^3)	1.2
Volume skidded/PMH (m^3)	23.0
Volume skidded/SMH	16.7
Production per 8-hour shift	
No. of trees	111.2
Volume (m^3)	133.4

Time and Production Summary - Shift Level Study

	Regular Operator Machine A	Trainee Operator Machine A	Total Machine A	Total Machine B
Productive machine hours (%)	68.4	73.7	70.2	78.6
Mechanical delays (%)	26.2	18.75	23.6	16.7
Non-mechanical delays (%)	5.4	7.6	6.2	3.7
Total scheduled machine hours	275.8	145.9	421.7	424.6
Machine utilization (%)	68.4	73.7	70.2	78.6
No. of trees skidded/turn	10.1	10.3	10.2	11.6
No. of trees skidded/PMH	16.1	11.9	14.6	17.5
No. of trees skidded/SMH	11.0	8.8	10.3	13.7
Average net volume per trees (m^3)	1.1	1.0	1.1	1.1
Volume skidded for PMH (m^3)	17.7	11.9	16.1	19.3
Volume skidded for SMH (m^3)	12.1	8.8	11.3	15.1
Production for 8-hour shift				
No. of trees	88.0	70.4	82.4	109.6
Volume (m^3)	96.8	70.4	90.6	120.6

During the shift-level study period of 68 days there was a total of 48 scheduled operating days.

OTHER COMMENTS: The original feller-director heads had to be modified because of continual saw pinching and bar bending. Modifications: repositioning both the saw box and push bar, replacing the push-bar teeth with a bar, extending the grapple legs, and increasing the chain-drive spocket speed.

CITATION: Moore, Trevor. 1987. A COMPARISON OF A GRAPPLE AND A CABLE SKIDDER ON EASY TERRAIN. Logging Industry Research Association, New Zealand. Vol. 12, No. 13, pp. 1-6.

MACHINE SYSTEM: Caterpillar 528 fitted with an Esco 47 (100") grapple.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: The grapple skidder started accumulating the load by picking up the trees furthest from the skid road and then driving to the next piece. Cable skidder bladed trees prior to hook up.

DESCRIPTION OF OPERATION: Both skidders were monitored for two days in adjoining blocks. 125 cycles for grapple and 86 cycles for cable skidder were recorded. The average load on the grapple skidder was below its optimum.

DESCRIPTION OF SITE: Flat terrain.

DESCRIPTION OF STAND: 40 year old radiata pine, waste-thinned twice and production-thinned in 1982. Spacing between crop trees was uneven, with a great variation in tree size.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Stocking (stems/ha)	211
Avg. tree DBH (cm)	52.5
Avg. Merchantable tree size (m^3)	3.0

PRODUCTION DATA:

<u>Production Statistics</u>

Piece size (m^3)	2.1
Pieces per cycle	2.1
Volume per cycle (m^3)	4.4
Haul distance (m)	150
Productivity (m^3/PMH)	57

Time Distribution	Mean time Per cycle
Travel empty (min.)	1.01
Blade logs (min.)	0.14
Position (min.)	0.25
Load (min.)	0.85
Travel loaded (min.)	1.60
Fleet (min.)	0.79
Travel cycle time (min.)	4.64

OTHER COMMENTS: For a grapple of this size a piece size of 2.5 - 3.0 m or larger would allow the grapple skidder to outproduce a cable skidder. In the easy terrain areas, the grapple skidder can increase productivity and reduce production costs. High productivity of both skidders is due to favorable terrain and piece size. Skidders typically achieve 6-7 PMH in an 8-hour day.

CITATION: Johnson, L.R. 1988. SUMMARY OF PRODUCTION AND TIME STUDIES OF MECHANIZED HARVESTING EQUIPMENT IN THE INTERMOUNTAIN WEST. Forest Products Department, University of Idaho (Unpublished).

MACHINE SYSTEM: Caterpillar 518 grapple skidder.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Manual felling → Caterpillar 518 grapple skidder → Stroke-boom delimber.

DESCRIPTION OF OPERATION: Clearcut

DESCRIPTION OF SITE: Average slope 3.253% (SD = 3.040)

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

	Avg.	SD
Butt diameter	13.74	3.45

PRODUCTION DATA:

Time Distribution	
Travel unloaded (%)	13.7
Load grapple (%)	33.6
Travel loaded (%)	15.9
Decking (%)	15.3
Delays (%)	21.5
	100
Utilization (%)	78.5

Production Statistics	Avg.	SD
Trees/turn	2.506	1.029
Minutes/delay	1.51	---
Turn time (min.)	3.779	1.731
Skidding distance (ft)	193.7	95.6
Slope (%)	-3.253	3.040
Trees/PMH	39.8	---
Trees/SMH	31.2	---

Regression Equation:
Total turn time (min.) = 0.518 + 0.0107 (skid dist) + 0.0011 $(\text{slope})^3$ + 1.62 LN (pieces per turn)

OTHER COMMENTS:

CITATION: Massey, G.F. 1978. LOGMA LIMBER-BUNCHER INTRODUCED INTO AUSTRALIA. Australian Forest Industries Journal. January 1978.

MACHINE SYSTEM: Logma T-310 limber-buncher with telescopic boom. The boom grips, delimbs and bucks. Case 850 feller-buncher.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-buncher → fallers → Limber-buncher

DESCRIPTION OF OPERATION: Clearcutting operation producing sawlogs and pulpwood from softwood plantations.

DESCRIPTION OF SITE: Morwell, Victoria, Australia. Terrain varying from 15° to 19° in slope.

DESCRIPTION OF STAND: 7 Ft. x 7 Ft. spacing, radiata pine plantation.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree volume = 0.45 m^3 (clearcut site)

PRODUCTION DATA:

Clear Falling (Manual Felling)	
Average tree size (m^3)	0.5
Production/machine hour (m^3)	22
Slope	Flat

OTHER COMMENTS:

CITATION: Peterson, J.T. 1987. SURVEY OF MECHANIZED PROCESSING EQUIPMENT, EVALUATION OF THE LIM-MIT PROCESSOR. FERIC. Technical Note No. TN-105.

MACHINE SYSTEM: The Lim-mit processor was mounted on a John Deere 790 tracked carrier. Maximum tree capacity = 94 cm diameter. Saw capacity: circular topping saw = 22 cm, bucking saw = 88 cm. Tree funnel capacity = 75 cm diameter. Caterpillar 235 feller-buncher. JD 740A grapple skidder, Cat 235 log loader.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
(Cat 235) Feller-buncher → (JD 740A) Grapple skidder → Processor → (Cat 235) Loader

DESCRIPTION OF OPERATION: Clearcut. Trees were felled and bunched with a Caterpillar 235 feller-buncher equipped with a Lodge cutting head. The bunches were then skidded to the roadside or the landing by a John Deere 740A grapple skidder, where they were processed by a Lim-mit processor and loaded onto trucks.

DESCRIPTION OF SITE: 46 km North of Gransle, B.C. Processed at landings and at roadsides.

DESCRIPTION OF STAND: 61% lodgepole pine, 25% white spruce, 11% balsam fir, and 3% trembling aspen. 550 stems/acre. Net volume = 39.6 m^3/hectare.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Study Period: 20 days in February 1987.

Time and Production Summary for Shifts Worked

Productive time - processing (%)	58.5
Non-productive time (%)	
Mechanical	26.6
Non-mechanical	14.9
Machine utilization (%)	58.5
Average gross volume/tree (m^3)	0.9
No. of trees processed/PMH	88.5
Volume processed/PMH (m^3)	79.7
Volume processed/SMH (m^3)	46.6
Production per 8-hour shift	
Number of trees	414.2
Volume (m^3)	372.8

OTHER COMMENTS: The majority of the mechanical delay time was due to saw-related problems.

CITATION: Johnson, L.R. 1988. SUMMARY OF PRODUCTION AND TIME STUDIES OF MECHANIZED HARVESTING EQUIPMENT IN THE INTERMOUNTAIN WEST. Forest Products Department, University of Idaho (Unpublished).

MACHINE SYSTEM: Roger stroke-boom delimber.

OPERATOR RATING: 3 months experience.

DESCRIPTION OF SYSTEM: Skidder → Stroke-boom delimber

DESCRIPTION OF OPERATION: Trees were skidded with butts forward. Tree decks and log decks were both located above the road. Large logs had been sorted into separate decks and processed manually.

DESCRIPTION OF SITE: Flat.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

1) Average tree butt diameter = 13.99", SD = 4.38"

Inches	Freq.	Inches	Freq.	Inches	Freq.
8	41	18	40	28	4
10	79	20	24	30+	0
12	105	22	26		
14	143	24	15		
16	62	26	12		

2) Average tree length = 101.71 ft., SD = 31.84 ft.

Feet	Freq.	Feet	Freq.	Feet	Freq.	Feet	Freq.
50	6	100	64	150	80	200	4
60	35	110	22	160	15	210+	0
70	79	120	61	170	15		
80	32	130	19	180	3		
90	152	140	5	190	9		

3) Average log diameter = 13.56", SD = 40.04"

Inches	Freq.	Inches	Freq.	Inches	Freq.
8	49	18	52	28	4
10	137	20	30	50	0
12	175	22	28		
14	199	24	16		
16	93	26	12		

4) Average log length = 27.16 ft., SD = 8.90 ft.

Feet	Freq.	Feet	Freq.	Feet	Freq.
8	12	18	28	30	0
10	6	20	1	32	206
12	19	22	0	34	146
14	7	24	57	36	1
16	152	26	100	44	59
		28	1		

5) Average log volume = 23.89 cu. ft., SD = 22.19 cu. ft.

Feet	Freq.	Feet	Freq.	Feet	Freq.
0	1	45	11	100	4
5	124	50	13	105	2
10	161	55	10	110	2
15	107	60	17	115	3
20	129	65	6	120	0
25	80	70	12	125	5
30	27	75	1	130+	2
35	49	80	6		
40	13	85	10		
		90	0		
		95	0		

PRODUCTION DATA:

Time Distribution	
Position and grab log (%)	7.1
Swing loaded (%)	9.9
Process log (%)	29.5
Handle log (%)	13.3
Swing empty (%)	6.1
Move (%)	5.0
Delays (%)	29.0
Utilization (%)	71.0

Production Statistics	
Number of trees	551
Number of logs	795
Avg. trees/PMH	56.7
Avg. trees/SMH	40.2
Avg. logs/PMH	81.5
Avg. logs/SMH	57.8
Ft^3/PMH	1,946.8
Ft^3/SMH	1,381.3

Regression Equations:

Tree volume (Ft^3)/PMH = 2041 - 1968 (no. logs) + 0.321 (length tree)^2 [$R^2 = 0.67$]

Log volume (Ft^3)/PMH = - 582 + 8.92 (log diameter)^2 + 1.05 (log length)^2 [$R^2 = 0.75$]

OTHER COMMENTS:

CITATION: Peterson, J.T. 1987. SURVEY OF MECHANIZED PROCESSING EQUIPMENT EVALUATION OF THE CATERPILLAR DL221 PROCESSOR. FERIC. Technical Note No. TN-103.

MACHINE SYSTEM: The Caterpillar DL221 processor has a Tanguay EC200 processor upper section, which is mounted on a Tanguay AC200 feller-buncher undercarriage. Delimbing capacity = 56 cm.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: A Madill 084 grapple yarder was used to yard timber which had been either handfelled or mechanically felled. After processing, logs were loaded by a Caterpillar 225 log loader.

DESCRIPTION OF OPERATION: Clearcut.
Area 1: A feller-buncher felled and bunched timber. The bunched wood was grapple yarded to roadside windrows, with butts facing the road.
Area 2: The timber was handfelled and then grapple yarded to a windrow, with many of the trees having tops facing the road.

DESCRIPTION OF SITE: Near Buckley Bay, B.C.
Area 1: Level ground (± 5%).
Area 2: Slope on lower side of road varied from 30 to 50%.

DESCRIPTION OF STAND: 50% balsam fir, 39% western hemlock and 11% western red cedar. 454 stems/hectare. Net volume/hectare = 690 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Study Duration: 5 days in January 1987.

Observed Time - Distribution Summary

	Area 1	Area 2	Combined
Productive time (%)	63.3	50.4	52.6
Repair and service (%)	26.7	30.4	29.8
Delays (%)	10.0	19.2	17.6
Process time per tree (min.)	1.2	1.6	1.4
Process time per log (min.)	0.7	1.0	0.9
Average gross volume/tree process (m^3)	1.32	1.56	1.48
No. of trees processed/PMH	41.8	22.0	26.2
No. of trees processed/SMH	26.5	11.1	13.8
No. of logs processed/PMH	68.4	34.5	41.6
No. of logs processed/SMH	43.3	17.4	21.9
Volume processed/PMH (m^3)	55.2	34.3	38.8
Volume processed/SMH (m^3)	35.0	17.3	20.4

	Area 1	Area 2	Combined
Production/8-hour shift			
Number trees	212.0	88.8	110.4
Volume (m^3)	279.8	138.5	163.4

OTHER COMMENTS: The limiting factor on the processor's ability to lift and swing trees was the holding power of the delimbing grapple.

CITATION: Rotherham, T. 1978. CENTRAL SLASHING AND A 2 MILE SKID. Canadian Forest Industries. 98(1):18, 19, 21, 23.

MACHINE SYSTEM: (2) Tanguay slasher/sorters

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
(6) Cat 518 line skidders → (1) Drott Cruzaire loader → (2) Tanguay slasher/sorters
(8) Timberjack 240 line skidders → (2) Cat 966 loaders → (2) Tanguay slasher/sorters

DESCRIPTION OF OPERATION: Clearcutting. Trees are felled, topped and delimbed in the bush, then they are skidded butt-first to the yard. The tree-length material is fed to the slasher by the Cat 966 loaders.

DESCRIPTION OF SITE: Quebec.

DESCRIPTION OF STAND: Mixed stand dominated by birch, beech and maple.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Product	Size	Percent
Hardwood pulp	8'	61%
Softwood pulp	8'	11%
Softwood sawlogs	16',14',12'	17%
Hardwood sawlogs	16',14'12'	8%
Veneer	9'3"	3%

Average tree volume = 20-35 Ft^3.

PRODUCTION DATA:

Slasher Sorter	
Scheduled hours	737
Down time (hours)	13
Delays (hours)	144
Utilization (%)	79
Productivity (cunits/PMH)	21.7

OTHER COMMENTS: A centralized slashing-sorting complex served by long distance (up to 14,000 Ft.) skidding.

CITATION: Anon. 1979. MF 450 S LOG LOADER, MACHINERY EVALUATION. Logging Industry Research Association, New Zealand. Vol. 4, No. 1.

MACHINE SYSTEM: Two Massey Ferguson MF 450 S track type hydraulic excavators were converted for logging operations. Modifications included replacing the bucket with a grapple, altering the boom to improve lift height and improving cab protection.

OPERATOR RATING: Experienced.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. Both machines were studied during normal operations which involved handling, sorting, stacking and loading.

DESCRIPTION OF SITE: Waipori Forest, New Zealand.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: Export logs: 4, 6, 8 and 12 meters in length. Mill logs: 2.5 - 7 m. Pulpwood: 2.5 - 7 m. Maximum diameter for pulp logs = 25 cm, minimum diameter for large pulp logs = 25 cm.

PRODUCTION DATA: Mechanical availability was 96%, productive utilization 85%. The machines loaded out an average of 2.4 loads per day (range: 1 - 3 loads). Average truck load size (for 24 loads) = 27.1 tons (26.2 m^3). Study duration was 7 days.

	Machine "A" (MF Grapple)				Machine "B" (Hiab Grapple)			
Log Load Type	Avg. log size (m^3)	Avg. No. of grapple loads	Avg. No. of times loader moved	Avg. loading time per tonne (min.)	Avg. log size (m^3)	Avg. No. of grapple loads	Avg. No. of times loader moved	Avg. loading times per tonne (min.)
12m Export logs	0.87	30	12	1.29	1.06	17	0	0.87
Mill logs	0.52	40	13	1.60	0.45	27	5	0.75
Pulpwood	N.A.	30	15	2.39	N.A.	22	3	0.84

Time Distribution

Sorting and stacking (%)	58
Loading trucks (%)	25
Clear landing (%)	2
Mechanical delays (%)	4
Non-mechanical delays (%)	11

OTHER COMMENTS: The machines are limited by lifting capacity and reach, and are suited to low production logging systems.

CITATION: Williams, M. 1989. AN EVALUATION OF A HYRAULIC KNUCKLEBOOM LOADER IN A HIGH PRODUCTION/MULTIPLE LOG SORT OPERATION. Logging Industry Research Association. Project Report No. 47.

MACHINE SYSTEM: 1980 model Mitsubishi MS 230 excavator modified to log loader configuration. Prentice model 848-W log by-pass grapple.

OPERATOR RATING: Experienced loader operator with two years experience on this machine.

DESCRIPTION OF SYSTEM: D 65 Komatsu with arch, D45 E Komatsu → Mitsubishi MS 230 loader.

DESCRIPTION OF OPERATION: Tree-length extraction by tractors to landing. Loader sorted, stacked, and loaded in a hot deck system.

DESCRIPTION OF SITE: Kinleith Forest (New Zealand). Four different landings were used during the trial. Landing size ranged from 0.2 to 0.26 hectares.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Extracted mean volume/piece	1.79 m^3	(Range: 0.06 - 7.32 m^3)
Extracted mean length/piece	22.4 m	(max.: 42.5 m)
Mean large end diameter	44.3 cm	
Mean small end diameter	21.6 cm	

PRODUCTION DATA:

Treatment	No. of Sorts	Activity	Productivity (Tonne/hour) /SMH	/AMH	/PMH
1	8	Load	91	102	121
		Sort and stack	52	52	77
2	7	Load	97	97	129
		Sort and stack	75	85	105
3	9	Load	74	75	102
		Sort and stack	51	53	75
Overall		Load			117
		Sort and stack			85

Truck loading time averaged 0.55 minutes per tonne, with pulp logs taking 50% longer to load than quality logs.

OTHER COMMENTS: Regular truck scheduling has a major effect on loader utilization, and therefore overall loader productivity. There is potential to produce at higher production levels if other logging systems are not limiting.

CITATION: Vaughan, L. 1989. LOADING LOGS: A COMPARISON OF BELL SUPER-LOGGERS AND RUBBER-TYRED FRONT-END LOADERS AT TARAWERA FOREST. Logging Industry Research Association, New Zealand. Vol. 14, No. 16.

MACHINE SYSTEM: Rubber-tyred loaders in 97 to 100 kW range; Cat 936, Dresser 520 and Volvo 1610. Bell Superlogger with 40 kW Deutz air-cooled engine.

OPERATOR RATING: Experienced.

DESCRIPTION OF SYSTEM:
Manual falling → Cable skidder → Bell super logger, Cat 936, Dresser 520, Volvo 1610

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: Tarawera Forest (New Zealand). Flat ground.

DESCRIPTION OF STAND: Radiata pine. 27 years old. 350-400 stems/ha. Average piece size = 1.2 to 2.0 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Product	Length (m)	Minimum SED (cm)
Export sawlogs	8, 12	28
	8, 10	23
Domestic sawlogs	Customer specified	20
C and I peelers	4	30
Groundwood	4-6, 8-12	10
Kraft	4-6	60
Pulp	6, 8, 12	10

PRODUCTION DATA:

<u>Frontend Loader:</u>

Loading productivity average	98 m^3/PMH
Range for individual loads	80 to 120 m^3/PMH
Load time = 22.0 - 4.55 (piece size)	[R^2 = 0.69]

<u>Bell Superlogger:</u>

Loading productivity average	62 m^3/PMH
Range for individual loads	50 to 80 m^3/PMH
Load time = 20.2 + 0.104 (no. of logs)	[R^2 = 0.49]

OTHER COMMENTS: The lower productivity of the Bell is offset by lower owning and operating costs, resulting in lower costs ($/tonne) than front-end loaders. The Bell is best suited to an operation producing up to 150 tonnes/day. The higher loading rates of front-end loaders make them better suited to higher producing operations.

CITATION: Anon. 1979. HITACHI KH100 LOG LOADING CRANE. Machinery Evaluation. Logging Industry Research Association, New Zealand. Vol. 4., No. 2.

MACHINE SYSTEM: Standard Hitachi KH100 hydraulic crawler crane, with 95 kW engine and equipped with the twin-rope operated log grapple.

OPERATOR RATING: Experienced.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Four days detailed time study with loader applied in log load-out operations. Sawlogs and long pulp were loaded.

DESCRIPTION OF SITE: Kinleith Forest, New Zealand

DESCRIPTION OF STAND: Old crop radiata pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Log Type	Avg. Log Size
Sawlogs	1.61 tonnes
Long pulp	0.61 tonnes

PRODUCTION DATA:
Average Trailer Unload Time = 1.87 min.
Avg. Truck Log-loading Time = 15.90 min.
Avg. Truck Log-loading Time/Tonne = 0.61 min.

Log Type	Avg. Log Size (tonnes)	Avg. No. of Pieces Per Cycle	Avg. Tonnes Per Cycle	Avg. No. of Cycles Per Minute	Avg. Log Loading Time Per Tonne
Sawlogs	1.61	1.18	1.91	1.20	0.44 min.
Long Pulp	0.61	2.34	1.42	0.99	0.71 min.

OTHER COMMENTS: Log loading ability of this machine is good. To optimize loading rate, the weight of logs picked up per grapple must be maximized, while the time spent doing this must be minimized.

CITATION: Twaddle, A. 1979. RUBBER-TIRED FRONT-END LOADER APPLICATION. Logging Industry Research Association, New Zealand. Vol. 4, No. 2.

MACHINE SYSTEM: Fiat-Allis 645 B rubber-tired front-end loader.

OPERATOR RATING: Skilled.

DESCRIPTION OF SYSTEM:
Komatsu D80 tractor (with arch) → Manual bucking → Front-end loader → Truck.

DESCRIPTION OF OPERATION: Clearfelling. Stems were yarded to the landing and manually bucked. The loader collected the logs in the processing area, sorted and decked them, and loaded trucks.

DESCRIPTION OF SITE:

DESCRIPTION OF STAND: Old crop radiata pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
5 log sorts were made.

PRODUCTION DATA:

Loader Time Distribution

Sorting and stacking (%)	38.5
Loading (%)	17.3
Idle (%)	25.0
Repair/maintenance (%)	0.3
Operator rest (%)	18.9
Average skidding cycle (min.)	17
Average skidding volume (m^3)	13

OTHER COMMENTS:

CITATION: Peterson, J.T. 1987. EFFECT OF FALLING TECHNIQUES ON GRAPPLE YARDING SECOND-GROWTH TIMBER. FERIC. Technical Note No. TN-107.

MACHINE SYSTEM: 1969 Washington model 108 swing yarder. Mounted on a rubber-tired undercarriage. Johnson Y86 (218-cm) yarding grapple. 1970 Caterpillar D8 back-spar. 91-cm Weyerhaeuser W34 feller-director head mounted on a Timbco 2518 carrier.

OPERATOR RATING: Both operators were skilled and efficient.

DESCRIPTION OF SYSTEM: Grapple yarding of feller-director bunched and unbunched wood. Area A: Trees were felled by the feller-director and bunched with butts facing the haul road at a 45° angle. Area B: Trees were felled by the feller-director with butts facing the road at ~45° angle. Johnson Creek: Trees were felled by the feller-director and partially bunched.

DESCRIPTION OF OPERATION: Clearcutting. Two man crew - a machine operator and a hooktender. 45% of the hookups in Area A required spotting by the hooktender. The Johnson Creek area required the hooktender to spot 88% of the hookups by radio.

DESCRIPTION OF SITE: 35 km East of Olympia, Washington. Area A and B: Average slope = 5%. Terrain: even. Johnson Creek: Average slope = 28%. Terrain: even. Heavy morning fog.

DESCRIPTION OF STAND: Area A & B: 458 stems/ha. Johnson Creek: 733 stems/ha.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Area A & B: Estimate gross volume/tree yarded = 1.50 m^3.
Johnson Creek: Estimate gross volume/tree yarded = 1.64 m^3.

PRODUCTION DATA: Time and Production Summary for Shifts Worked

	Area A	Area B	Johnson Creek
Report period	Mar 21-31/86	Aug. 4-12/86	Sept. 13-19/86
Productive time ratio (%)	86.1	95.8	92.7
Availability (%)	99.2	96.3	92.7
Volume per PMH	97.6	88.5	51.9
Trees per PMH	65.1	59.0	31.7
Turns per PMH	33.6	41.9	24.3
Trees per turn	1.9	1.4	1.3
Volume per turn (m^3)	2.9	2.1	2.1
Production per 8-hour shift			
Volume (m^3)	710.5	644.3	377.8
Number trees	473.9	429.5	230.8

OTHER COMMENTS: FERIC observed that the feller-director bunches were loosely built. When the grapple was hooking-up, it was seldom able to get all the pieces in the bunch.

CITATION: Powell, L.H. and G. St. Jean. 1979. TRIAL OF OSA 670 FELLER BUNCHER AND OSA 705 PROCESSOR IN BRITISH COLUMBIA. FERIC. Technical Report No. TR-31.

MACHINE SYSTEM: OSA 670 feller-buncher with a 28 inch capacity chain saw felling head.

OPERATOR RATING: Many operators participated in the study. Experience ranged from much to little.

DESCRIPTION OF SYSTEM: OSA 670 Feller-buncher → OSA 705 processor

DESCRIPTION OF OPERATION: Clearcut. Trial operation.

DESCRIPTION OF SITE: British Columbia, Canada.
Range of slopes: Site 1: 0-61%; Site 2: 0-50%; Site 3: 0-15%.
Avg. slope, direction of travel: Site 1: +21%; Site 2: +23%; Site 3: 0.

DESCRIPTION OF STAND:

Site	1	2	3
Species composition	Lodgepole pine Alpine fir Englemann spruce	Lodgepole pine Englemann spruce Alpine fir	Lodgepole pine Englemann spruce Alpine fir
Merch. trees/acre	490	394	123
Unmerch. trees/acre	275	557	88
Stand volume (cunits/acre)	15-50	25-40	60-65
Avg. vol. tree (Ft^3)	15	18.7	25.0
Avg. tree height (Ft)	85	75	93

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Avg. piece size (Ft^3): Site 1: 18.7; Site 2: 14.6; Site 3: 23.1.

PRODUCTION DATA:

Site	1	2	3
Availability	75.0	67.5	65.6
Utilization	74.4	59.3	54.6
Trees/PMH	41	67	91
Cunits/PMH	7.6	10.0	21.0
Number of shifts	36	62	102

Time Distribution (Total)	
Productive time (%)	60.8
Mechanical delays (%)	31.5
Non-mechanical delays (%)	7.6
	100

OTHER COMMENTS: Maximum slope possible is 40 to 45% perpendicular to the contour and 20 to 25% parallel to the contour.

CITATION: Levesque, R. 1983. SHORT-TERM EVALUATION OF THE TIMBCO 2518 FELLER-BUNCHER IN EASTERN CANADA. FERIC. Technical Note No. TN-72.

MACHINE SYSTEM: Timbco 2518 feller-buncher with 69 cm wide tracks, side and front tilting cab, John Deere 6466T (132 kW) engine and LDC-206 shear accumulator head. Bombardier Valmet BT-12 clambunk skidder, sliding boom delimber and Tanguay CC-100 slasher.

OPERATOR RATING: Good.

DESCRIPTION OF SYSTEM:
Feller-buncher → Clambunk skidder → Delimber → Slasher

DESCRIPTION OF OPERATION: Clearcutting. Feller-buncher cut strips about 12 meters wide. Piles containing 12-20 trees were placed at 45° angle to the direction of travel with the butt-ends of the stems toward the roadside.

DESCRIPTION OF SITE: 40 km southwest Chicoutimi, Quebec.
Block 1: Soft and fragile ground with many obstruction, 10-20% slope.
Block 2: Firm ground. 15 to 20% slope in the bottom part. 30% slope in the top part.
Block 3: Soft and boggy.

DESCRIPTION OF STAND:
Block 1: Low density stand, 30% spruce, 70% balsam fir, with unmerchantable white birch.
Block 2: Relatively dense stand, 100% spruce, with unmerchantable white birch.
Block 3: Relatively dense stand, 100% spruce, with unmerchantable white birch.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Block 1: Mean merchantable volume: spruce = 67 m^3/ha, balsam fir = 88 m^3/ha. Mean volume per tree = 0.23 m^3, mean DSH (diameter at stump height) = 23.3 cm.
Blocks 2 & 3: Mean merchantable volume: spruce = 343 m^3/ha. Mean volume per tree = 0.19 m^3, mean DSH = 21.4 cm.

PRODUCTION DATA: Study Date: November 8-12, 1982

Short-term Study of the Timbco 2518 Feller-Buncher - Summary of Productivity

	Block 1	Block 2	Block 3
Mean time per cycle (cmin)	129.7	142.1	126.0
Trees per cycle	2.2	3.8	3.1
Trees per PMH	103.8	160.9	147.6
Volume per PMH (m^3)	24.0	30.9	27.4

Longer-Term Performance

All Time During Regular Work Shift (No overtime)	Time	Code	Formula
Total scheduled time (hours)	2,026	SMH	
Repairs, servicing, wait for parts and mechanic (hours)	327	REP	
Non-productive operating time and delays (hours)	151.5	--	
Productive machine-hours (hrs.)	1,547.5	PMH	
Availability	83.9		$\frac{\text{SMH}-\text{Repair}}{SMH} x100$
Utilization (%)	76.4		$\frac{PMH}{SMH} x100$

Productivity

Trees/PMH	106.8
m^3/PMH (approximate)	13

Time Distribution	Block 1	Block 2	Block 3
Travel empty (%)	36	21	24
Cutting (%)	20	35	36
Travel loaded (%)	26	19	17
Piling (%)	6	7	9
Brushing (%)	3	2	4
Delays (%)	9	16	10

OTHER COMMENTS:
Block 1: The operator spent a good deal of time moving around to gather scattered merchantable stems. The low stand density also did not allow him to take full advantage of the accumulating feature of the felling head.

CITATION: Hemphill, D.C. 1985. CLAMBUNK SKIDDER APPLICATIONS. Logging Industry Research Association, New Zealand. Vol. 7, No. 2.

MACHINE SYSTEM: 520 Timberjack clambunk skidder.

OPERATOR RATING: Best operators.

DESCRIPTION OF SYSTEM:
Feller-buncher → loader (shovel logging) → clambunk skidder → Hahn harvester or power saw
Feller-buncher → clambunk skidders → Hahn harvester or power saw
Feller-buncher → skidding tractor → Hahn harvester or power saw

DESCRIPTION OF OPERATION: Clearcut. The area was mechanically felled and bunched, with trees over 60 cm in diameter being manually felled. The clambunk skidders were used to remove wood from favorable grades. The operators preferred to cut a 12 meter log off the butt of all trees over 60 cm in diameter prior to skidding.

DESCRIPTION OF SITE: Near Port Angeles, Washington. Clay hill country, with benchy slopes. Slopes averaging about 40%, with short pitches up to 60%.

DESCRIPTION OF STAND: Second growth Douglas fir, with some small-sized secondary pieces. Average tree size was about 1.2 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
About 7% of the production is contributed by the loader "shovel logging."

PRODUCTION DATA:

Productivity of 520 Timberjack Clambunk Skidder

Trees/machine/9.5 hour day	275
Tonnes/machine/9.5 hour day	310

OTHER COMMENTS: On slopes inaccessible to the clambunk skidder, "shovel logging" was used.

CITATION: Peterson, J.T. 1987. HARVESTING ECONOMICS: TWO CASE STUDY OF A CYPRESS 72806 SWING YARDER. FERIC. Technical Note No. TN-115.

MACHINE SYSTEM: 1985 Cypress 7280B swing yarder, with 2 guylines through two fairleads. Height to top of fairlead = 21 m. Maximum grapple opening = 240 cm. Hitachi UH14 mobile backspar with two tail blocks.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Area A: Trees were handfelled parallel to the haul road to facilitate grapple. Trees were processed at stump. Used a mobile backspar.

DESCRIPTION OF OPERATION: Clearcutting.
Area A: Three man crew: an operator, a hooktender, and a utilityman. Stump rigging was used. The full trees were either hand processed at the roadside or hauled full length.

DESCRIPTION OF SITE:
Area A: 60 km northwest of Campbell River, B.C. Average slope = 6%, Rolling terrain. Obstacles: high old stumps.

DESCRIPTION OF STAND:
Area A: Second growth: 3% alder, 7% Douglas-fir, 25% western red cedar, 65% hemlock. 621 stems/ha. 550 m^3/ha (gross).

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Area A: Estimated gross volume/piece yarded = 0.89 m^3.

PRODUCTION DATA: Study Period: 10 days in March, April and May, 1987

	Area A
Productive machine hours (%)	71
Non-productive time - mechanical (%)	29
- other (%)	0
Average time per turn (min.)	1.53
Average no. pieces per turn	1.3
Average yarding distance	134
Average move time (min.)	2.7
No. moves per PMH	11
Pieces per PMH	516
Pieces per SMH	36.6
m^3 per PMH	45.9
m^3 per SMH	32.6
Pieces per 8-hour shift	2928
Volume per 8-hour shift (m^3)	260.8
Total SMH	32.0

Area A:

Outhaul time (min.) = 0.00302 x distance
Inhaul time (min.) = 0.00317 x distance
Fixed time/turn = 0.52 min.

Total turn time = Fixed time + Outhaul and Inhaul Time
(Distance in meters)

OTHER COMMENTS: More than half the Area A mechanical delay time resulted from line clutch and activator problems. There was a 36-minute difference in average move time when comparing the mobile-backspar and stump-rigging tailblock move times.

CITATION: Sauder, E.A. 1981. GRAPPLE YARDING WITH A STEEL TOWER. FERIC. Technical Note No. TN-53.

MACHINE SYSTEM: The J-78 grapple tower yarder is a modfied Madill 009 yarder and 27.4 meter tower mounted on an overhauled Kenworth truck. Major modifications: an extra mainline drum, double mainline sheave, electro-servo controls and hydraulic winch. Fauchon carriage with Mar grapple.

OPERATOR RATING: The operator was extremely skilled in the yarder operation and grapple tower technique.

DESCRIPTION OF SYSTEM: Uphill and downhill. Grapple yarder was rigged like a highlead tower. The additional mainline drum was used to operate a grapple.

DESCRIPTION OF OPERATION: Clearcutting. Four man crew: yarder operator, landing man, spotter and hooker. Logs that were out of reach of the grapple were choked and brought to a suitable location.. The inhaul was then completed using the grapple.

DESCRIPTION OF SITE:
Uphill: Uniform terrain. Average slope = 13%, good deflection.
Downhill: Some rock outcross. Average slope = 49%, fair deflection.

DESCRIPTION OF STAND: Timber types: hemlock and balsam fir.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Uphill: Average log size = 1.52 m^3.
Downhill: Average log size = 2.05 m^3.

PRODUCTION DATA:

Summary of J-78 Production

	Yarding Direction	
	Uphill	Downhill
Production		
Average volume yarded/shift (m^3)	167	176
Average pieces/shift	110	86
Average yarding distance (m)	110	140
Average time/shift (hrs.)	7.7	8.2
Average no. of turns/shift	104	83
Machine availability (%)	99	97
Machine utilization (%)	61	60
Average net cycle time (min.)	2.37	2.75
Average delay time (min.)	1.60	1.94
Average total turn time (min.)	4.31	5.13

Time Distribution: % of Total Time

	Uphill	Downhill
Productive time		
Yarding (%)	54	52
Yarding road change (%)	8	8
Delays		
Mechanical (%)	1	3
Yarder set-ups (%)	3	2
Other delays (%)	34	35

OTHER COMMENTS:

CITATION: Sauder, E.A. 1980. AN EVALUATION OF GRAPPLE-CRANE YARDING IN COASTAL B.C. FERIC. Technical Note No. TN-36.

MACHINE SYSTEM: (2) Madill 044 grapple crane yarders with either modified (#'s 3 & 4) or standard grapples (#'s 1 & 2). (1) American 7250 grapple yarder equipped with a standard grapple. Mobile backspars used throughout.

OPERATOR RATING: Highly skilled and competent.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. 3 man crew. The yarder operator prepared the deck using logs within 100 feet of the yarder. Then, the yarder operator sent the grapple out, swung the boom to position the grapple, grappled the log and brought it to the landing.

DESCRIPTION OF SITE: Coastal, B.C., spring. Area had "good" deflection with the uphill yarding slope being 30%.

DESCRIPTION OF STAND: Douglas fir, western hemlock, western red cedar.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

	Madill 044				American 7250
	1	2	3	4	1
Avg. log volume (cunits)	0.36	0.42	0.35	0.54	0.62

PRODUCTION DATA:

	Madill 044				American 7250
Study	1	2	3	4	1
Grapple type*	STD	STD	MOD	MOD	STD
Avg. log volume (cunits)	0.36	0.42	0.35	0.54	0.62
Avg. Volume/turn (cunits)	0.40	0.52	0.41	0.62	0.70
Avg. Yarding distance (feet)	427	370	333	371	387
Total yarding cycle (min.)	1.34	1.34	0.95	1.34	1.75

Time Distribution (combined)	
Productive yarding (%)	74
Repair and service (%)	8
Operational (%)	2
Delays (%)	16

OTHER COMMENTS:

CITATION: Johnson, L.R. 1988. SUMMARY OF PRODUCTIVE TIME STUDIES OF MECHANIZED HARVESTING EQUIPMENT IN THE INTERMOUNTAIN WEST. Forest Products Department, University of Idaho (Unpublished).

MACHINE SYSTEM: Roger stroke-boom delimber.

OPERATOR RATING: 1 month of experience.

DESCRIPTION OF SYSTEM:
Swing yarder → Skidder swing → Stroke-boom delimber

DESCRIPTION OF OPERATION: Clearcutting. Trees were yarded and decked below the road with a cable yarder. The material was then swung to decks above the road for processing.

DESCRIPTION OF SITE:

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

1) Log diameter Avg. = 13.52", SD = 4.93"

Inches	Freq.	Inches	Freq.	Inches	Freq.
6	1	16	160	26	23
8	168	18	104	28	18
10	334	20	86	30	2
12	180	22	47		
14	183	24	52		

2) Log length Avg. = 23.69 ft., SD = 7.83 ft.

Feet	Freq.	Feet	Freq.	Feet	Freq.
8	20	20	24	32	539
10	27	22	18	34	0
12	76	24	231	36	1
14	77	26	34		
16	286	28	4		
18	12	30	9		

3) Log volume Avg. = 22.75 cu.ft., SD = 22.43 cu.ft.

Cu.Ft.	Freq.	Cu.Ft.	Freq.	Cu.Ft.	Freq.	Cu.Ft.	Freq.
0	5	30	73	60	17	95	0
5	372	35	53	65	2	100	5
10	250	40	46	70	17	105	0
15	165	45	36	75	15	110	5
20	87	50	32	80	3	115	9
25	90	55	43	85	22	120	0
				90	9	125	2

4) Tree butt diameter Avg. = 14.042", SD = 5.42"

Inches	Freq.	Inches	Freq.
6	1	20	55
8	89	22	36
10	213	24	43
12	106	26	23
14	102	28	18
16	84	30+	3
18	62		

5) Tree length Avg. = 102.12 ft., SD = 39.40 ft.

Feet	Freq.	Feet	Freq.	Feet	Freq.
40	1	100	58	160	21
50	24	110	49	170	43
60	65	120	75	180	13
70	213	130	22	190	10
80	53	140	24	200	18
90	97	150	46	210+	3

PRODUCTION DATA:

Time Distribution	
Position and grab (%)	7.5
Swing loaded (%)	8.2
Process (%)	22.2
Handle log (%)	14.6
Swing empty (%)	7.2
Move to new deck (%)	3.8
Delays (%)	36.6
Utilization (%)	63.4

Production Statistics	
No. of trees	838
No. of logs	1,358
Trees/PMH	35.3
Trees/SMH	22.4
Logs/PMH	57.1
Logs/SMH	36.2
Ft^3/PMH	1,299.6
Ft^3/SMH	824.6

Regression Equations:

Tree volume (cu.ft.)/PMH = 1184 - 933.5 (no. logs) + 1759 (basal area) [$R^2 = 0.69$]

Log volume (cu.ft.)/PMH = - 1758 + 174.6 (log diameter) + 32.5 (log length) [$R^2 = 0.70$]

OTHER COMMENTS:

CITATION: Murphy, Glen. 1978. LOADING FOR A CABLE LOGGING OPERATION. Looging Industry Research Association, New Zealand. Vol. 3, No. 5, pp. 1-4.

MACHINE SYSTEM: Fiat-Allis 645-B front-end loader, rubber tired.

OPERATOR RATING: 20 years of experience, owner of the machine.

DESCRIPTION OF SYSTEM: The cable logging operation landed tree lengths, which were trimmed and bucked with chainsaws. The front-end loader sorted and stacked logs, and loaded trucks.

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: Loader was working on two landings, 0.25 and 0.45 ha.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

	Landing A	Landing B
Mean tree volume (m^3)	4.5	4.5
Landing size (ha)	0.25	0.45

Sorting Information

Log type	Log length, m
Domestic sawlogs	9.9; 11.0; random
Peeler logs	min. 1.8
Export sawlogs	11.9; 8.0

PRODUCTION DATA: 3 Month Assessment Period

Element	% of Total Time	Element	% of Total Time
Productive		Unproductive	
Stacking	20.0	Refueling	1.8
Loading	21.9	Repairs and maintenance	7.4
Clearing landing	7.5	Unavoidable delays	0.1
Assisting skidders	0.6	Other	4.5
Assisting hauler	0.1	Waiting for work	18.8
Subtotal	50.1	Machine idle	17.2

Number of loaded trucks	442
Avg. load (tonnes)	26.2
Avg. load (m^3)	25.4
Avg. loading time (min.)	16.02
Avg. loaded trucks per day	8.6

OTHER COMMENTS:

CITATION: Twaddle, A. 1979. RUBBER TIRED FRONT-END LOADER APPLICATION. Logging Industry Reasearch Association, New Zealand. Vol. 4, No. 2.

MACHINE SYSTEM: Fiat-Allis 645 B rubber-tired front-end loader.

OPERATOR RATING: Skilled.

DESCRIPTION OF SYSTEM:
Madill 009 highlead yarder → Manual bucking → Front-end loader → Truck

DESCRIPTION OF OPERATION: Clearfelling. Stems were yarded to the landing and manually bucked. The loader collected the logs in the processing area, sorted, decked, and also loaded trucks.

DESCRIPTION OF SITE:

DESCRIPTION OF STAND: Old-crop radiata pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
10 different log sorts were made.

PRODUCTION DATA: Study Duration: 8.9 hours

Loader Time Distribution

Sort and stack (%)	42
Loading trucks (%)	33.7
Idle (%)	17.7
Repair/maintenance (%)	0.8
Operator rest (%)	5.8
	100

Average yarding cycle = 8 min.
Average volume/yarding cycle = 5 m^3

OTHER COMMENTS: Idle time occurred at irregular intervals, because of the yarder's complicated work pattern.

CITATION: Peterson, J.T. 1986. BUNCHED TURN GRAPPLE YARDING. Canadian Forest Industries. 106(8):B21-B24.

MACHINE SYSTEM: Case 1187 feller-buncher with Drott shear head. Madill 084 grapple yarder. Hitachi UH14 mobile backspar.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
1) Mechanically fell and bunch, then grapple yard to roadside for processing.
2) Handfall tree-length grapple yard to roadside, for processing.

DESCRIPTION OF OPERATION: Clearcut. Maximum yarding distance of 150 m.

DESCRIPTION OF SITE: East coast of Vancouver Island.
System 1: bunched wood. Avg. slope = 18%, rolling terrain.
System 2: handfelled wood. Avg. slope = 23%, rolling terrain.

DESCRIPTION OF STAND: 110-year-old coastal second-growth stand. System 1: gross m^3/ha = 566. System 2: gross m^3/ha = 713.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
System 1: Actual delivered net m^3 = 5,592, avg. piece volume = 0.59 m^3.
System 2: Actual delivered net m^3 = 6,402, avg. piece volume = 0.91 m^3.

PRODUCTION DATA: Study Period: over a period of 7 months, 161 hours of detailed timing (9451 pieces yarded)

Summary of Detailed Timing

	System 1	System 2
Avg. piece/turn	2.18	1.41
Avg. productive time/turn (min.)	1.20	1.30
Pieces/productive machine minute	1.80	1.09
Machine move		
Avg. time/move (min.)	3.16	6.64
No. moves/PMH	3.6	1.5

Time Distribution

	System 1	System 2
Yarding (%)	56	51
Move (%)	17	13
Deck (%)	4	8
Maintenance (%)	15	22
Other (%)	8	6

Grapple Comparison

	Pieces/PMH	
Grapple Size	System 1	System 2
Mantle 65 (165 cm)	---	46.1
Johnson Y96 (244 cm)	92.4	65.5
Johnson Y106 (269 cm)	110.9	80.8

OTHER COMMENTS:

CITATION: Fisher, J.G. 1986. LOGGING WITH A HYDRAULIC EXCAVATOR: A CASE STUDY. MF Paper. Department of Forest Engineering, College of Forestry, Oregon State University.

MACHINE SYSTEM: Cat 245 with a custom built 52 foot Young boom and 60 inch Pierce grapples.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Trees were manually felled along the contour and topped, limbed and bucked.

DESCRIPTION OF OPERATION: Clearcut. Shovel walked along a predetermined road location and yarded logs within a 100 foot swath, decking logs above or below the intended road. The shovel used two techniques:

1) Conventional swinging.
2) Throwing a turn downhill.

DESCRIPTION OF SITE: Coast Range of S.W. Oregon. Average slope = 35% (range 0-60%).

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Piece size ranged from 16 to 434 Ft^3, and averaged 68 Ft^3.
Diameters ranged from 5 to 60 inches, and averaged 16 inches.

PRODUCTION DATA:

Results of gross time study

Yard (%)	29.1
Travel to load (%)	2.6
Load (%)	41.7
Travel (%)	8.5
Road work (%)	4.1
Delays (%)	14.0

Production Rates:
Conventional:
45.7 cunits/PMH
24.4 cunits/SMH
Throw:
93.16 cunits/PMH
46.67 cunits/SMH

Regression Equations:

Hourly volume production: conventional swing (cubic feet) =
- 13176.00 + 10340.218057 (LNV) - 248.616487 (ABSLOPE) - 1448.609938 $(DISTANCE)^{1/2}$ - 91.402326 (SLOPE) [R^2 = .6417][N = 102]

Pieces per hour: conventional swing =
+ 350.5439 - 3.259746 (DIAMETER) - 1.927939 (ABSLOPE) - 10.18297 $(DISTANCE)^{1/2}$
[R^2 = .3832][N = 102]

Hourly volume production: throw technique (cubic feet) =
- 98379.41 + 6340331 (DIAMETER) - 1733.478 (SLOPE) + 155.3929 (VOLUME)
[R^2 = .7965][N = 38]
* Eqn. is limited to -45 to -50% slopes

Hourly piece production: throw technique =
- 111.177 + 3.11288 (DIAMETER) - 3.834312 (SLOPE) [R^2 = .1850][N = 38]

Where:
LNV = Natural log of cubic foot volume
ABSLOPE = Absolute value of % slope
SLOPE = Plus or minus % slope
DISTANCE = Yarding distance in feet
DIAMETER = Small end, inside bark, in inches

Yarding distance ranged from 5 to 205 feet, and averaged 57.5 ft.

OTHER COMMENTS: Crew was on an incentive plan.

CITATION: Gibson, D.F., et al. 1982. PREBUNCHING SMALL TIMBER IN STEEP TERRAIN. Transactions of the ASAE. ASAE Paper No. 82-1581.

MACHINE SYSTEM: (2) Kolpe Radio-Tir 740 winches (6 hp/4500 RPM)

OPERATOR RATING: No prior experience.

DESCRIPTION OF SYSTEM: Tree-length clearcut. Trees were felled, limbed and topped at 5 inches.

DESCRIPTION OF OPERATION: 4 methods tried:
1) Disjoint (D) = all trees felled prior to yarding
2) Integrated (I) = one tree was felled, then yarded
3) Single bunch (S) = single bunch
4) Multiple bunch (M) = a deck

DESCRIPTION OF SITE: Gallatin National Forest, near Bozeman, Montana. Site was representative of timber and terrain conditions in the N. Rockies, East of Continental Divide.

DESCRIPTION OF STAND: Terrain: S = > 40% slope; G = < 40% slope.
Ground Condition: F = Favorable; U = Unfavorable.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Time Distribution

Walk	15%
Skid	63%
Hook/Unhook	22%

Days Timed	Slope	Ground Conditions	System	Method	Trees/ Day	Average Tree (Ft^3)	Skidding Distance (ft)	Turn Time(min)
2	G	F	D	S	36	23	50	3.37
16	G	F	D	S	24	18	80	5.61
5	G	U	D	S	32	22	77	5.37
11	G	U	I	M	17	21	33	2.45
14	G	U	D	M	22	22	46	5.39
12	S	F	I	M	14	25	33	2.83
7	S	F	I	M	18	20	44	2.35
3	S	F	D	M	13	27	51	4.96

OTHER COMMENTS: If an individual element exceeded 9 minutes, the cycle was not included in the above table.

CITATION: McDonald, M.J. 1981. EVALUATION OF THE FINNING SWING HYDRAULIC YARDER. FERIC. Technical Note No. TN-40.

MACHINE SYSTEM: Finning SY 235 prototype swing yarder. Cat 235 undercarriage with a 3-drum hydraulic interlock and 12-metre boom. Swing capability and capability for grapple or choker yarding with the running skyline system. Cat D7 mobile backspar.

OPERATOR RATING: The crew was experienced in interior grapple yarding.

DESCRIPTION OF SYSTEM: The prototype operated as a grapple yarder with the running skyline system on several sites. Logs were skidded with a wheeled skidder from the deck to a landing where they were sorted, bucked and loaded with a front-end loader.

DESCRIPTION OF OPERATION: Clearcutting. One shift basis. It yarded uphill, downhill, on cleanup operation and as a full production yarder. Crew consisted of a yarder operator, spotter (also tailspar Cat operator) and a landing man.

DESCRIPTION OF SITE: Interior B.C. During the work sample study of the machine, the terrain was uniform with sufficient deflection.

DESCRIPTION OF STAND: Species composition: 84% spruce, 14% balsam fir, 1% cedar and 1% lodgpole pine. Average butt diameter = 38 cm, maximum butt diameter = 94 cm, average length = 17 m, volume per hectare = 280 m^3/ha.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average net volume per piece = 0.97 m^3

PRODUCTION DATA: Study Period: September 10 - 14, 1979.

Time Distribution of SY235

Productive (%)	67
Repair & service (%)	15
Non-productive (%)	10
Delays (personnel) (%)	8

Summary of Production from Operator's Shift Records

Average piece size - net volume (m^3)	0.77
Number of shifts worked	44
Number of scheduled shifts	51
Piece count per shift worked	277
Net volume per shift worked (m^3)	215
Productivity - cubic meters/SMH	21.1
- cubic meters/PMH	34.9

Productivity of SY235

Productivity (m^3/shift)	
Work sample study	300
Shift-level study	195
Availability (%)	72
Utilization (%)	60

OTHER COMMENTS: It must be noted that the Finning SY235 is a prototype machine and as such was shut down occasionally to perform hydraulic pressure checks, and to correct minor mechanical and line problems as they occurred. Under normal circumstances many of these minor problems would be checked at the end of the shift.

CITATION: Cottell, P.L., B.A. McMorland and G.V. Wellburn. 1976. EVALUATION OF CABLE LOGGING SYSTEMS IN INTERIOR B.C. AND ALBERTA. FERIC. Technical Report No. TR-8.

MACHINE SYSTEM: Washington 078 Skylok grapple yarder. Tracked undercarriage, 44-ft. tower, and 4 winches. Used a Euclid 8240 as mobile backspar which allowed for mounting tailblock at different heights.

OPERATOR RATING: The two trained operators were performing well.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Clearcutting. The yarder moved along the roadside yarding log-length timber both up and downhill. Horizontal yarding distance rarely exceeded 500 feet.

DESCRIPTION OF SITE: East side of the Monashee Mountains, B.C. Yarded on slopes up to 70%.

DESCRIPTION OF STAND: 60% Douglas fir, larch and white pine; 20% cedar; and 20% hemlock. Average butt diameter = 16 in., maximum butt diameter = 30 in., volume/acre = 50-65 cunits.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

	Summary A	Summary B
Avg. piece size (Ft^3) (all landings)	32	31

PRODUCTION DATA:
Study Periods:
Summary A: October 29, 1974 - February 28, 1975 (FERIC Study Period)
Summary B: March 1975 - November 21, 1975 (Company Reports)

Shift Level Results: Company D Washington 078 Grapple Yarder

	Summary A	Summary B
Productive time (hours)	3.2	6.2
Mechanical delays (hours)	2.4	1.3
Landing change delays (hours)	0.5	0.2
Other non-mechanical delays (hours)	1.9	0.3
Total: SMH	8.0	8.0

	Summary A	Summary B
Mechanical availability (%)	69	84
Machine utilization (%)	39	78
No. of scheduled shifts	73	111
Piece count per shift	95	155
Gross volume per shift (cunits)	30	48
Cunits/scheduled machine hour	3.80	6.01
Cunits/productive machine hour	6.64	7.48
No. of shifts worked	50	108

OTHER COMMENTS: Grapple yarding in winter had been a problem - logs and stumps could not be located in the snow, and clearance for the grapple was reduced by the amount of snow depth.

CITATION: Schuh, D. and L. Kellogg. 1989. MECHANIZED DELIMBING AT A CABLE LANDING. Logging Industry Research Association, New Zealand. Technical Release. Vol. 11, No. 4.

MACHINE SYSTEM: Roger delimber (max. dia. = 76 cm) mounted on a tracked Northwest Timbermaster 45K carrier.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Motor manual felling → Madill 122 swing yarder → Roger delimber → Knuckleboom loader

DESCRIPTION OF OPERATION: Clearcutting. Delimber cleared chute, delimbed, bucked, topped and decked trees from two positions next to yarder.

DESCRIPTION OF SITE: Near Powers, Oregon. Cable yarding terrain. Landing sizes = 0.073 ha and 0.097 ha.

DESCRIPTION OF STAND: Second growth Douglas fir and cedar. 170 trees/ha. Average tree DBH = 40 cm.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average log volume 0.94 m^3.
Average log length 10.4 m (2.4 - 13.4 m).

PRODUCTION DATA:

		Sample Size	Meantime (cmin)	S.D.
Actual Productive:	Reach	1,338	9.6	6.2
	Load	1,332	12.1	6.6
	Butt	69	10.2	7.9
	Delimb	1,356	24.7	13.6
	Top	1,313	3.2	2.4
	Deck	1,311	13.4	7.3
Other Productive:	Move	4	30.8	11.5
	Sort	272	23.5	14.0
	Brush	307	32.3	29.6
	Stack	71	30.3	15.0

1,434 logs in 17.5 PMH = 82 logs/PMH, 76.7 m^3/PMH
Utilization = 42.6%

OTHER COMMENTS: Yarder related delays were almost entirely responsible for poor level of delimber utilization. Landing size and layout is important for reducing workspace interference.

CITATION: Schuh, D. and L. Kellogg. 1988. MECHANIZED DELIMBING AT A CABLE LANDING. *In* proceedings: International Mountain Logging and PNW Skyline Symposium. Department of Forest Engineering, College of Forestry, Oregon State University. pp. 112-120.

MACHINE SYSTEM:
Madill 122 swing yarder → Roger delimber mounted on a Timbermaster 45K carrier → Hydraulic knuckle boom loader.

OPERATOR RATING: All experienced.

DESCRIPTION OF SYSTEM: Yarder → Delimber → Loader

DESCRIPTION OF OPERATION: Clearcut.

DESCRIPTION OF SITE: Coast Range of Oregon, summer.

DESCRIPTION OF STAND: Stand consisted of Douglas-fir and Port Orford cedar. Stand contained 10,420 bf/acre with average tree being 16 inches in DBH.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
For Delimber: Average volume per log = 33.5 cu.ft. Log lengths ranged from 8 to 44 feet, averaging 34 feet.
For Yarder: Average volume per piece averaged 45.2 cu. ft.

PRODUCTION DATA:

Delimber Production:
82 logs or 27.4 cunits/PMH
Utilization = 42.6%

Yarder Production:
18 cunits/PMH
Utilization = 66.5%

Loader Production:
70 logs or 23.5 cunits/PMH
Utilization = 45%

Operating Cycle Element Times (All Times in Centi-minutes.)

Activity	Mean	Standard Deviation	Min.	Max.	Sample Size
A. Delimber					
Actual Productive					
Reach	9.6	6.2	0.0	70.0	1,338
Load	12.1	6.6	2.0	75.0	1,332
Butt	10.2	7.9	2.0	45.0	69
Delimb	24.7	13.6	3.0	123.0	1,356
Top	3.2	2.4	0.0	28.0	1,313
Deck	13.4	7.3	2.0	93.0	1,311
Other Productive					
Move	30.8	11.5	20.0	47.4	4
Sort	23.5	14.0	5.0	93.0	272
Brush	32.3	29.6	3.0	176.0	307
Stack	30.3	15.0	8.0	81.0	71
B. Yarder					
Actual Productive					
Hook	188.4	92.6	42.0	674.0	321
Inhaul	117.0	46.7	19.0	382.0	311
Unhook	89.0	51.3	26.0	431.0	305
Outhaul	86.4	34.5	15.0	292.0	308
Lateral inhaul	24.3	9.6	12.0	91.0	122
Lateral outhaul	77.1	24.1	18.0	179.0	115
Other Productive					
Hangups	106.2	79.1	10.0	284.0	28
C. Loader					
Actual Productive					
Deck	41.5	23.6	10.0	282.0	914
Load	40.2	18.1	1.0	200.0	1,029
Clear Chute	64.2	47.4	11.0	431.0	142
Other Productive					
Sort	34.1	14.7	11.0	93.0	99
Spread Deck	51.6	56.8	17.0	233.0	13
Brush	79.6	86.5	14.0	492.0	94
Unload Trailer	170.6	86.7	25.0	404.0	36
Walk Between Decks	218.2	155.0	106.0	458.0	5

OTHER COMMENTS: Low delimber utilization was attributed to a 6 load per day quota and system imbalance.

CITATION: Moore, T. 1990. PILOT TRIALS WITH LOADER LOGGING IN NEW ZEALAND. Logging Industry Reseach Association, New Zealand. Vol. 15, No. 2.

MACHINE SYSTEM: Sumitomo LS 4300 30 tonne hydraulic loader with a Prentice 610 boom, a Pierce live-heel and a Prentice 8-48W continuous rotation grapple. Extra guarding on underside of machine.

OPERATOR RATING: Inexperienced in cutover.

DESCRIPTION OF SYSTEM: Manual cutting → Sumitomo LS 4300 loader

DESCRIPTION OF OPERATION: Trees felled parallel to road. Trees within 20 meters of the road were cut to log-length. Others marked but not cut by fallers. Beginning one boom length from the road, and moving parallel to it, all logs were stacked by sort. Four windrows at 20 meter intervals were completed, then the logs were retrimmed and cut to length. The loader swung windrows to the road and sorted.

DESCRIPTION OF SITE: Kinleith Forest (New Zealand). Predominantly flat with 13° slope over one third of area.

DESCRIPTION OF STAND: Radiata pine, second crop. Affected by windthrow. Stocking 260 stems/hectare. Average tree size = 2.1 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

	Length (Metres)
"A" Grade sawlog	4.3 - 6.1
Japanese export	8.1 and 12.1
No. 1 Pulp < 40 cm LED	1.7 - 13.0
No. 3 Pulp > 30 cm SED	3 - 13.0

PRODUCTION DATA:

Activity	Time (Machine hours)	% of Total Time
Windrow	9.3	32
Return swing	10.5	36
Sort and stack	9.5	32
Total	29.3	100

Volume produced = 819 tonnes
Productivity for 7 machine hours/day = 195 tonnes/day

OTHER COMMENTS: At seven machine hours logging and two hours loading, extraction and loading cost was NZ $4.30/tonne.

CITATION: Moore, T. 1990. PILOT TRIALS WITH LOADER LOGGER IN NEW ZEALAND. Logging Industry Research Association, New Zealand. Vol. 15, No. 2.

MACHINE SYSTEM: Sumitomo LS 4300 30 tonne hydraulic loader with a Prentice 610 boom, a Pierce live-heel and a Prentice 8-48 W continuous rotation grapple. Extra guarding on underside of machine.

OPERATOR RATING: Inexperienced in cutover.

DESCRIPTION OF SYSTEM: Manual cutters → Sumitomo LS 4300 loader

DESCRIPTION OF OPERATION: Swung whole trees downhill to the hauler landing. Maximum swing distance was 100 meters. Heel used to form contour track to access side slope.

DESCRIPTION OF SITE: Kinleith Forest, New Zealand. Slopes approximately 18°.

DESCRIPTION OF STAND: Old crop radiata pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: Merchantable piece size of 3.8 m^3.

PRODUCTION DATA:

Study No.	Time (Hours)	Volume (Tonnes)	Production per hour (Tonnes)
1	1.5	81	54
2	3.5	202	58
3	2	90	45
Total	7	373	

OTHER COMMENTS: Loader extracted trees when it was not needed by the yarder. (During line shifts or mechanical delay.) The cost for seven machine hours logging and two loading was NZ $2.20/tonne.

CITATION: Peterson, J.T. 1987. HARVESTING ECONOMICS: TWO CASE STUDY OF A CYPRESS 7280B SWING YARDER. FERIC. Technical Note No. TN-115.

MACHINE SYSTEM: 1985 Cypress 7280B swing yarder. 2 guylines through two fairleads. Height to top of fairlead = 21 m. Maximum grapple opening = 240 cm. Hitachi UH14 mobile backspar with two tailblocks.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Area B: Trees were handfelled parallel to the haul road. Only oversized material was bucked at the stump. Trees under a 60-cm butt diameter were yarded as full trees.

DESCRIPTION OF OPERATION: Clearcutting.
Area B: Four man crew: an operator, a hooktender, and two utilitymen. Stump rigging was used. The full trees were either hand processed at the roadside or hauled full length.

DESCRIPTION OF SITE:
Area B: 50 km southwest of Campbell River, B.C. Average slope = 46%. Terrain: gullied.

DESCRIPTION OF STAND:
Area B: Old growth: 5% Douglas-fir, 9% western red cedar, 21% cypress, 25% western hemlock, and 40% balsam fir. 266 stems/ha, 630 m^3/ha (gross).

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Area B: Estimated gross volume/piece yarded = 2.37 m^3.

PRODUCTION DATA: Study Period: 10 days in March, April, and May 1987.

	Area B
Productive machine hours (%)	87
Non-productive time - mechanical (%)	7
- others (%)	6
Average time per turn (min.)	1.62
Average number pieces per turn	1.1
Average yarding distance	122
Average move time (min.)	16.1
Number moves per PMH	0.5
Pieces per PMH	40.6
Pieces per SMH	35.5
m^3 per PMH	96.2
m^3 per SMH	84.1
Pieces per 8-hour shift	284.0
Volume per 8-hour shift (m^3)	672.8
Total SMH	31.6

AREA B:

Outhaul time (min.) = 0.00321 x DISTANCE
Inhaul time (min.) = 0.00292 x DISTANCE
Fixed time/turn = 0.73 min.

Total turn time = Fixed time + Outhaul and Inhaul Time
(distance in meters)

OTHER COMMENTS:

CITATION: Kellogg, Loren. 1987. SMALL LANDING OPERATIONS USING A MOBILE HAULER AND KNUCKLEBOOM LOADER. Logging Industry Research Association, New Zealand. Vol. 12, No. 7, pp. 1-8.

MACHINE SYSTEM: Sumomito Link Belt 4300, 30 tonne hydraulic knuckleboom loader was fitted with a Prentice 610 boom and Pierce designed log grapple and heel rack. Maximum lifting capacity was 12.6 tons, maximum reach 9.75 meters.

OPERATOR RATING: Operator had a previous experience on a smaller loader.

DESCRIPTION OF SYSTEM: After partial or complete log preparation in the bush, a Madill 071 cable hauled logs, and a Sumomito Link Belt 4300 hydraulic knuckleboom loader sorted logs and loaded trucks on the landing.

DESCRIPTION OF OPERATION: Operation was designed to evaluate possibility for using small landings for hauling and loading operations. A work sampling and a detailed time studies were conducted.

DESCRIPTION OF SITE: Slopes up to 70%.

DESCRIPTION OF STAND: 62 year old Douglas-fir stand, with 217 stems/ha. Merchantable volume = 741 m^3/ha, mean DBH = 58 cm, mean merchantable tree volume = 3.4 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: Landing area was approximately 0.07 ha (25 m by 28 m). Logs were sorted into 4 bunches - pulp, random lengths, 9.8 meters, and 12.3 meters. Pattern of stacks was radial, around the loader.

PRODUCTION DATA:

	Log Preparation Method	
	Complete	Partial
Activity	% of Time	% of Time
Sorting logs	35.9	33.9
Truck loading	12.9	16.6
Assisting skidders	5.1	6.7
Assisting hauling	0.5	0.5
Interference - skidders	13.5	12.9
Interference - Hauler	9.0	8.5
Idle	11.3	8.9
Clean landing	2.0	3.1
Other	9.8	8.8
Total	100.0	100.0

Loader work content

	Shorts		Longs	
Truck Type	Mean	Range	Mean	Range
Loading cycle (min.)	16.6	13.8-19.6	12.1	7.3-25.8
Delays, foreign elements (min.)	2.2	0.0-4.0	1.2	0.0-4.0
Total (min.)	18.8	14.7-25.7	13.3	7.5-26.6
Truck Preparation (min.)	4.5	2.6-5.8	2.9	2.1-4.8
Logs per load	75	54-107	20	12-37

Truck Loading Times

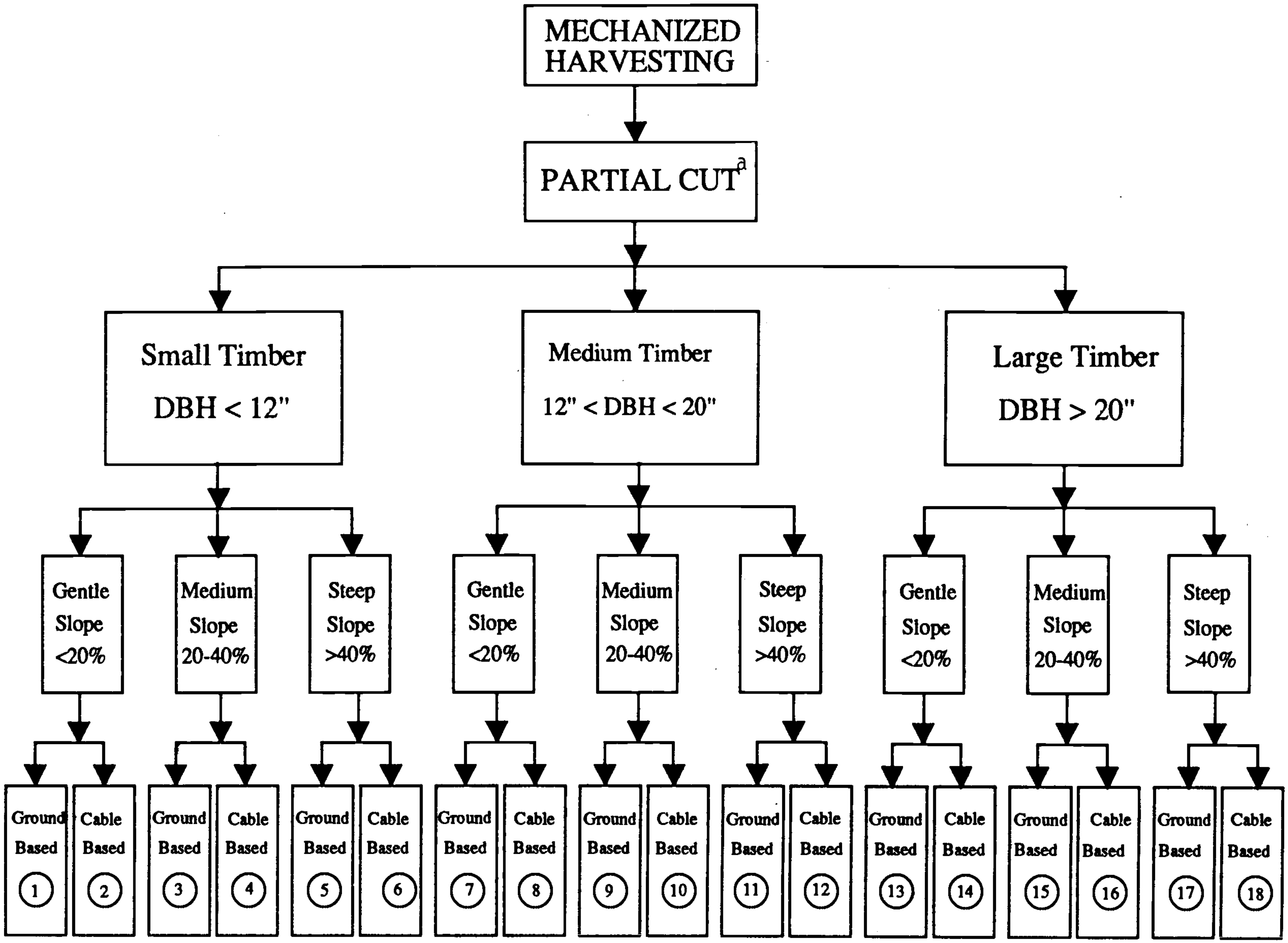
Mechanical availability (%)	95
Operation delay time (%)	11
Machine used (%)	87
Machine utilization (%)	76

OTHER COMMENTS: Loader activities should be confined to an area adjacent to the hauler with minimal movement around the landing. When a substantial portion of log preparation is done in the bush, loader time can be utilized much better.

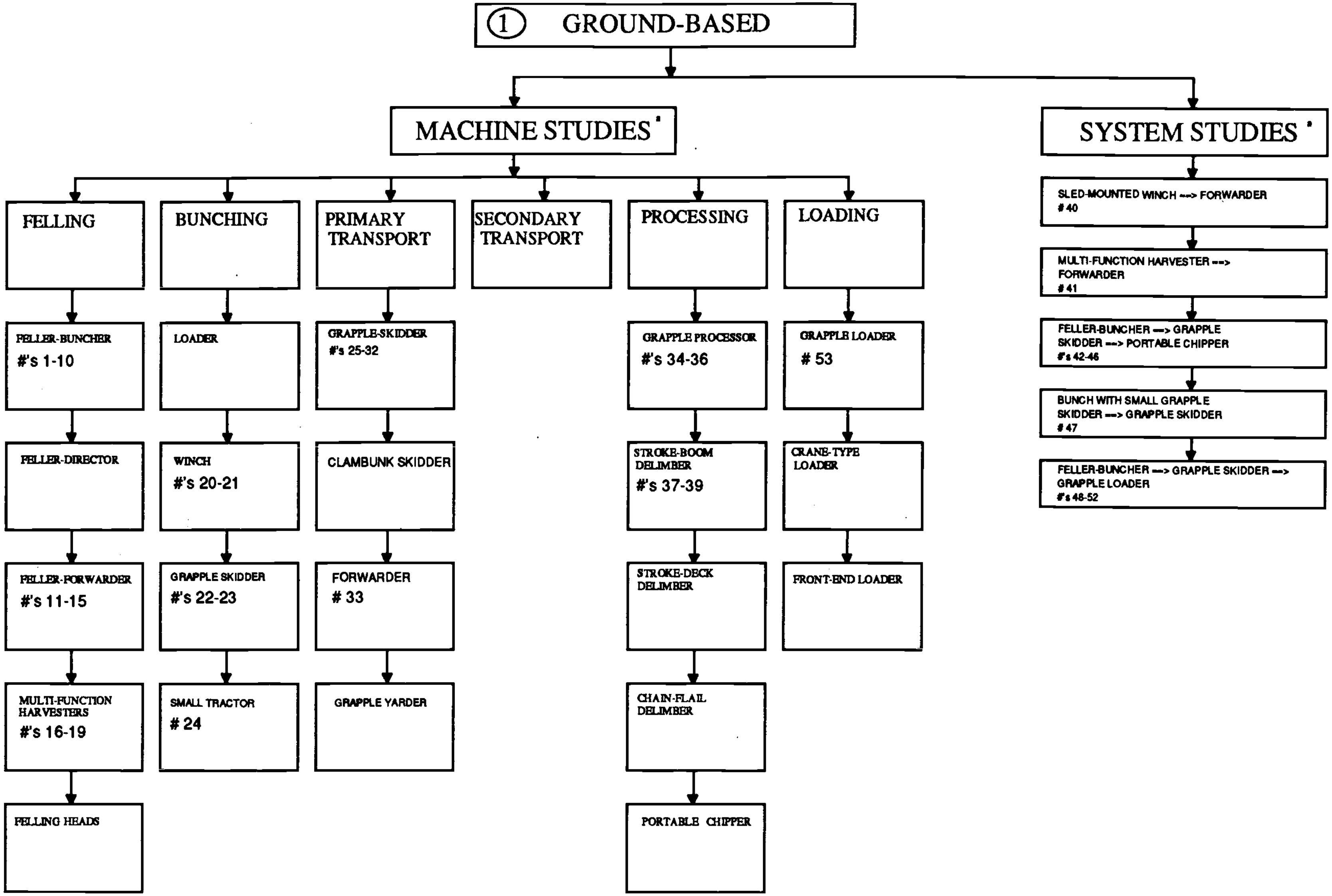
HIERARCHY II: MECHANIZED HARVESTING IN PARTIAL CUTS

Pathways Chart for Locating Abstract Citations

HIERARCHY II : MECHANIZED HARVESTING IN PARTIAL CUTS



[a] Numbers in circles refer to subsequent pages of the pathways chart for this hierarchy.



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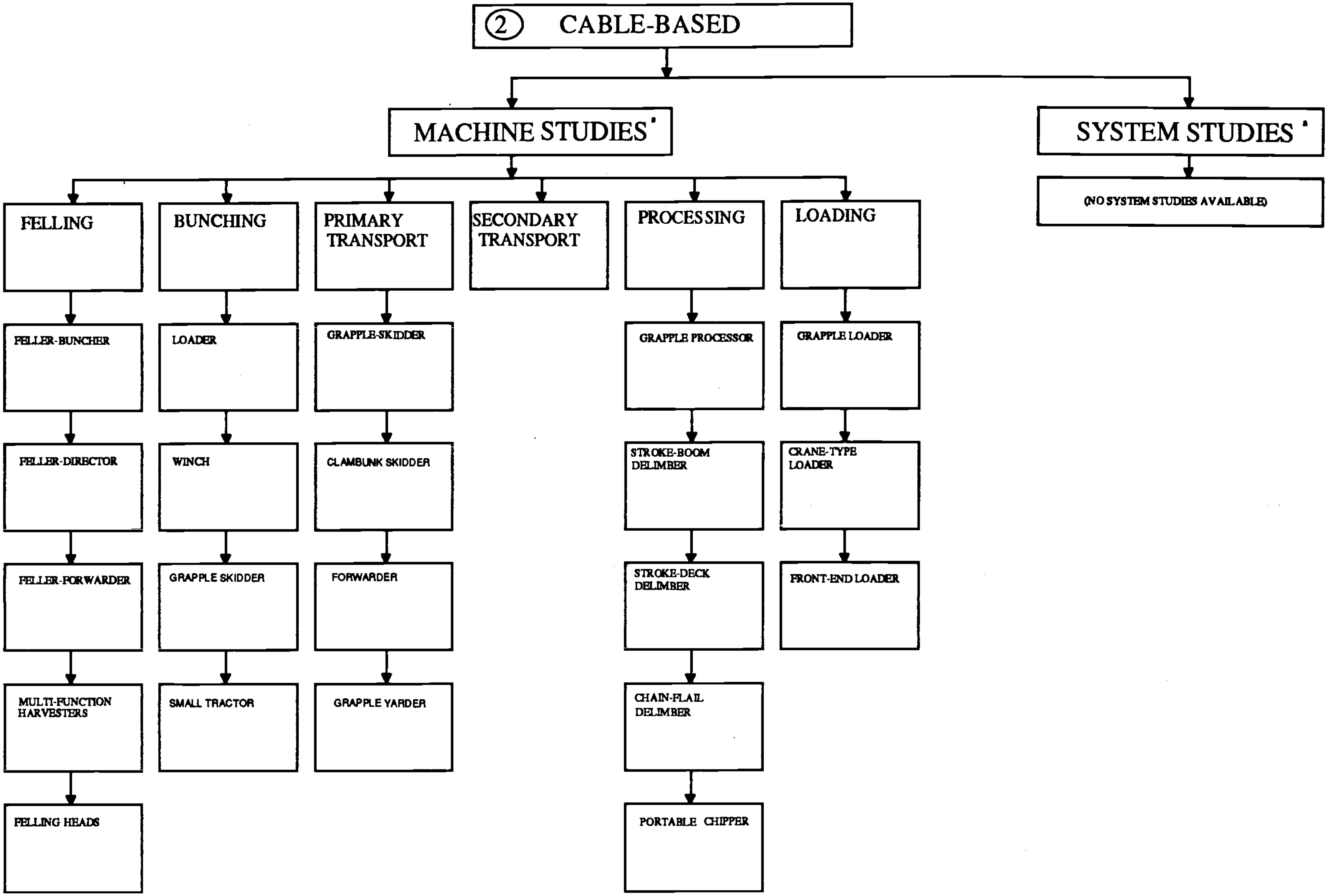

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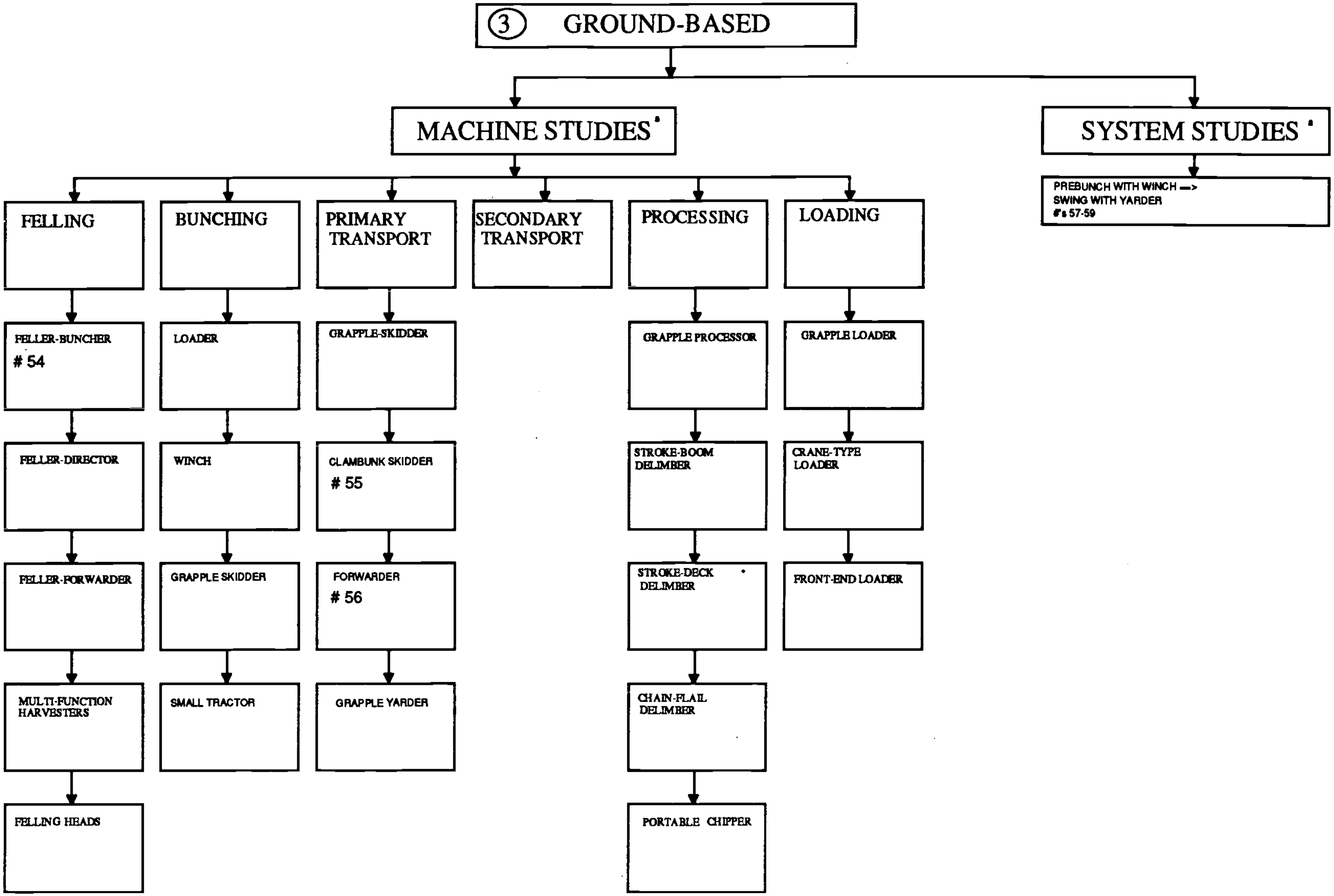

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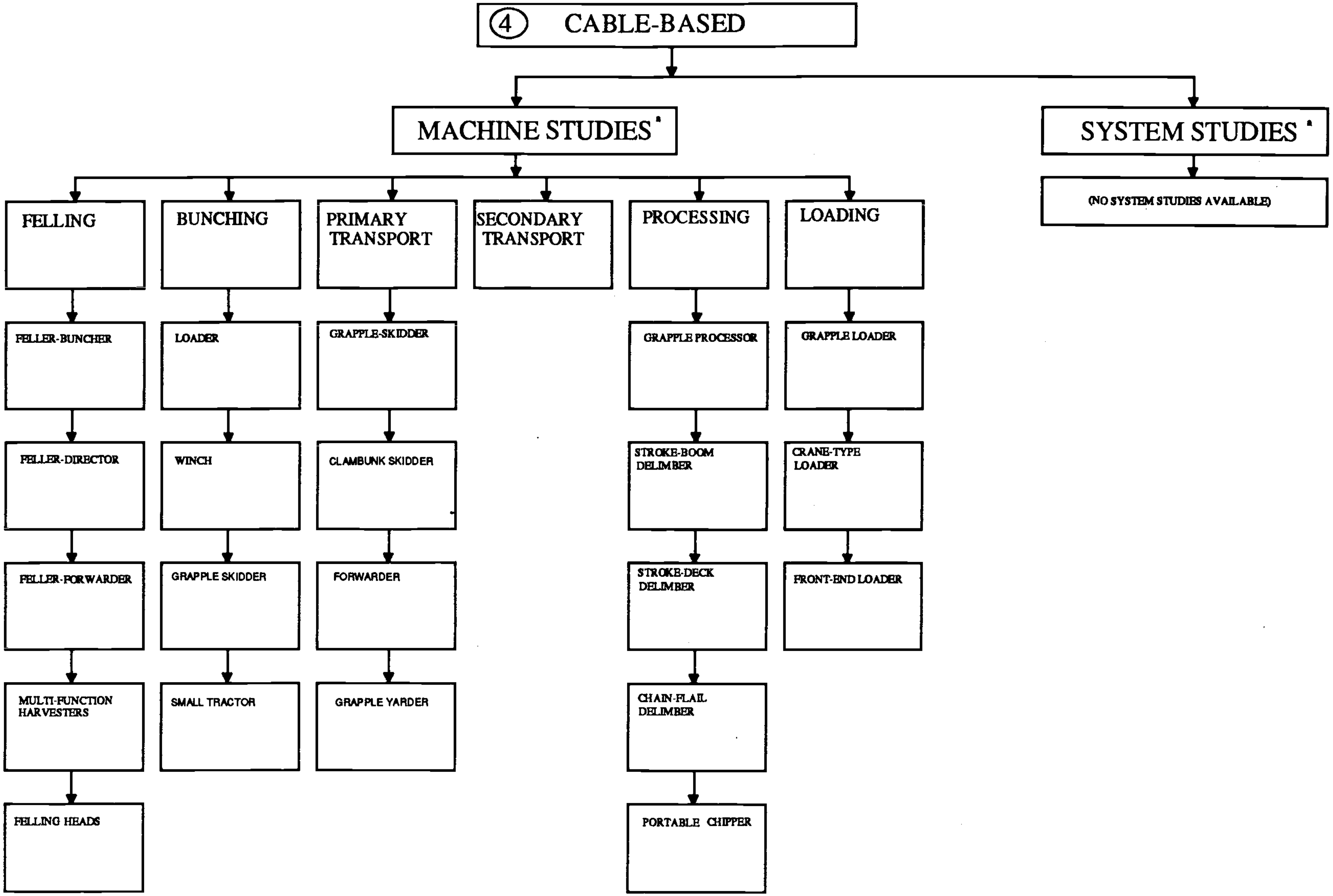

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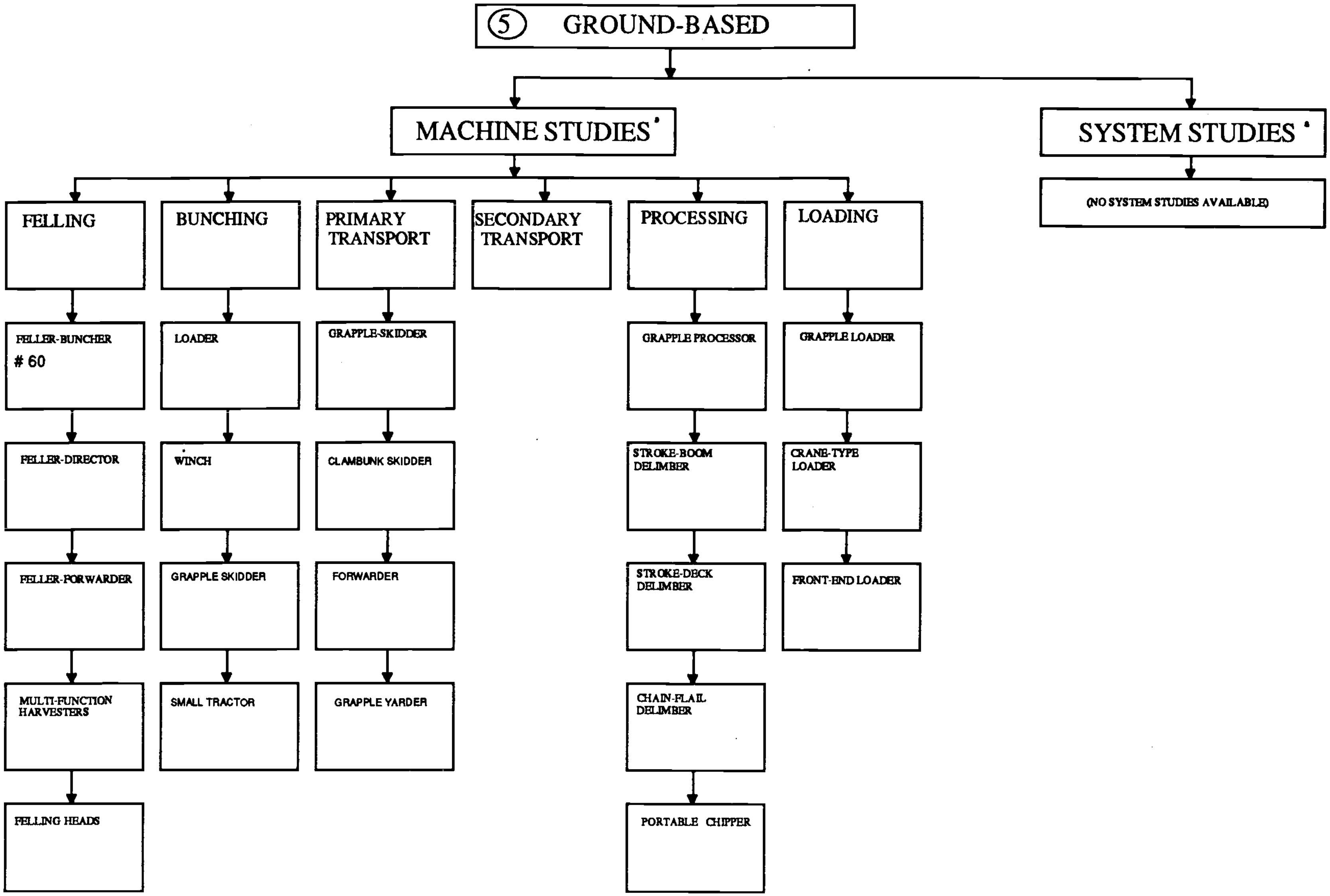

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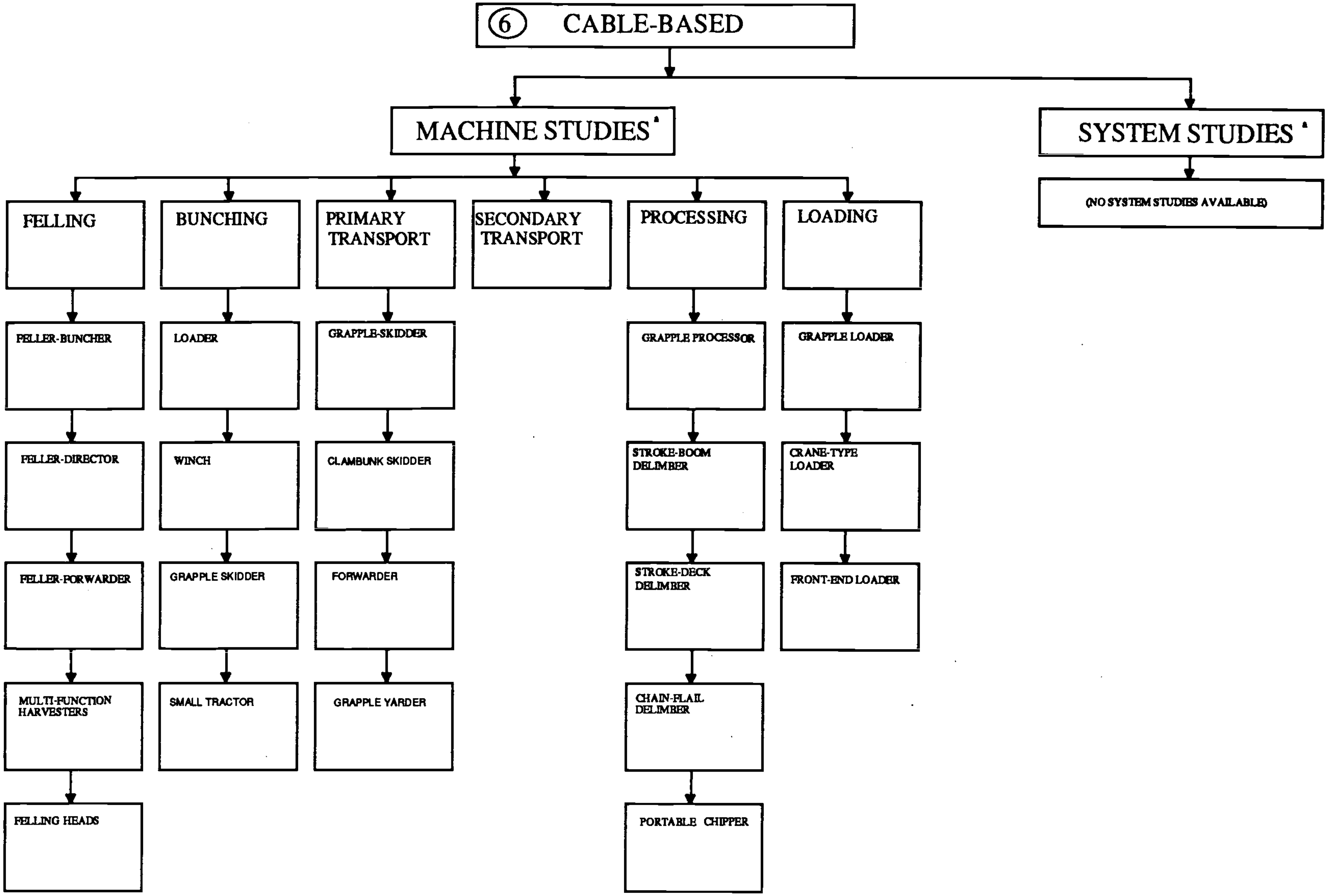

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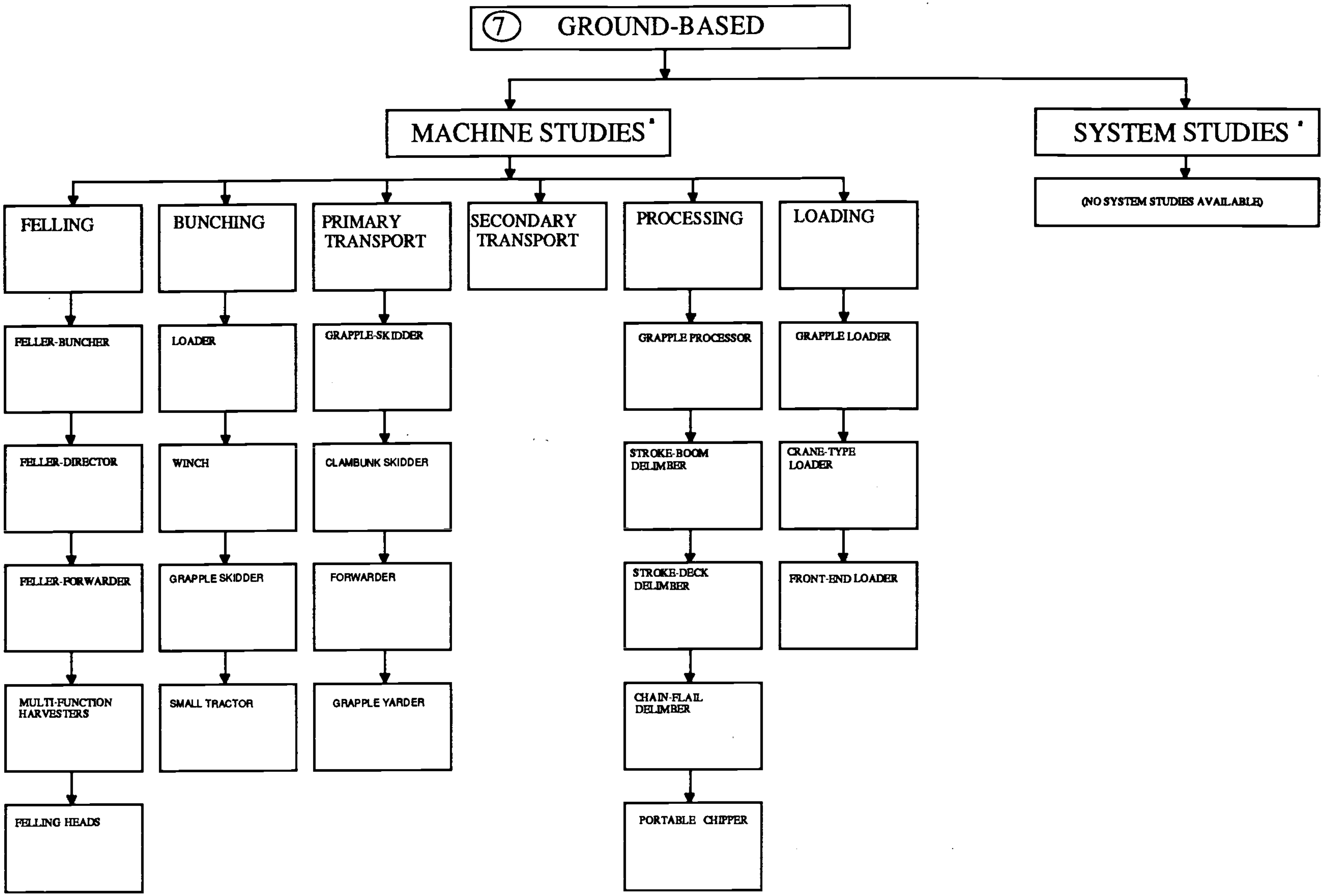

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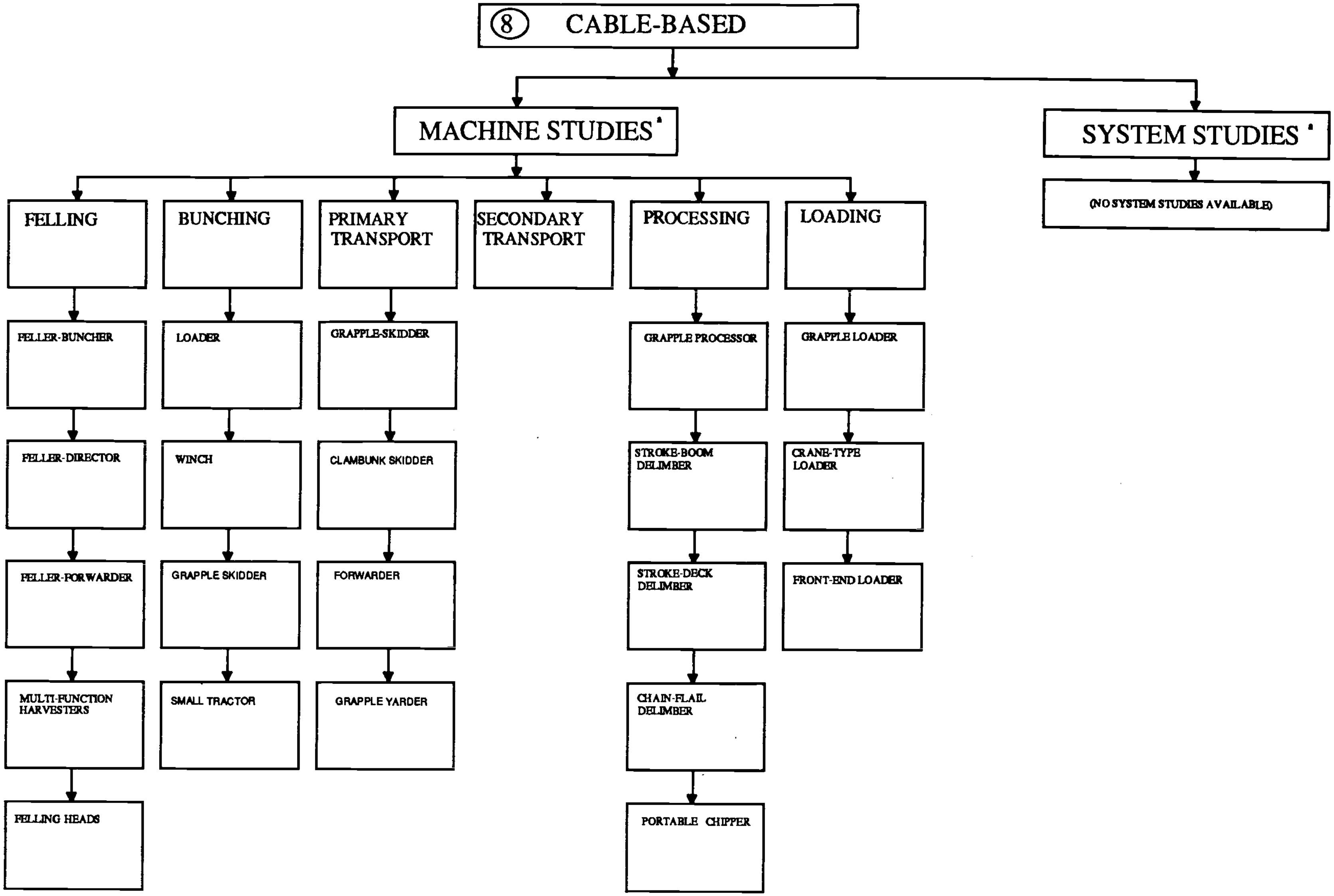

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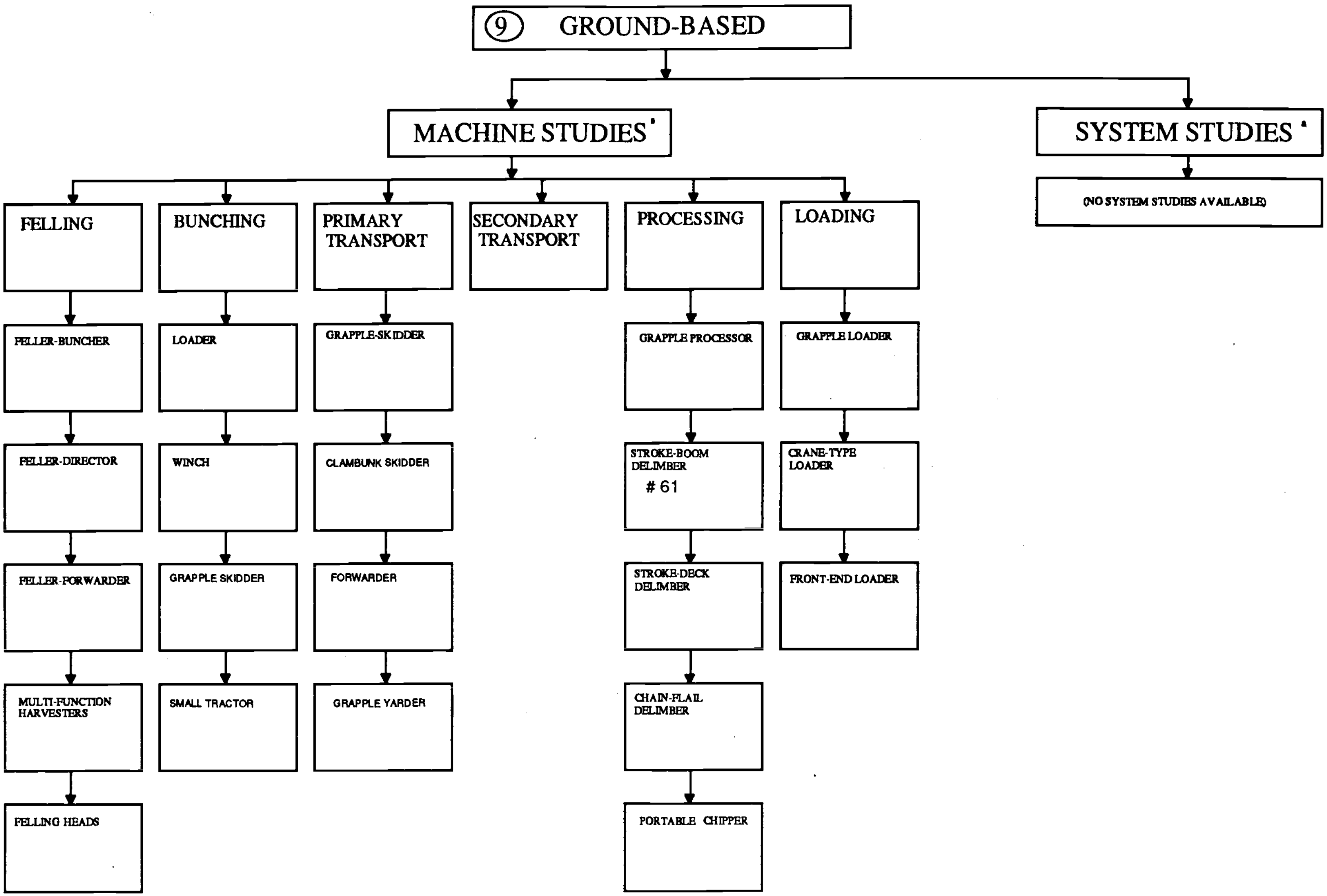

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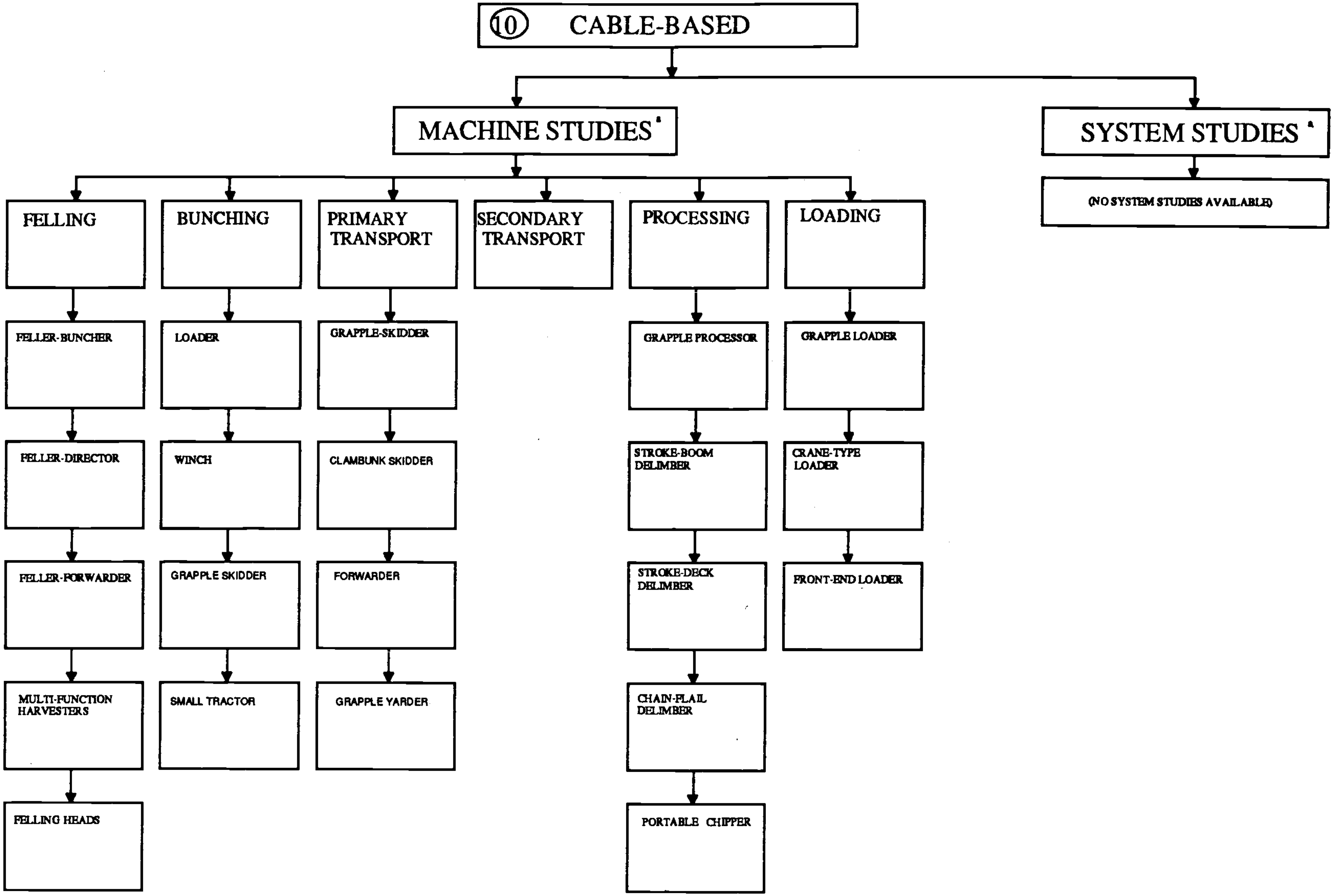

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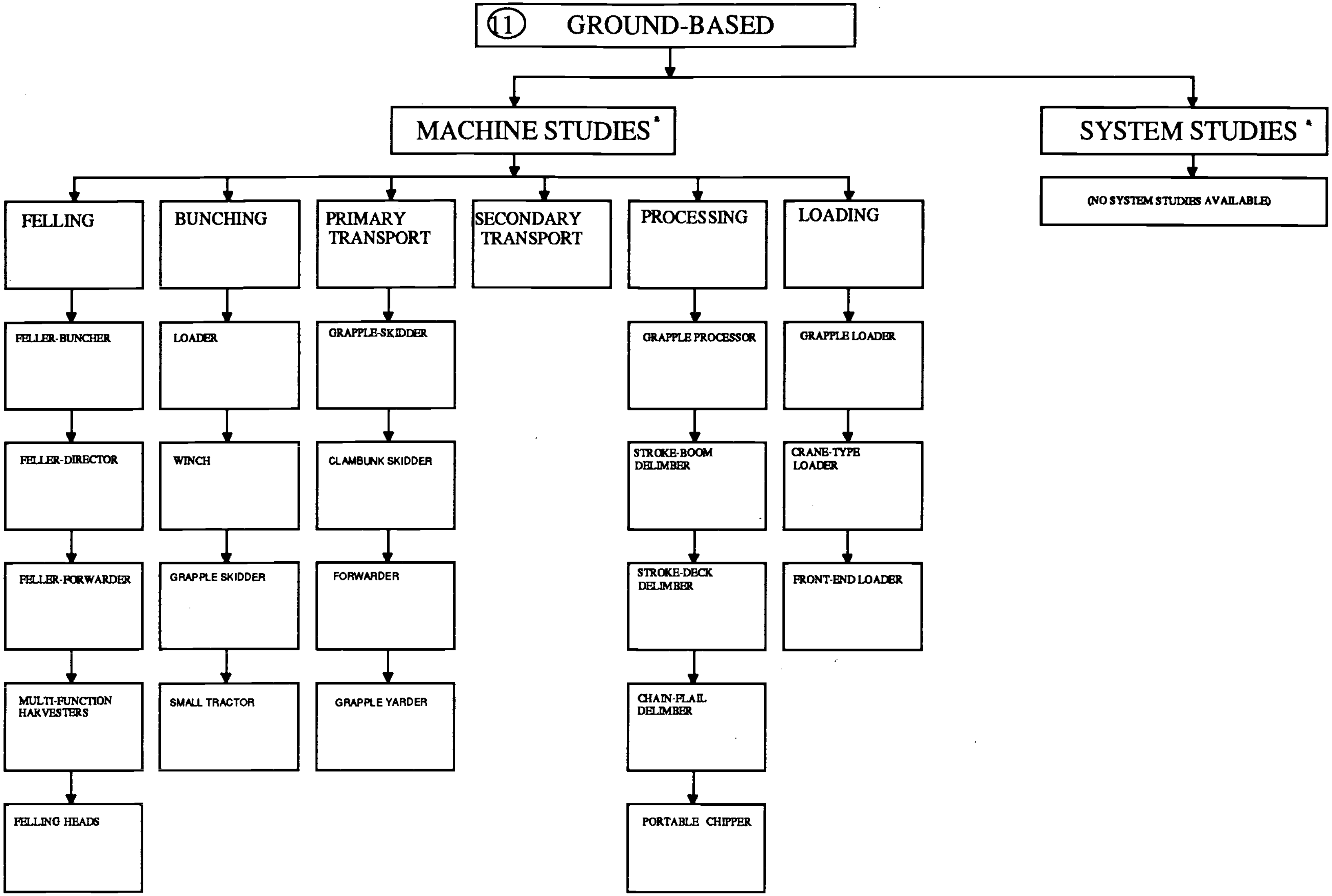

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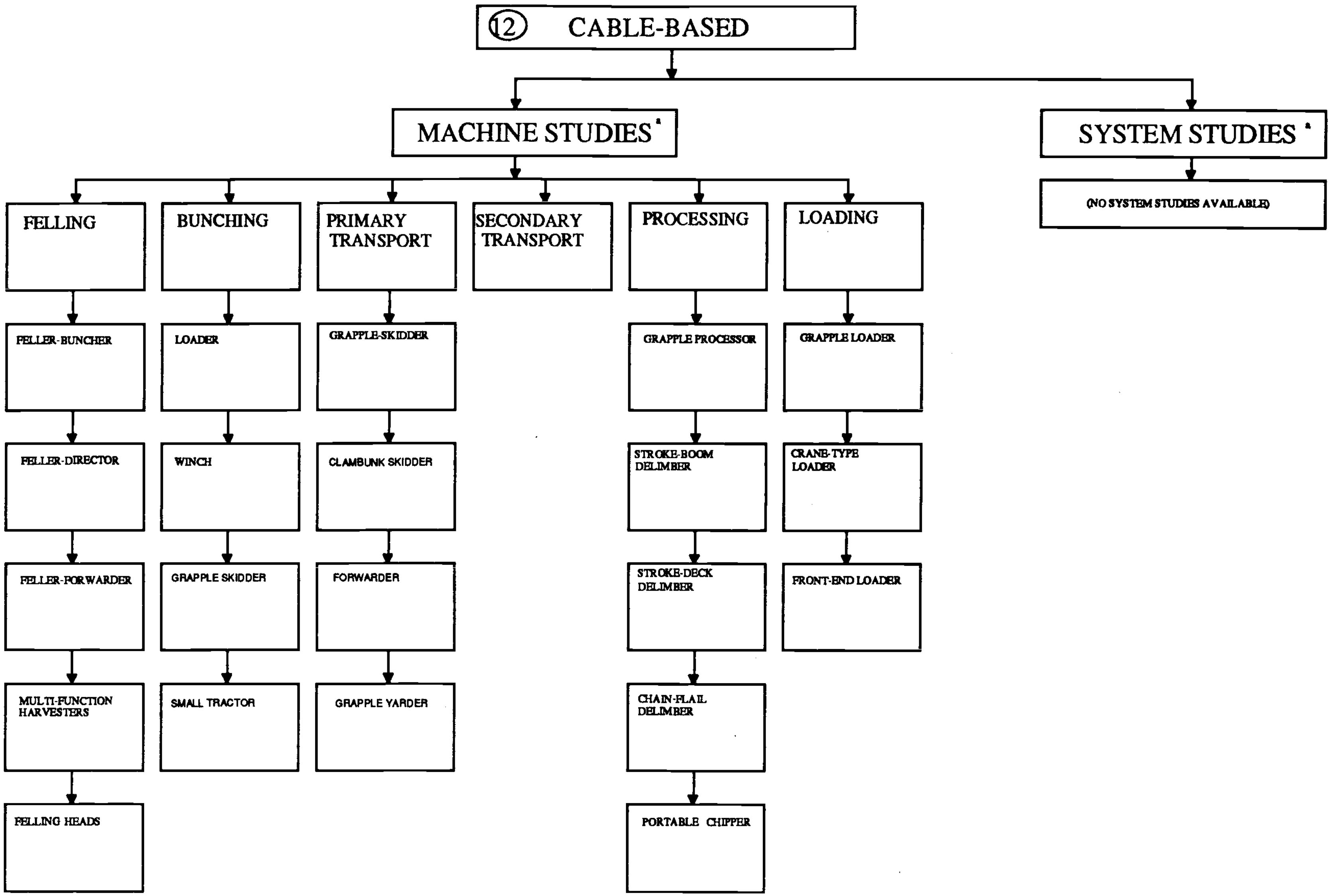

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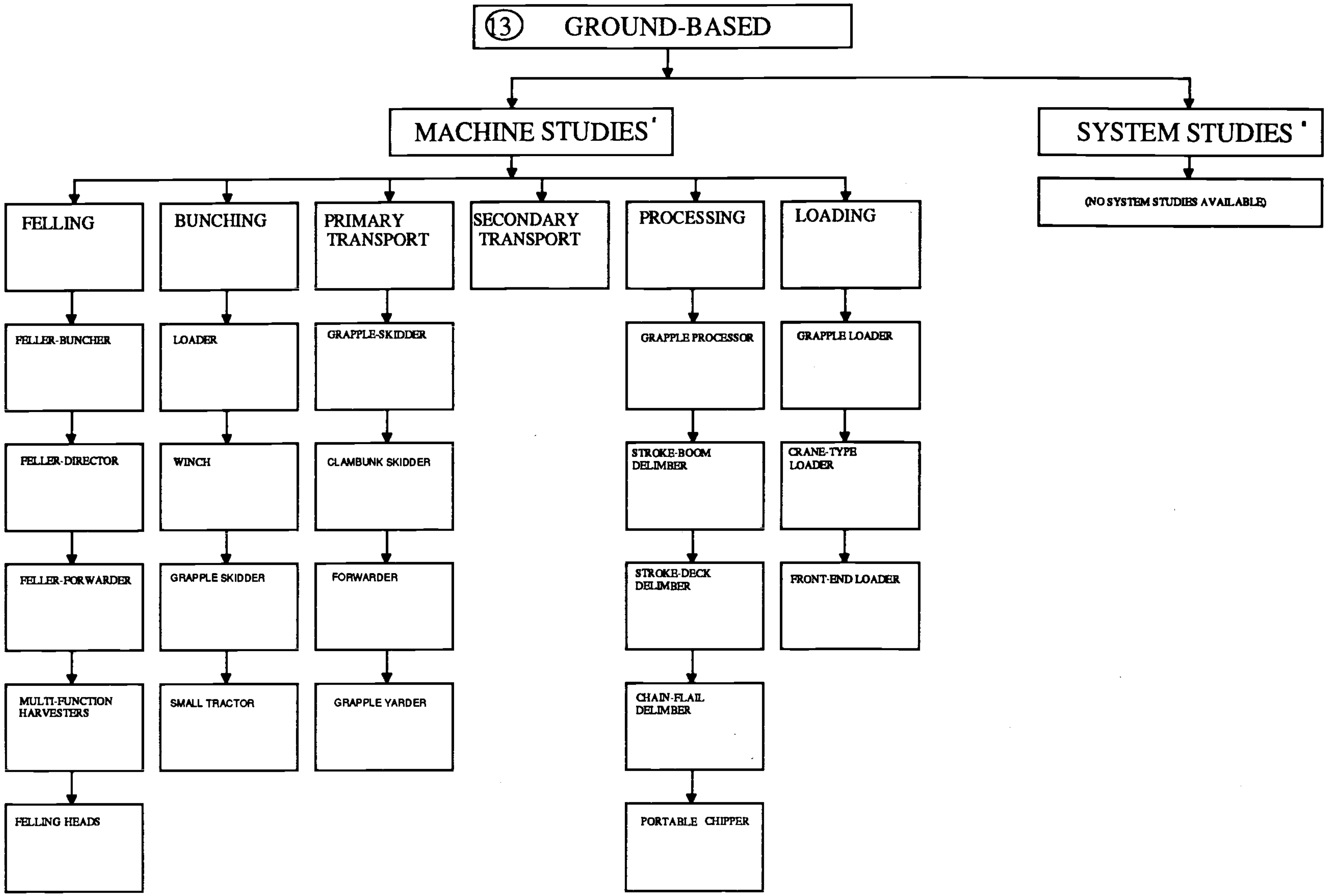

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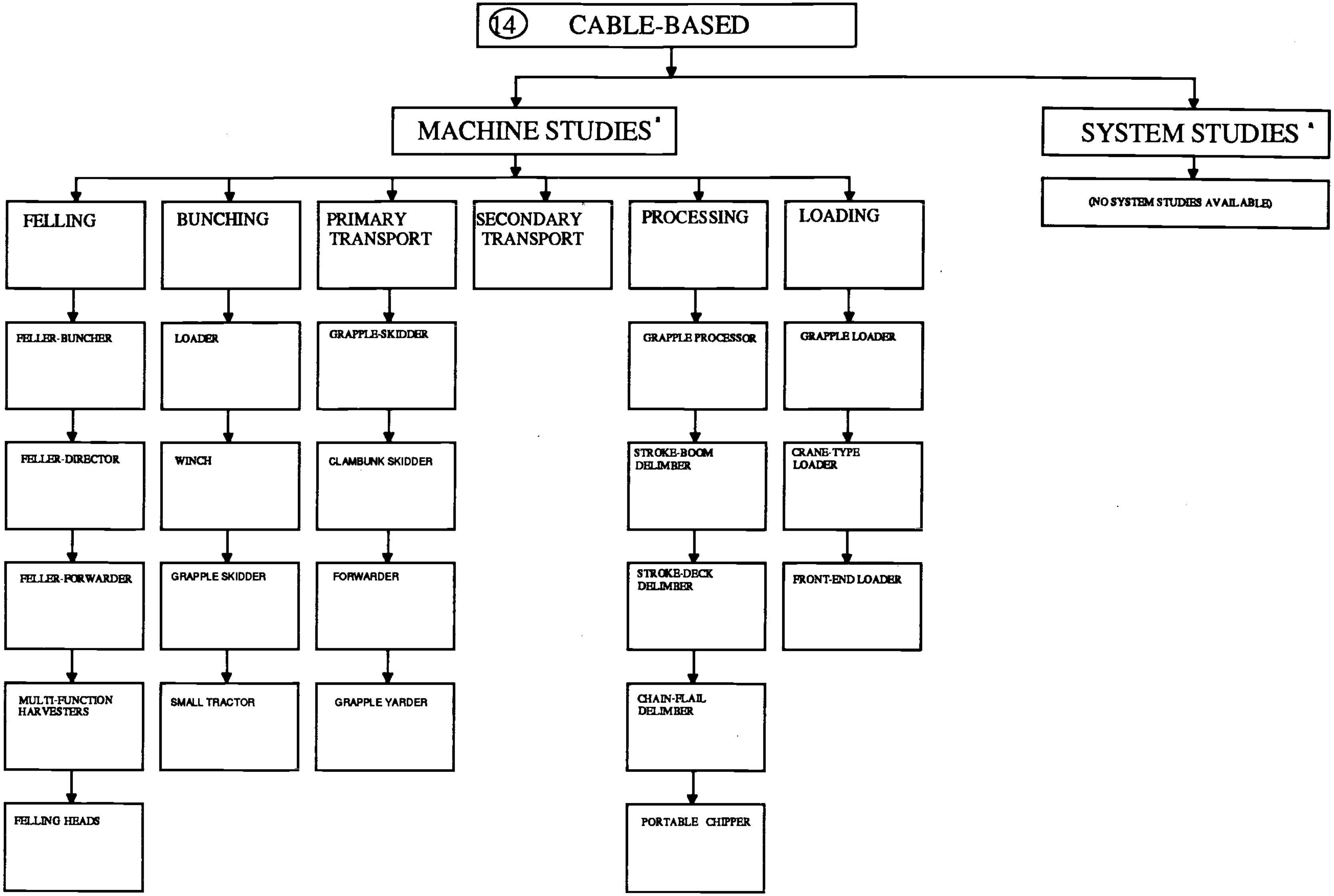

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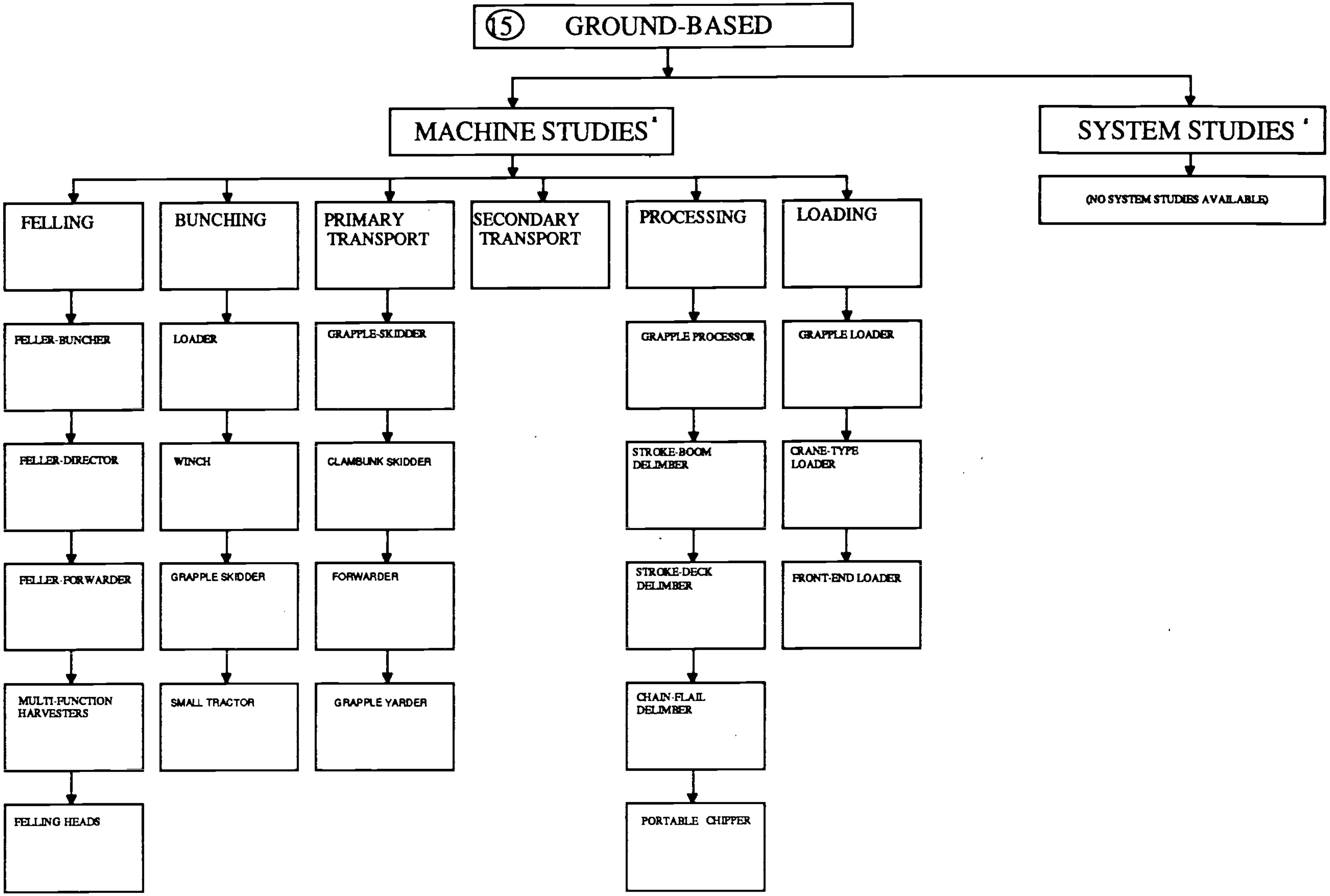

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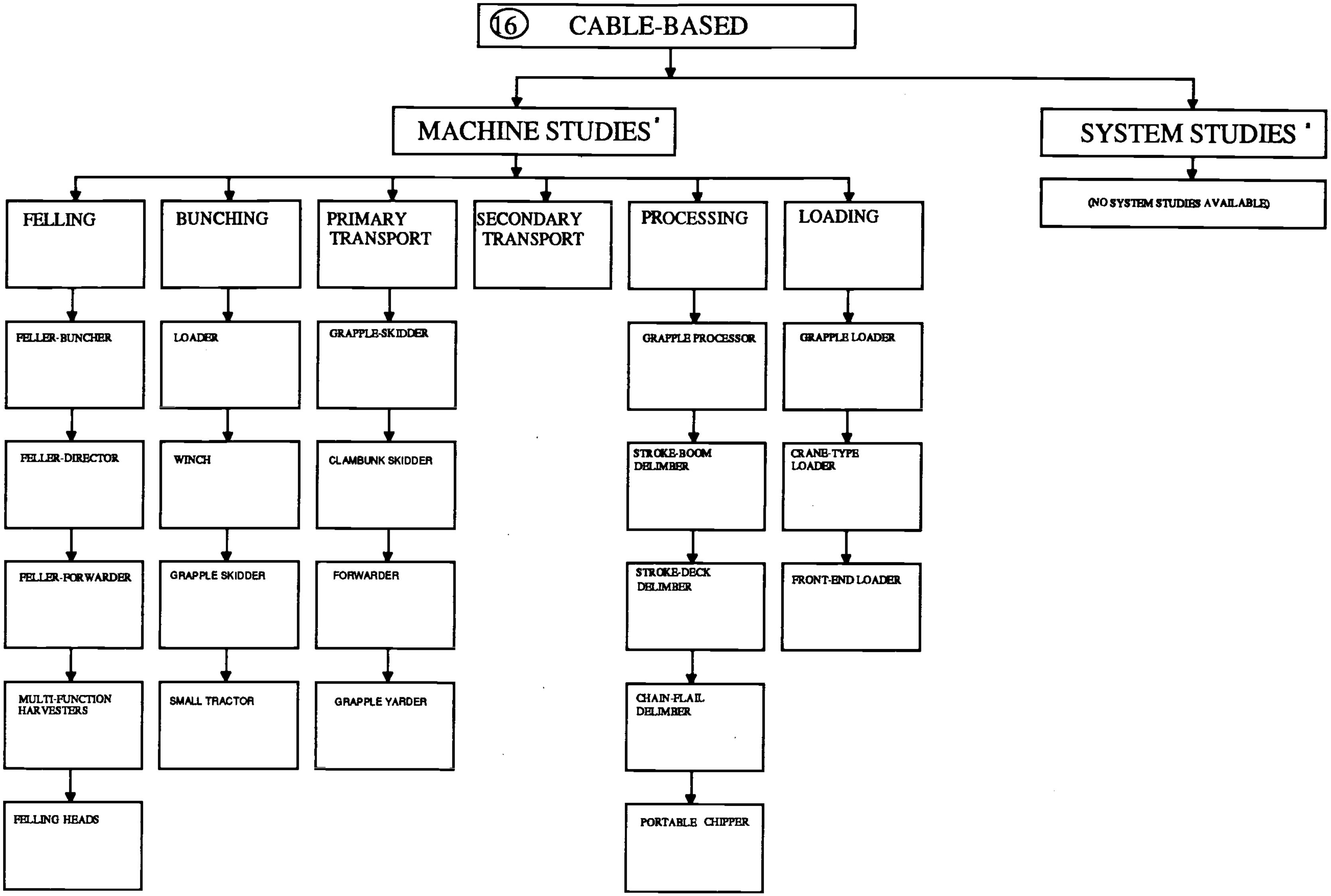

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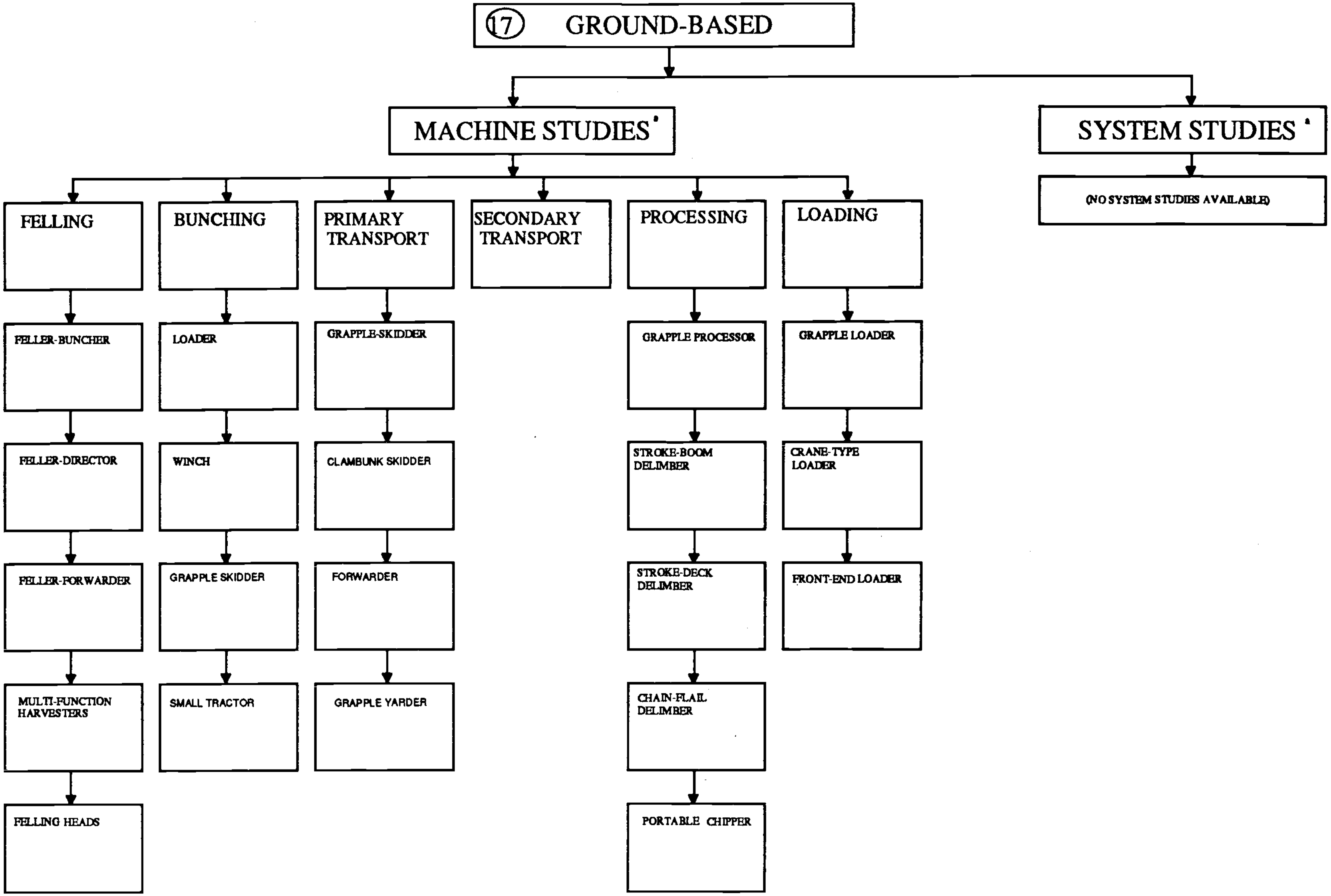

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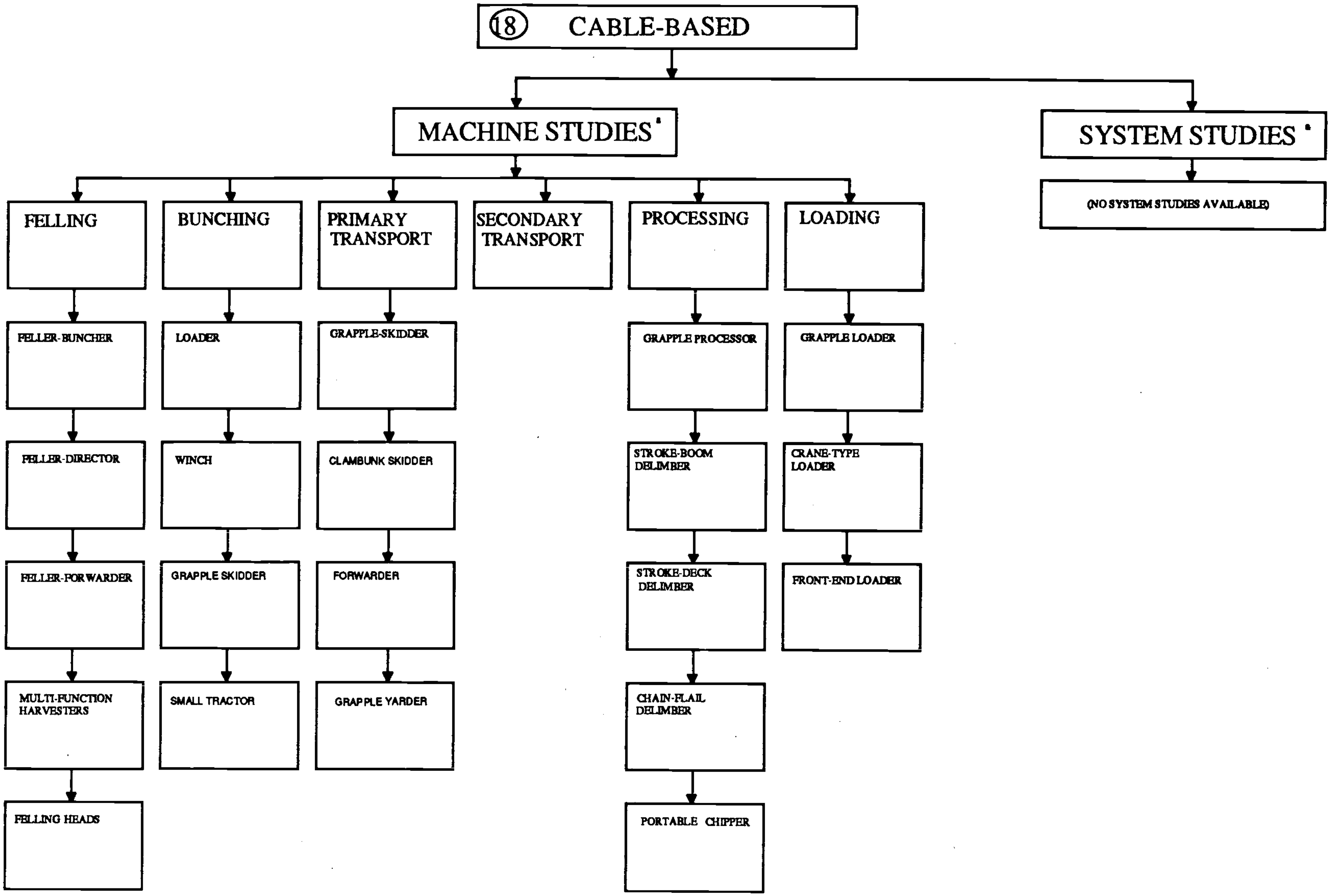

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HIERARCHY II: MECHANIZED HARVESTING IN PARTIAL CUTS

Citation Abstracts

CITATION: Raymond, K.A., Moore, T. 1986. MECHANIZED FELLING WITH A BELL LOGGER. Logging Industry Research Association, New Zealand. Vol. 11, No. 8, pp. 1-4.

MACHINE SYSTEM: Bell Logger 120, with the Hultdins F45 felling grapple and Trelleborg T 414 wide tires. Felling grapple is used for bunching as well.

OPERATOR RATING: The Bell operator had approximately 500 hours experience on the machine, and had adapted to the adverse stand conditions.

DESCRIPTION OF SYSTEM: The operation was a combined outrow and selective thinning. Bell felled and bunched stems. Trimmers delimbed and topped stems, and Tree Farmer C7T skidder extracted them to landing.

DESCRIPTION OF OPERATION: Machine was observed in normal operation over a 3.33 hour period. Also, in an attempt to estimate the potential productivity, a detailed work study was undertaken for 3 hours.

DESCRIPTION OF SITE: Rolling flat sandy country.

DESCRIPTION OF STAND: 16 - 18 years old unthinned radiata pine regeneration with total of 3,520 stems per hectare. Stocking and piece size were highly variable. 2,740 unmerchantable stems per hectare were removed with the Bell Logger prior to the thinning.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Average stocking (stems/ha)	405	Mean merchant. piece (m^3)	0.28
Average diameter (cm)	19.5	Volume range per piece (m^3)	0.22-0.43

PRODUCTION DATA:

1. WORK STUDY

Average felling and bunching (min/tree)	2.98
Shift duration (hours)	7.5
Average piece volume (m^3)	0.28
Production (m^3/day)	42.3
Delays (%/SMH)	13.0

2. WORK STUDY

Productivity (Stems/PMH)	59.4
Productivity (m^3/PMH)	16.3
Shift duration (productive hours)	6.5

Table 1 - Bell Logger felling and bunching work cycle

Element	Mean Time per Cycle (min)	% of Total Time
Travel/select	0.15	15
Move in	0.23	22
Fell	0.13	13
Remove hangup	0.08	8
Bunch	0.42	8
Total	1.01	100
(95% confidence interval	0.83 - 1.20 mins)	

OTHER COMMENTS: Major influences on productivity were soil and terrain conditions and operator skill. Operating on more stable soils would increase productivity.

CITATION: Hensel, J.S. 1973. CATERPILLAR MODEL 950 TREE HARVESTER. American Pulpwood Association. 73-R-33.

MACHINE/SYSTEM: Caterpillar Model 950 Tree Harvester. Shearing capacity at stump diameter = 18 inches. Caterpillar DGC grapple skidder. Caterpillar 960 log loader.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Delimbed near the bunching or piling area.
Tree harvester → Grapple skidder → Loader
Tree Harvester: sheared, delimbed, topped and bunched trees.

DESCRIPTION OF SITE: 73 miles southeast of Bend, Oregon.

DESCRIPTION OF STAND: Lodgepole pine.
Average DBH = 13 inches. Average height = 70 feet. Volume = 7 cords/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: Produced tree-length pulpwood.

PRODUCTION DATA:

Tree Harvester Production Data.

Operation Period	April 1973 - August 1973
Machine Availability (%)	73.8
Utilization (%)	84
Production per Operating Hour (cds/hr)	9.00

OTHER COMMENTS:

CITATION: Anon. 1978. TREE HARVESTER REAPS EFFICIENCY REWARDS. Australian Forest Industries Journal. December 1978. pp. 21-23.

MACHINE/SYSTEM: John Deere 743 Tree Harvester, equipped with a shear-type felling head.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: John Deere 743 tree harvester → Manual Bucking → Forwarder.

DESCRIPTION OF OPERATION: Thinning operation producing pulpwood. Harvester operates with two phases on each outrow, one of three selection rows is thinned on first pass, with the remainder thinned on the second pass. The tree-length material is then bucked manually and forwarded to the landing.

DESCRIPTION OF SITE: S.E. South Australia.

DESCRIPTION OF STAND: Radiata pine stand. Average tree contained 0.156 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Harvester Productivity

Average Tree Volume (m^3)	Productivity (m^3)/PEMH*
0.1335	10
0.1410	11
0.1710	13
0.1860	14
0.2010	15
0.2160	16

*PEMH = Per Effective Machine Hour.

OTHER COMMENTS:

CITATION: Greene, N.D. and Piedrahita, M. 1986. COST AND PRODUCTIVITY OF THE BARKO 775 FELLER-BUNCHER. Transactions of the ASAE. ASAE paper No. 86-1618.

MACHINE/SYSTEM: (2) Barko 775 feller-bunchers with S1 CM Barko Accumulating Head.

OPERATOR RATING: Study A: 6 months experience. Study B: 1 year experience.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Partial cut for both operations. Only the feller-bunchers were studied.

DESCRIPTION OF SITE:
Study A: Piedmont of Georgia Slopes less than 15%.
Study B: Piedmont of Georgia. Terrain was rolling with slopes ranging from 20-25%.

DESCRIPTION OF STAND: Loblolly pine plantation.
Study A: Average volume/hectare = 327 m^3; Average trees/hectare = 573.
Study B: Average volume/hectare = 226 m^3; Average trees/hectare = 815.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Study A: Average tree was 27.4 cm DBH (SD: 9.1 cm), 22.6 m tall (SD: 4.6 m) and contained 0.58 m^3 (SD: 0.427 m^3).
Study B: Average tree was 21.1 cm in DBH (SD: 7.37 cm), 18.3 m tall (SD: 3.17 m) and contained 31 m^3 (SD: 0.26 m^3).

PRODUCTION DATA: Data was Combined.

Total Time Per Tree:

$$TPT = 0.4712 + 0.005975\,(DBH) - 0.09773\,(TPAC) \qquad [R^2 = 0.25]$$

Where: TPT = Total time/tree (min.)
DBH = Diameter breast height (cm)
TPAC = Trees accumulated per cycle (1,2 or 3)

Time Distribution:

Move to tree	49.4%
Shear	10.6%
Move to dump	28.6%
Dump	9.4%
Bunch Maint.	2%

Productivity
Averaged 27.33 m^3/PMH.

OTHER COMMENTS: Machine productivity was most affected by the number of trees harvested per acre.

CITATION: Johnson, L.R. 1988. SUMMARY OF PRODUCTION AND TIME STUDIES OF MECHANIZED HARVESTING EQUIPMENT IN THE INTERMOUNTAIN WEST. Forest Products Department, University of Idaho. (Unpublished)

MACHINE/SYSTEM: Timbco 2520 feller-buncher with 20" Rotosaw felling head.

OPERATOR RATING: Skilled.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Overstory removal.

DESCRIPTION OF SITE: Gentle terrain, slopes averaged 7%.

DESCRIPTION OF STAND: Average diameter: 11.18 inches SD: 3.54 inches.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Diameter Distribution

Inches	Freq.	Inches	Freq.	Inches	Freq.	Inches	Freq.	Inches	Freq.
4	4	8	110	12	167	16	28	20	11
5	32	9	128	13	76	17	23	21	5
6	34	10	156	14	56	18	15	22	10
7	55	11	139	15	46	19	8	23	6
								24	8

PRODUCTION DATA: (Sample size = 1,117 trees)

Time Distribution

Swing & Move	37.6%
Saw & Bunch	35.6%
Extra Move	11.5%
Delay	15.3%
	100%

Production Statistics	Avg.	SD
Trees/productive Hour	99.1	-----
Trees/Sched. Hour	84.0	-----
Pieces/Turn	1.013	0.112
Pieces/Cycle	4.34	3.108
Distance Moved	17.46	13.86
Avg. Diameter	11.18	3.54
Utilization (%)	84.7	-----

Regression Equation

Trees PMH = 109.9 - 4.45 (move distance) + 0.596 (move distance)^2/pieces turn + 19.44 Exp (pieces/turn) - 24.41 (sum of end area)/(pieces/turn)
[$R^2 = 0.29$]

OTHER COMMENTS:

Cycle = felling + bunching activity at a single location.
Turn = felling + bunching activity.

CITATION: Spahr, M. 1981. MAKERI FELLER-BUNCHER - AN EVALUATION OF PERFORMANCE IN WHOLE TREE THINNING. Department of Operational Efficiency, College of Forestry, Garpenberg, Sweden.

MACHINE/SYSTEM: Makeri feller-buncher.

OPERATOR RATING: 6 Months of experience.

DESCRIPTION OF SYSTEM: Feller-buncher → Forwarder

DESCRIPTION OF OPERATION: A low thinning with narrow corridors spaced on 34-56 meter centers. The feller-buncher felled and bunched timber, placing the butts near the edge of the corridor. Then, a forwarder hauled the stems to the landing.

DESCRIPTION OF SITE: There were 2 sites in Sweden - one was in Dalarna Province, the other was in Alvdalen Parish. The sites were described as wet and sandy with the slopes averaging 19%.

DESCRIPTION OF STAND: There were 825 trees per acre, with the average tree being 5 inches in diameter and 41 feet tall. Volume, was estimated to be 19 cunits per acre. The species mix consisted of 60% pine and 40% spruce.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: The average tree harvested was 4.1 inches in diameter and 34 feet tall.

PRODUCTION DATA:

Time Distribution:	
Travel Empty (%)	26
Position & Shear (%)	30.6
Travel to next tree (%)	11.9
Return loaded/unloaded (%)	31.5

Regression Equation:

$T = 25.0 + 40.0\,Tct + 5.2\,Td$ $[R^2=0.62]$

T = Time per cycle, cmin.

Tct = Total trees cut per cycle

Td = Average distance traveled per cycle

Production Statistics:	
Total Time per cycle (cmin.)	149.2
Avg. trees/cycle	2.04
Avg. DBH/cycle (in.)	4.25
Avg. distance/cycle (ft)	26 (range: 0 - 97.5 ft)
Avg. production/PMH (cunits)	1.3 (range: 0.63 - 2.3 cunits)
Sample size (trees)	811

OTHER COMMENTS:

CITATION: Schroerin, J.D., Lanford, B.L. and B.J. Stokes. 1985. FRANKLIN 105 FELLER-BUNCHER: FIFTH ROW THINNING APPLICATIONS. Southern Journal of Applied Forestry. 9(2):110-113.

MACHINE/SYSTEM: Frankling 105 feller-buncher with a Tidewater DL-12 accumulating shear.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: A combination of row harvesting and selective thinning. For part of the study, every fifth row was removed with selective thinning performed on the 4 adjoining rows. For the remainder of the study a 15 foot wide corridor was cut and followed by selective thinning on each side for 25 feet.

DESCRIPTION OF SITE: Upper coastal plain. Slopes ranged from 0 to 6%, with brush conditions classified as moderately heavy.

DESCRIPTION OF STAND: 18 year old loblolly pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

	DBH		Trees/Acre		
	Avg.	Range	Avg.	Range	Vol/Acre
Initial Stand	6.1"	2.5-13.0	675	590-840	36.1 cords*
Harvested Stand	5.6"	2.5-9.5	399	250-540	17.3 cords*
Residual Stand	4.8"	2.5-13.0	276	180-380	18.8 cords

PRODUCTION DATA:

Cycle time per tree (min.) = 0.34 + 0.00034 (RTA*SELECT) - 0.018 (XDBH) + 0.00520 ($XDBH^2$*1/TS)

Where: RTA = Residual trees/acre
XDBH = Avg. DBH of trees in the accumulation prior to dumping
$XDBH^2$ = square of XDBH
TS = the number of trees in the accumulation prior to dumping
Select 0 for row/corridor, 1 for selective

Feller-Buncher Accumulation Statistics

Variable	N	Avg.	SD	Range
(Row Corridor Harvesting)				
Trees/Accumulation	25	4	1.51	1-7
DBH (inches)	25	6.1	0.91	4.7-7.8
(Selective Thinning)				
Trees/Accumulation	46	4.3	1.58	1-8
DBH (inches)	46	5.5	0.78	4.3-7.3

OTHER COMMENTS: 49 residual trees per acre were damaged. 56% of these were adjacent to the access corridor.

CITATION: Ashmore, C., Stokes, B.J. and B.L. Lanford. 1983. THINNING PERFORMANCE OF THE HYDRO-AX 411 IN FIFTH-ROW REMOVAL. Transactions of the ASAE. ASAE Paper No. 83-1604.

MACHINE/SYSTEM: (3) Hydro-Ax 411's with 16 inch high speed felling and bunching heads.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: During the study only corridor trees in a row-select thinning operation were removed.

DESCRIPTION OF SITE: 2 sites were in N. Carolina; one site was in Mississippi. Slopes were zero percent. Visibility was less than one chain because of brush.

DESCRIPTION OF STAND: Loblolly pine plantation containing an average of 627 trees per acre. The average tree harvested was 5.3 inches DBH (ranging from 1.2-13.6" DBH), 42.2 feet tall (ranging from 19.1 to 55.5 feet) and contained 2.53 ft^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Sample size 869 trees, 197 cycles

Element	Avg.	SD	Production Statistics
Move to Tree	0.089 min.	0.116 min.	Avg. trees/cycle = 4.4 (Range 1-12)
Position & Shear	0.062 min.	0.030 min.	Avg. trees/PMH = 218
Move to Dump	0.074 min.	0.074 min.	Avg. production/PMH = 551.5 ft^3
Dump	0.049 min.	0.049 min.	
Cycle Time	0.2750 min.		

OTHER COMMENTS:

CITATION: Anon. 1976. CLARK BOBCAT FELLER BUNCHER. Machinery Evaluation. Logging Industry Research Association, New Zealand. Vol. 1, No. 2.

MACHINE/SYSTEM: Clark Bobcat 1075 feller-buncher equipped with 38 cm shear.

OPERATOR RATING: Inexperienced.

DESCRIPTION OF SYSTEM:
Feller-Buncher → Manual Limbing → Grapple Skidder

DESCRIPTION OF OPERATION: Thinning. Feller-buncher felled and bunched trees from the access corridor in a herringbone pattern, then thinned selectively in between the rows. The access corridors were 5-6 meters wide and spaced on 16-20 meter centers. Average bunch size 4-5 stems.

DESCRIPTION OF SITE: Tarawera Forest, New Zealand. Soils were loose, with slopes ranging from 2 to 7 degrees.

DESCRIPTION OF STAND:
Stand 1: 13 year old radiata pine.
Stand 2: 9 year old radiata pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Stand	1	2
Average Ht. (m)	21.3	12.8
Average Butt Diam. (cm)	24.6	17.0
Average Volume (m^3)	0.26	0.07

PRODUCTION DATA:
Production Summary (short duration study)

Stand	1	2
Cycle Time (min/tree):		
Shear	0.15	0.19
Bunch	0.13	0.22
Reposition	0.10	0.18
Stems/PMH	158	101
Utilization (%)	- 82 -	

OTHER COMMENTS: Machine is most productive on slopes less than 9%.

CITATION: Tufts, D.M. 1976. EFFECT OF TREE SIZE ON FELLING AND BUNCHING WITH ROME INDUSTRIES' ACCUMULATOR SHEAR. American Pulpwood Association. 77-R-4.

MACHINE/SYSTEM: Rome Industries' Accumulator Shear mounted on a John Deere 544B carrier shear capacity = 20 in.

OPERATOR RATING: The operator of the feller-buncher had several months experience and was considered to be a good operator.

DESCRIPTION OF SYSTEM: Feller-Buncher → Skidders → Chipper or Pole Trailer.

DESCRIPTION OF OPERATION: Thinning. The feller-buncher cut the main skid roads and corridors, laying the trees in a 0.75 cord pile for the grapple skidder. The bunches were skidded to a whole tree chipper. If the timber was larger, it was loaded directly on a pole truck.

DESCRIPTION OF SITE: Central Louisiana, level terrain.

DESCRIPTION OF STAND: A 16-year old direct-seeded pine plantation. Most of the trees below 7 inches in diameter.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average volume per pile by feller-buncher = 0.75 cords.
Average shear load = 0.165 cords.

PRODUCTION DATA:

<u>Timing Summary</u>	
No. of trees timed	202
No. of cycles	52
Total time (hours)	1.1417
Total volume (cords)	8.577
Productivity (cords/hr)	7.51
<u>Time (seconds)</u>	
Travel time/cycle	14.4
Dump time/cycle	12.1
Delays/cycle	3.5

OTHER COMMENTS: Feller-buncher drove over the tree piles, this tended to knock off some of the limbs, which in turn lowered the twig and needle content in the chips. Most of the delay time consisted of backing up to the beginning of the next row.

CITATION: Kluender, R.A. 1977. NEW GENERATION OF TJ-30 HARVESTER OPERATED IN LOUISIANA. American Pulpwood Association. 77-R-29.

MACHINE/SYSTEM: Timberjack TJ-30 Harvester. An improved production version. Modifications: one piece felling boom, and improved guarding. Maximum shear capacity = 13 inch. Maximum delimbing length = 42 feet.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Felled and processed the trees into the hinged wood bunk. When the bunk is full (3/4 to 1 cord approx.) it dumps the load into a pre-bunched file.

DESCRIPTION OF OPERATION: Thinning. The machine felled and then processed the trees into the hinged bunk. When the bunk was full, it dropped the load into a pile.

DESCRIPTION OF SITE: Flatwoods. Louisiana.

DESCRIPTION OF STAND:

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Time Data

DBH O.B. (in.)	Total Time (Sec.)	Cords/Hour
3	27.00	1.20
4	29.57	2.43
5	32.10	3.36
6	34.94	4.84
7	37.94	6.45
8	41.08	8.06
9	44.24	9.60
10	47.47	10.92

Time Breakdown by Function	
Travel (%)	3.9
Felling (%)	30.8
Limbing (%)	41.6
Dumping (%)	4.7
Straightening (%)	1.9
Delay (%)	17.1

OTHER COMMENTS:

CITATION: Lanford, B.L. 1981. PERFORMANCE OF THE TJ30 IN ROW THINNING. *IN* Proceedings: "Harvesting Small Timber: Waste Not, Want Not." Forest Products Research Society. Portland, OR. April 28-30, 1981. pp. 63-71.

MACHINE SYSTEM: Timberjack Model TJ30 feller-buncher (Production model). Modifications include a Hydrostatic transmission. Timberjack model RW30 feller-buncher had been modified to a TJ30 feller-buncher. Cutting capacity was 14 inches for both machines. The grapple skidder had 90 horsepower.

OPERATOR RATING: The operator had several years of experience on the RW30, but only one month experience on the TJ30.

DESCRIPTION OF SYSTEM: After severing, the full trees were accumulated in a wood bunk until the desired load size was reached. The load was then dumped off the side of the machine. The bunches were then delimbed with a delimbing gate and a grapple skidder.

DESCRIPTION OF OPERATION: Thinning. Three selection methods were used: 1) row cut only, 2) select from one adjacent row only, and 3) select from both adjacent rows.

DESCRIPTION OF SITE: Autauga and Sumter counties, Central Alabama. Slopes less than 5% and firm ground conditions.

DESCRIPTION OF STAND: Natural loblolly stand approximately 20 to 25 years of age. The other stand was a 22 year old loblolly pine plantation.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Study Period: Summer 1980

Productive Time and Stand Summaries - TJ30

Item	N	Mean	Range
Move, Shear & Accumulate Time/tree (seconds)	307	26.2	2.1-226.6
DBH (inches)	307	6.1	2.0-14.0
Dump time/Bunch (seconds)	26	27.2	15.9-91.3
Maximum Load Size (Ft^3 inside bark)	26	54.2	14.5-134.6
Tree/acre	26	40.3	153-984
Basal area/ acre (Ft^2)	26	89	23-191
Volume/acre (cunit)	26	17.9	4.3-40.0

Move, Shear and Accumulate Time per Tree, Seconds (MSA) - TJ30

$MSA = B_1 X_1 + B_2 X_2$

Where $X_1 = 1$

$X_2 = 100 \times (TPA)^{-\frac{1}{2}}$ IF DBH $\leq$ 10 inches or

$= (DBH)^2 \times (TPA)^{-\frac{1}{2}}$ IF DBH > 10 inches

$B_1 = -5.57$ AND

$B_2 = 5.77607$ with R^2(Uncorrected) $= 0.68$

TPA = Trees per acre

MSA = TJ 30 and RW 30

$MSA = B_1X_1 + B_2X_3$

Where X_3 = 100 IF DBH $\leq$ 10 inches or
= DBH x DBH IF DBH > 10 inches

OTHER COMMENTS: Very short trees would not reach the rear support on the TJ30. The larger bunk of the TJ30 had more problems maneuvering in the young stand without damaging residual trees.

CITATION: Folkema, M.P. 1977. THE KOEHRING FELLER-FORWARDER: 6 MONTHS OF DATA COLLECTION FROM TWO SOFTWOOD OPERATIONS. FERIC. Technical Note No. TN-15.

MACHINE/SYSTEM: Koehring Feller-Forwarder (First Production Model).

OPERATOR RATING: Both of the operators had only 1 month of experience at the start of the study.

DESCRIPTION OF SYSTEM: Feller-Forwarder → Processor

DESCRIPTION OF OPERATION: Clear cut, full tree operation. Average forwarding distance was 580 ft. The full trees were dumped at roadside and were delimbed with a trimming head mounted on a Drott 40 tracked carrier.

DESCRIPTION OF SITE: Mantouwadge, Ontario. Terrain in the harvesting area varied from gentle slope to some broken areas and some swampy areas.

DESCRIPTION OF STAND: Averaged 250 merchantable softwood tree/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree volume = 5.9 Ft^3.

PRODUCTION DATA: Study Period: December 1976 to June 1977.

Time Distribution % of Total Time	
Productive (PMH) (%)	55.4
Repair & Maint. (%)	35.3
Non-Product. (%)	2.7
Delays (%)	6.4

Breakdown Information	
Total No. of Repairs	175
Mean Time to Repair (hr)	1.9
Mean Time Between Repairs (hr) (based on PMH)	6.1

Productivity of KFF (First Production Model) Machine and Operations	
Mechanical availability (%)	68
Utilization (%)	57
Total Time Utilization (%)	55
Avg. Forwarding Distance (ft)	580

Production	
Trees/cunit	17
Trees/PMH	110
Productivity (m^3/PMH)	6.5
Productive per shift (cunits) (8 Hr. x Util. x Ct/PMH)	29.6

OTHER COMMENTS:

CITATION: Legault, R. 1976. EVALUATION OF KOEHRING FELLER-FORWARDER, MODEL KFF. FERIC. Technical Report No. TR-7.

MACHINE/SYSTEM: Koehring feller-forwarder model KFF (A preproduction model). Basic chassis is similar to that of Koehring short-wood harvester but is 12 feet longer. 24 inch multiple tree shear. Logma T-310 limber-bunchers.

OPERATOR RATING: Both operators had approximately 1 month experience.

DESCRIPTION OF SYSTEM:
Feller-Forwarder → Limber-bunchers

DESCRIPTION OF OPERATION: Overstory cut. The operator usually began to cut a strip at the landing and built up the load as he moved away from the landing. The trees were then unloaded in the center of the landing where they were delimbed by the Logma Delimber.

DESCRIPTION OF SITE: Millinocket, Maine. Slope: negligible. Snow depth = 18 in.

DESCRIPTION OF STAND: 65% fir and 35% spruce. DBH in stand = 6.8 in.
Merchantable trees per acre = 860.
Merchantable volume in stand = 50 cunits/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
DBH Harvested = 8.9 inches.
Volume per harvested tree = 9.2 Ft^3.
Mill regulations: The operator could fell only trees whose diameter exceed 5 inches at 20 feet above the ground.

PRODUCTION DATA: Study Period: February 1976.

Production of KFF	
Average forwarding distance (ft)	400
Trees per load	75
Volume per load (Ft^3)	690
Average collection time (min/tree)	0.65
Total time per turn (min)	52.6
Productivity - trees/PMH	92
- cunits/PMH	7.9

Sample size = 268

Equation (Times per trees)

Felling & Loading:
$FL = 42.0 - 7.2\ NT_3 + 1.2\ VT - 11.20\ PN$ [$R^2 = 0.33$]

Collection Time Per Tree:
$CT = 70 - 7.2\ NT_2 - 14.6\ NT_3 + 1.2\ VT - 20.6\ OPN$ [$R^2 = 0.43$]

Where
NT_2 = 1 when two trees are accumulated, otherwise = 0
NT_3 = 1 when three trees are accumulated, otherwise = 0
VT = Volume per tree, Ft^3
OPN = 1 for fast operator, otherwise = 0

Summary of Times/Tree	% of Total Time	Cmin/ Tree
Moving in stand	21	13
Felling & Loading	65	43
Brushing	8	5
Delays	6	4
Collection Time/Tree, (CT)	100	65

OTHER COMMENTS: During 40% of the study period, the operator used the accumulator on the felling head to harvest more than one tree.

Equations of times per turn
Time in cut (min):
TCT = -1.17 + 0.58 TPL [$R^2 = 0.75$]

Total terminal time (min):
TT = 0.52 + 0.60 TPL [$R^2 = 0.77$]

Where TPL = Tree per Load
Sample size = 12 turns

CITATION: Folkema, M.P. 1977. THE KOEHRING FELLER - FORWARDER: 6 MONTHS OF DATA COLLECTION FROM TWO SOFTWOOD OPERATIONS. FERIC. Technical Note No. TN-15.

MACHINE SYSTEM: Koehring feller-forwarder, a pre-production model.

OPERATOR RATING: Both of the operators had 10 months of experience on the KFF at the start of the study.

DESCRIPTION OF SYSTEM:
Feller-Forwarder → Delimber

DESCRIPTION OF OPERATION: Clearcutting, full tree operation. The KFF harvested strips 20 chains long, with an average forwarding distance of 660 feet. The full trees were dumped at roadside and delimbed by a LOGMA T-310.

DESCRIPTION OF SITE: Millinocket, Maine. Cutting area was flat to gently rolling with occasional lowland areas.

DESCRIPTION OF STAND: Uniform softwood stands contained 600 undersize, unmerchantable stems/acre. The stands averaged 250 to 300 merchantable softwood trees/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average volume/tree = 6.7 Ft^3.

PRODUCTION DATA: Study Period: October 1976 to April 1977

Time Distribution % of Total Time	
Productive (PMH) (%)	50.9
Repair & Maintenance (%)	31.1
Non-productive (%)	4.1
Delays (%)	13.8

Breakdown Information	
Total No. of repairs	169
Mean time to repair (hr)	2.3
Mean time between repairs (based on PMH) (hr)	5.8

Productivity of KFF (Pre-production model)	
Machine and Operations	
Mechanical Availability (%)	66
Utilization (%)	51
Production	
Trees/cunit	15
Trees/PMH	101
Productivity (cunit/PMH)	6.6
Production/shift (cunits) (8 hr. x UTIL. x CT/PMH)	26.9

OTHER COMMENTS:

CITATION: Ansley, J.R. 1981. HITACHI FELLER BUNCHER TRIAL. Logging Industry Research Association, New Zealand. Vol. 3, No. 3, pp. 1-4.

MACHINE SYSTEM: Hiatachi UH04 excavator modified with a Waratah felling and delimbing head.

OPERATOR RATING: Experienced, but unfamiliar with the system.

DESCRIPTION OF SYSTEM: In the shortwood operations, the logs were extracted with skidders or forwarders. In the log-length operations the logs were extracted with agricultural tractors.

DESCRIPTION OF OPERATION: Fifth row outrow thinnings. Prior to felling, every tree was delimbed to a 7 meter height.

DESCRIPTION OF SITE: Gentle land, bisected by small gullies.

DESCRIPTION OF STAND: Heavy blackberry undergrowth. 12 year old radiata pine stand. Stocking = 1,100-1,200 stems/ha.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
No. of measured trees = 52. Avg. DBH = 20.3 cm. Avg. Merch. Vol. = 0.23 m^3.
Delimbed length = 6.68 m (range: 2.3 - 8.95 m).
Not delimbed length = 3.56 m (range: 0.23 - 8.6 m).
Delimbed Volume: 79% of the total volume.

PRODUCTION DATA:
Average production: 12.6 tons/hour
Average short pulp production: 5.5 tons/hour

<u>Production Cycle</u>	
Reach (min.)	0.24
Delimb and Shear (min.)	0.29
Lay Stem (min.)	0.39
Move, Clear Ground (min.)	0.10
Total time per tree (min.)	1.02

OTHER COMMENTS: The machine works effectively on gentle slopes. It caused little damage to the residual crop. This system can greatly increase the productivity of normal thinning operations.

CITATION: Jackson, B.D., Hackfield, M.C., and Jenkins, M.W. 1984. USING A MAKERI HARVESTER TO THIN A NATURAL LOBLOLLY PINE STAND FOR THE FIRST TIME. Southern Journal of Applied Forestry. 8(3):132-135.

MACHINE SYSTEM: Makeri Harvester with "wet site" track design.

OPERATOR RATING: 6 months of experience.

DESCRIPTION OF SYSTEM:
Makeri Harvester → Forwarder

DESCRIPTION OF OPERATION: A combination of row and selection thinning. Corridors were 10 feet wide, and on 60 foot centers. Residual basal area was 62 ft^2. Trees were cut and moved to stacks where they were processed into 5.25 foot pulpwood bolts. The stacks were than gathered and moved to a central area by a forwarder.

DESCRIPTION OF SITE: Winter, Louisiana. Terrain was level and wet, with little brush.

DESCRIPTION OF STAND: A 14 year old natural stand of loblolly pine, containing 835 trees per acre. Average DBH = 5.1 inches, and 7.1 inches on DGL. Basal area = 112 ft^2/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average volume per tree cut and processed = 2.05 Ft^3 OB.
Average of 5 trees per stack, and 83 stacks/acre.

PRODUCTION DATA:
Utilization = 73% (excluding cut and leave activities)
Productivity/Sched. hour = 45.9 trees/hour (88.1 Ft^3/hour)
Productivity/Productive hour = 62.8 trees/hour
Average cycle time (ACT) = 0.955 min./tree (not including delays, ect.)
Sample size = 450 trees.

Regression Model:
$Y = 0.60722 + 0.10710 (X_1) + 0.0083 (X_2)$ [$R^2 = 0.44$]
where Y = Cycle time per tree, in minutes
X_1 = Tree volume in Ft^3 to a 3 inch top, OB
X_2 = Distance in feet from tree to stack

OTHER COMMENTS:

CITATION: Raymond, K., McConchie, M., and Evanson, T. 1988. TREE LENGTH THINNING WITH THE LAKO HARVESTER. Logging Industry Research Association, New Zealand. Vol. 13, No. 11.

MACHINE SYSTEM: Lako 3T grapple harvester (max dia. 55 cm) mounted on a Foresteri 1278 crane (9 m reach). The base machine was a Martimex LKT 120-A skidder.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Lako 3T → Bell Logger (bunching) → Clark 664 grapple skidder

DESCRIPTION OF OPERATION: Tree-length thinning operation, removing every seventh row of trees, with selective thinning of three rows on either side of the outrow. Bunched by the Bell Logger for skidding by Clark 664 grapple skidder.

DESCRIPTION OF SITE: Kaingaroa Forest, New Zealand. Flat terrain.

DESCRIPTION OF STAND: 15 year old radiata pine. Crop stocking = 250 stems/ha. Merch. yield stocking = 380 stems/ha. Average DBH = 25 cm. 81% trees with branch index = 1, 4% trees with branch index = 4.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Mean merch. length = 13.8 m.
Mean merch. volume = 0.35 m^3.

PRODUCTION DATA:

Element	N	Mean Per Cycle (min.)	95% Conf. Int. (min.)	% of Total Cycle
Select	320	0.128	± 0.007	17.0
Fell	320	0.125	± 0.005	16.6
Delimb	320	0.291	± 0.026	38.8
Move	208	0.183	± 0.012	24.4
Op. Delay	31	0.024	± 0.004	3.2
Total Cycle	320	0.752	± 0.034	100.0
Trees/PMH		79.9	± 3.6	

Process time per tree* = - 0.1276 + 0.0174 (DBH in cm)
(select, fell, delimb) + 0.1889 (branch index) [R^2 = 0.59]

(* for trees 10-40 cm dia.)

Branch index = 1: Trees with branches all less than 4.0 cm diameter
Branch index = 2: Trees with some branches between 4.0-6.0 cm diameter
Branch index = 3: Trees with branches greater than 6.0 cm diameter
Branch index = 4: Malformed trees (including double leaders)

OTHER COMMENTS: A mean piece size of 0.25-0.35 m^3 is best suited for the Lako harvester. Lightly branched trees are processed quickly. Malformed or large branched trees can take 83% to 128% longer to process than lightly branched trees.

CITATION: Raymond K. 1990. FORTEC 1300 GRAPPLE HARVESTER. FERIC. Field Note No. Processing - 15.

MACHINE SYSTEM: Fortec 1300 grapple harvester with hydraulic chainsaw felling head (35 cm) mounted on a John Deere 70D tracked carrier (modified boom).

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Fortec 1300 Harvester → Forwarder

DESCRIPTION OF OPERATION: Thinning in hardwood stands to produce pulpwood bolts.

DESCRIPTION OF SITE: Lake States Region, USA. Flat terrain.

DESCRIPTION OF STAND: 78% birch, 22% maple.
Total stocking = 1,200 stems/ha.
Merch. yield trees = 760 stems/ha.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: 87% birch, 13% maple.
Average merch. tree size = 0.11 m^3; 3.9 bolts of 2.5 m pulpwood/tree.

PRODUCTION DATA:

Average work cycle (min.)			
Position head	0.15	No. of trees/cycle	1.0
Fell	0.29	No. of bolts/tree	3.9
Process	0.60	Trees/PMH	52.1
Clear slash	0.03	Bolts/PMH	204.5
Move machine	0.09	m^3/PMH	5.6
Total Cycle (min.)	1.15		

Long term sustainable daily production quoted by contractor at 60 m^3/shift for scheduled 9-hour shift.

OTHER COMMENTS: The unit was designed for use in pine plantations. In this stand, very little delimbing was required. Machine operated mainly as a merchandizer. The carrier unit did not supply sufficient power for the harvester when dealing with trees with a butt diameter over 22 cm.

CITATION: Thompson, M.A. and Sturos, J.A. 1984. BUNCHING WITH LOW-INVESTMENT SYSTEMS IN NORTHERN HARDWOOD POLE STANDS. Transactions of the ASAE. ASAE Paper No. 84-1599.

MACHINE SYSTEM: Radio-horse 9 sled-mounted winch.

OPERATOR RATING: Inexperienced operator.

DESCRIPTION OF SYSTEM: Two men. 1 man felled, limbed and topped trees. The other man winched the tree-length stems to the skid trail with radio horse.

DESCRIPTION OF OPERATION: Thinning operation. Skid trails laid out on 21 meter spacing. Thinning down to 20 m^2/ha. Winching distance ranged from 3 to 45 meters, averaging 17.4 meters.

DESCRIPTION OF SITE: N. Wisconsin, Summer. Flat, well drained with sandy loam soil.

DESCRIPTION OF STAND: Red oak, red maple, basswood. Average stand diameter = 16.5 cm. Average basal area = 32 m^2/ha.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Time studied for a total of 34.8 hours on 6 different days.

Productive Elements (45.4%)	
Pull cable & hook (%)	22.8
Winch (%)	16.8
Unhook (%)	5.8
Non Productive Elements (54.6%)	
Breaks (%)	15.6
Plan (%)	10.8
Set up & move (%)	10.2
Wait sawyer (%)	6.5
Clear area (%)	5.5
Help sawyer (%)	2.8
Mechanical delays (%)	1.1
Misc. delays (%)	2.1

Productive Time: 15.8 hours
# of Cycles: 649

Production
3.6 m^3 per schedule hour
7.8 m^3 per productive hour

OTHER COMMENTS: Low impact - 2 trees/ha were damaged, with minor soil disturbance. Inexperience of the operator reduced productivity.

CITATION: Deal, E.L. 1982. STEEP SLOPE FELLING AND BUNCHING IN SMALL TIMBER. *IN* Proceedings: "The Small Tree Resource: A Material Handling Challenge". Forest Products Research Society. Portland, Oregon. April 19-21. pp. 111-128.

MACHINE SYSTEM: Nordfor Bunching Winch (Flying Saucer). The "Flying Saucer" was a small radio-controlled bunching winch utilizing a hydraulically powered capsan. 16 hp air-cooled Kohler gasoline engine. Grapple skidders and a whole tree chipper.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Nordfor bunching winch → grapple skidders → chipper

DESCRIPTION OF OPERATION: Thinning. The winch was anchored to a tree or stump. The selected trees were then winched into a pile at the base of the tree. The bunches were then skidded to the landing.

DESCRIPTION OF SITE: North Carolina.

DESCRIPTION OF STAND: Hardwood stands.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Hardwood chips.

PRODUCTION DATA:

Productivity - Bunching with Flying Saucer System

DBH Class	Vol/ Tree (lbs)	Trees Per Ton	Time/ Tree (min)	Total Time/ Ton	Production Per Hour (tons)
2	19.72	101.40	1.02	103.40	.58
4	107.80	18.55	1.58	29.31	2.05
6	245.87	8.13	2.00	16.26	3.67
8	457.00	4.21	2.50	10.53	5.70
19	1088.71	1.84	3.10	5.70	10.53
12	1747.02	1.15	3.72	4.28	14.02
14	2390.18	.83	4.50	3.74	16.04
16	3242.96	.62	5.75	3.56	16.85
18	4120.56	.48	---	---	--

OTHER COMMENTS: The maximum working diameter limit for the Flying Saucer was found to be approximately 13 or 14 inches.

CITATION: Gleason, A.P. and J.A. Stolen. 1984. PREBUNCHING IN THINNING. Logging Industry Research Association, New Zealand. Vol. 9, No. 3.

MACHINE SYSTEM: Bell Logger grapple skidder.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Manual Felling → Prebunching → Line Skidder

DESCRIPTION OF OPERATION: Second thinning. After an area was manually felled, the Bell Logger would begin prebunching long and short stems into separate piles. A bench of slash was built to support the logs for later hooking.

DESCRIPTION OF SITE: Taranera Forest, New Zealand. Slopes were less than 25%.

DESCRIPTION OF STAND: 12 year old radiata pine plantation. Average tree volume = 0.16 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average stem size:
Long stems = 0.20 m^3
Short stems = 0.09 m^3

PRODUCTION DATA:

Avg. stems/bunch (long)	13.7
Avg. stems/bunch (short)	6.6
Total cycle time (min.)	15.46
Number of bunches	54
Productivity/PMH (m^3)	13

Time Distribution	
Build bench (%)	16
Travel empty (%)	19
Acquire stems (%)	29
Travel loaded (%)	18
Reposition bunch (%)	8
Clear slash (%)	5
Delay (%)	5

OTHER COMMENTS:

CITATION: Ashby, H. and Vaughan, L. 1988. THE BELL LOGGER - BUNCHING PRODUCTIVITY BEHIND MECHANIZED AND MOTOR MANUAL SYSTEMS. Logging Industry Research Association, New Zealand. Vol. 13, No. 25, pp. 1-6.

MACHINE SYSTEM: The Bell Logger was used for bunching trees. Two machines, both less than two years old, had strengthened booms and square sectional framing.

OPERATOR RATING: Two experienced operators, with no significant differences between their skill levels.

DESCRIPTION OF SYSTEM: System 1: A mechanized system with a Lako 3T Harvester. System 2: A motor manual system with 6 chainsaw operators. In both systems, the Bell was used for bunching and a Clark 664C grapple skidder was used for extraction.

DESCRIPTION OF OPERATION: A seventh row outrow thinning system.

DESCRIPTION OF SITE: Terrain was flat, and conditions were easy. The slopes were 0-5° in the Stand 1, and 0-2° in Stand 2.

DESCRIPTION OF STAND: Two 15 year old stands. Stand 1 had intermittent windrows.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Bunching Productivity	Motor Manual	Mechanized
Travel (min.)	0.74	0.80
Acquire (min.)	1.46	1.21
Travel Loaded (min.)	0.93	0.84
Reposition (min.)	0.69	0.78
Clear slash (min.)	0.18	0.08
Total cycle time (min.)	4.00	3.71
No. pieces/bunch	7.00	8.40
Avg. Processed piece size (m^3)	0.31	0.25
Avg. bunch size (m^3)	2.20	2.10
Bunching productivity (pieces/PMH)	105	136
Bunching productivity (m^3/PMH)	32	33

OTHER COMMENTS: The bunching productivity dropped rapidly on sloping or broken terrain. The increase in productivity after the Lako was due to its partial bunching of logs during processing. The Bell Logger can maintain this level of productivity only in very good conditions.

CITATION: Thompson, M.A. and Sturos, J.A. 1984. BUNCHING WITH LOW INVESTMENT SYSTEMS IN NORTHERN HARDWOOD POLE STANDS. Transactions of the ASAE. ASAE Paper 84-1599.

MACHINE SYSTEM: Holder A55F with Igland Primo winch. No skidding cone.

OPERATOR RATING: Inexperienced.

DESCRIPTION OF SYSTEM: Two men. One felled, limbed and bunched. The other bunched with the holder. Full merchantable length stems were bunched within, and parallel to, the skid trail and were "bladed" into a pile. Skidding distances ranged from 6 to 107 meters, averaging 69 meters.

DESCRIPTION OF OPERATION: Removal of mature trees and thinning poles. Stand was being thinned from 28 m^2/ha to 20 m^2/ha.

DESCRIPTION OF SITE: Upper peninsula of Michigan. Summer. Flat, sandy loam.

DESCRIPTION OF STAND: Sugar Maple. Average DBH = 22 cm.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Total study time: 12.7 hours on 2 different days.

Productive Elements		Non-Productive Elements		
Travel empty	12.2%	Breaks	15.6%	Total productive time - 7.7 hrs.
Choker & winch	18.8%	Wait sawyer	8.2%	Number of cycles - 4.0 hrs.
Travel loaded	12.2%	Pull hangers	5.7%	Number of pieces - 92
Unhook	5.9%	Talk	5.3%	Total Vol. skidded - 260 m^3
Deck	11.2%	Clear slash	2.2%	
		Misc.	2.7%	Productivity of 2.0 m^3/SH
	60.3%		39.7%	

OTHER COMMENTS: Bole damage was slightly more than if horses had bunched. Low production caused by operator.

CITATION: Wells, G.C. 1980. THE BELL LOGGER. Machinery Evaluation. Logging Industry Research Association, New Zealand. Vol. 5, No. 3.

MACHINE SYSTEM: Bell Logger with a hydraulic boom and grapple.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: The Bell was used in the place of a conventional skidder for skidding long length in radiata pine thinnings.

DESCRIPTION OF OPERATION:

DESCRIPTION OF SITE: Three sites in New Zealand.

DESCRIPTION OF STAND: Young radiata pine. Stand one, two and three were 14, 10 and 14 years of age, respectively.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Stand	1	2	3
Average Piece Size (Tonnes)	0.18	0.18	0.23

PRODUCTION DATA:

Stand	1	2	3
Avg. Pieces Extracted	5	5.8	4.2
Haul Distance (meters)	95	48	---
Production/Machine hour (tonnes)	8	8.5	8.5

OTHER COMMENTS:

CITATION: Robe, S.C., et.al. 1989. COMPARISON OF LARGE AND SMALL GRAPPLE SKIDDERS FOR CORRIDOR THINNING OF PINE PLANTATIONS. Forest Products Journal. 39(2):66-68.

MACHINE SYSTEM:
(1) Franklin 170 grapple skidder (5 mos. old).
(1) Franklin 105 grapple skidder (3 years old, engine recently rebuilt).

OPERATOR RATING: Both experienced.

DESCRIPTION OF SYSTEM:

System 170:
(2) Franklin 105 feller-bunchers
(1) Franklin 170 grapple skidders → delimbing gate grapple loader
(1) Timberjack 350-A grapple skidder → delimbing gate grapple loader

System 105:
(1) Franklin 105 feller-buncher
(1) Franklin 105 grapple skidder → (1) delimbing gate (1) grapple loader

DESCRIPTION OF OPERATION: Corridor and selection thinning. Corridors were cut on 70 foot centers at right angles to the main skid trail. Selection thinning was performed between corridors. The feller-bunchers bunched trees in the corridors, the skidders took the material to the landing where it was gate delimbed and loaded.

DESCRIPTION OF SITE: Coastal Plain of South Carolina. Flat.

DESCRIPTION OF STAND:

System 170: 16 year old loblolly pine plantation containing 483 trees/acre. Average DBH = 6.6 inches.
System 105: 19 year old loblolly pine plantation containing 315 trees/acre. Average DBH = 7.9 inches.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Weight of Payload(lbs.)	Avg.	SD	Min	Max
170	8,974	2,625	4,265	18,129
105	5,075	1,396	1,872	8,916

PRODUCTION DATA: (N = 132 round trips for 105 and, N = 95 round trips for 170)

	Average	SD	Min	Max
Round Trip Skidding Distance (Ft.)				
170	1,824	---	---	---
105	1,585	---	---	---
Round Trip Cycle Time (Min.)				
170	6.71	1.70	3.30	11.61
105	5.59	1.56	2.95	11.06
Productivity (Tons/Productive Hour)				
170	41.8	13.1	16.0	87.0
105	28.3	8.2	9.6	55.5

OTHER COMMENTS:

CITATION: Czerepinski, F.P. 1978. EVALUATION OF HARVESTING SYSTEMS USED IN PINE PLANTATIONS IN THE SOUTHEAST. American Pulpwood Association. 78-P-7.

MACHINE SYSTEM: Franklin 170 XL power shift grapple skidders.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-Bunchers → Grapple Skidders

DESCRIPTION OF OPERATION: Thinning. Every 3rd row was removed, with poor quality trees being removed from adjacent rows. The skidder backed down the row, grappled the bunch, and then skidded it to the landing.

DESCRIPTION OF SITE: Georgia.

DESCRIPTION OF STAND: Pine plantations. 19 to 21 years old.
Average height = 53 to 58 feet.
Average DBH = 6.7 to 7.4 inches.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Skidding in thinnings with Franklin 170 XL PS GS Skidders

Skid Distance	Time Per Turn	Turns Per Hour
700	3.43	17.5
800	3.70	16.2
900	3.93	15.3
1,000	4.10	14.6
1,100	4.28	14.0
1,200	4.42	13.6
1,300	4.53	13.2
1,400	4.60	13.0

Production -- Cords per Hour by DBH and Skid Distance

DBH	700' Skid	900' Skid	1,100' Skid	1,300' Skid
5	5.3	5.0	4.6	4.4
6	7.4	6.4	5.9	5.5
7	10.5	9.2	8.4	7.9
8	14.1	13.1	12.9	12.1

OTHER COMMENTS:

CITATION: Tufts, R.A., B.J. Stokes, and B.L. Lanford. 1988. PRODUCTIVITY OF GRAPPLE SKIDDERS IN SOUTHERN PINE. Forest Products Journal. 38(10):24-30.

MACHINE SYSTEM: 12 different models of rubber-tired grapple skidders. Horsepower ranged from 75.5 to 185.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-bunchers → grapple skidder → gate delimber → loader
Feller-bunchers → grapple skidder → loader

DESCRIPTION OF OPERATION: 1) Full tree from woods to deck, 2) skidding plus gate delimbing, 3) tree-length from woods to deck, 4) unbunched.

DESCRIPTION OF SITE: 24 study sites, 21 were located throughout central Alabama. Two were in Louisiana and one was in South Carolina. Level terrain with slopes averaging less than 4% with a maximum of 16%.

DESCRIPTION OF STAND: Southern Pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average # of bunched trees = 9.25.
Average # of bunches = 1.25.
Average # of unbunched trees = 3.43.
Pulpwood operation.

PRODUCTION DATA:

	Average	Minimum	Maximum
Skidding Distance (ft)			
Gate Delimbing	750	185	2,490
Full Tree	781	40	2,017
Tree Length	323	50	1,000
Load Weight (lbs.)	3405	518	13,190
Slopes (%)	3.74	0	16
Trees/Bunch	9.25	1	42
Bunches/Cycle	1.25	1	4
Cycle Times (min.)			
Gate Delimbing	5.03	1.44	12.73
Full Tree	5.16	1.18	14.35
Tree Length	4.03	1.31	9.43

Total cycle regression equations

BUNCHED

Skidding plus gate delimbing time (min.) = [$R^2 = 0.707$]

0.004509 x DIST + 0.000000239 x DIST x LOAD + 0.01579 x HP - 0.00002328 x DIST x HP + 0.001293 x DIST X NBNCH

Skidding fill trees to deck time (min.) =

- 0.5988 + 0.004539 x DIST + 0.01119 x HP - 0.00001554 x DIST x HP + 0.0003782 x DIST x NBNCH + 1.616 x NBNCH - 0.005599 x NBNCH x HP + 0.01398 x NBNCH x NTREES

Skidding tree length stems to deck time (min.) =

- 0.0158 + 0.005234 x DIST - 0.000443 x HP + 1.650 x NBNCH + 0.0000002581 x HP x LOAD - 0.000003336 x DIST x HP + 0.01398 x NBNCH x NTREES - 0.005599 x NBNCH x HP

UNBUNCHED

Skidding tree length to deck time (min.) =

1.0529 + 0.005234 x DIST - 0.000443 x HP + 0.0000002581 HP x LOAD + 0.3916 x NBNCH - 0.000003336 x DIST x HP

DIST = one way distance travel in feet; LOAD = load weight in pounds; HP* = machine flywheel horsepower; NBNCH = number of bunches grappled; NTREES = number of trees per load.

*HP ranged from 75.5 to 185

OTHER COMMENTS: Skid distance is the most significant variable affecting cycle time. But load weight is as important as skid distance for predicting production.

CITATION: Greene, W.D. and B.J. Stokes. 1988. PERFORMANCE OF SMALL GRAPPLE SKIDDERS IN PLANTATION THINNING APPLICATIONS. Paper submitted to the Southern Journal of Applied Forestry, January, 1988.

MACHINE SYSTEM: Franklin 105 grapple skidder with a Franklin M25 grapple.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-buncher → grapple skidder → gate delimbing

DESCRIPTION OF OPERATION: Trees were previously felled and then bunched in the corridors by a small feller-buncher. Delimbing was performed by the skidder backing trees through an iron delimbing gate. Silviculture was a combination of row and low thinning.

DESCRIPTION OF SITE: Summertime on the South Carolina coastal plain.

DESCRIPTION OF STAND: 20 year old loblolly pine stand containing 368 stems per acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average turn contained 10.5 stems (0.62 cords) of wood.

PRODUCTION DATA:
Sample size = 102 cycles
Cycle time = 2.4503 + 0.003818 * DIST [$R^2 = .79$]
Where: Cycle time = cycle time in minutes
DIST = average skidding distance (ft.)

Average productivity at average skidding distance of 809 feet was 7.85 cords per PMH.

OTHER COMMENTS:

CITATION: Gebhardt, P.G. 1977. TIMBER HARVESTING PRODUCTION RATES IN MIXED-CONIFER STANDS OF EASTERN OREGON AND WASHINGTON. Masters Thesis. University of Washington.

MACHINE SYSTEM: Rubber-tired skidders observed:
CAT 518
John Deere 540, 640 and 740

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Skidding.

DESCRIPTION OF OPERATION: Light selective cutting.

DESCRIPTION OF SITE: Eastern Oregon and Washington.
Ground slope = 20%.
Ground condition rating index = Fair.

DESCRIPTION OF STAND: Mixed - conifer stands.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

Volume/Log = 120 Bd.Ft.

PRODUCTION DATA:

Regression Equation for Ground Skidding (100 hp Grapple Skidder)

Outrun Time

= 0.40264	+ 0.00133 (ADS)	[R^2 = 0.81]
	+ 0.01923 (GRDSLP)	[R^2 = 0.84]
	+ 0.11670 (TOC)	[R^2 = 0.88]
		[N = 195]

Hookup Time

= 0.29443	+ 0.05399 (TOC)	[R^2 = 0.40]
	+ 0.31726 (NLOGS)	[R^2 = 0.49]
	- 0.81834 (GC)	[R^2 = 0.56]
	+ 0.0047 (MVDST)	[R^2 = 0.59]
		[N = 195]

InHaul Time

= 0.29972	+ 0.001809 (HDS)	[R^2 = 0.54]
	+ 0.14449 (TOC)	[R^2 = 0.60]
	+ 0.000314 (TOT-VOL)	[R^2 = 0.64]
		[N = 195]

Unhook & Deck Time

= 0.07489	+ 0.00108 (TOT-VOL)	[R^2=.06]
	+ 0.17126 (NLOGS)	[R^2=.10]
		[N=195]

Total Time

= 1.07168	+ 0.00314 (ADS)
	+ 0.01923 (GRDSLP)
	+ 0.31518 (TOC)
	+ 0.48852 (NLOGS)
	- 0.81934 (GC)
	+ 0.00469 (MVDST)
	+ 0.00139 (TOT-VOL)

Summary Statistics for Independent Variables
(Rubber-Tire with Grapple)

Independent Variable	MIN.	MAX.	AVG.	S.D.
GRDSLP (%)	0	20	4	6
GC	1	2	1.1	0.3
ADS (feet)	30	600	222	127
HP	94	145	120	15
TOC	0	2	1.6	0.8
LDMEN	----	----	----	----
NLOGS	1	5	2	0.9
VOL/LOG (BD.FT.)	10	1,200	197	520
MVDST	0	250	17	38
#0BS	--------------195----------------			

Definition of Independent Variables

ADS = Yarding Distance, in Feet
GRDSLP = Average ground slope, in percent
TOC = The type of cut performed:
- 0 - 95% of volume removed
- 1 - 50-95% of volume removed
- 2 - Light selective cut (less than 50% of volume removed)

NLOGS = # of logs yarded for each TURN
GC = Ground condition rating
- 0 - poor (excessive maneuvering)
- 1 - fair (moderate maneuvering)
- 2 - good (little maneuvering)

MVDST = Distance (feet) moved during hook-up period
TOTVOL = NLOGS x Volume per log

OTHER COMMENTS:

CITATION: Meyer, R.L. 1984. EQUIPMENT DESIGN FOR HARVESTING SMALL TREES IN FOREST-THINNING OPERATIONS. American Pulpwood Association. 84-A-5.

MACHINE SYSTEM: Dunham 660 Log Hog with grab-a-matic grapple/minigrapples. Two-wheel drive.

OPERATOR RATING: Sawlog: The operator was experienced.
Small Wood: The operator was inexperienced.

DESCRIPTION OF SYSTEM: Skidding.

DESCRIPTION OF OPERATION: The machine was observed skidding both sawlogs and small-diameter thinnings.

DESCRIPTION OF SITE: Southeastern U.S.
Sawlog: Trail conditions were excellent.
Small Wood: Poorer trail conditions

DESCRIPTION OF STAND:
Small Wood: Average diameter = 5-6 inch.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Productivity - sawlogs site		Productivity - small wood site	
Average skidding distance (ft)	450	Skidding distance (ft)	750-980
Average round trip time (min.)	4.2	Average round trip time (min.)	8.6
Average load size/turn (cords)	0.45	Average pieces/turn	3-11
Production (cords/hour)	6.4	Average no. of stems/turn	7.3
		Production (cords/hour)	1.5

OTHER COMMENTS: The machine's major purpose is to reduce machine cost on logging operations where four-wheel-drive skidders are not required.

CITATION: Gleason, A.P. 1985. BELL LOGGER EXTRACTION IN THINNINGS. Logging Industry Research Association, New Zealand. Vol. 10, No. 6.

MACHINE SYSTEM: Bell Logger with a fixed-boom and series 20 grapple.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Manual Felling → Bunching & Skidding

DESCRIPTION OF OPERATION: Thinning. Trees were felled with butts facing the skid road and then delimbed. The Bell Logger then assembled a bunch containing 1-6 logs and skidded it to the landing.

DESCRIPTION OF SITE: New Zealand. Flat terrain. Study block = a 330 meter strip, containing two rows of selected and mark trees.

DESCRIPTION OF STAND: 12 year old radiata pine stand. The stand was being thinned from 1,300 SPH down to 350 SPH.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average log size = 0.23 tonnes.
160 merchantable trees in the 330 M strip.

PRODUCTION DATA:

<u>Bell Logger Extraction Cycle Breakdown</u>

	Percent
Travel empty (%)	22
Clear slash (%)	8
Acquire load* (%)	21
Travel loaded** (%)	39
Skid (%)	7
Delay (%)	3
Total (%)	100

* Avg. No. of trees = 4.1 (0.95 tonnes)
** Avg. skidding distance = 170 m

<u>Productivity of Bell Logger</u>

No. of cycles	39
Time/cycle (min.)	6.69
Productivity (Tonne/PMH)	8.5

<u>Multiple Regression:</u>
TOTAL TIME = -0.71 + 0.029 x (skid distance in meters) + 2.48 x (load size in tonnes) [$R^2 = 0.84$]

OTHER COMMENTS: 12% of the final crop trees were damaged.

CITATION: Raymond, K. and Moore, T. 1989. MECHANIZED PROCESSING AND EXTRACTION OF SHORTWOOD THINNING. Logging Industry Research Association, New Zealand. Vol. 14., No. 5.

MACHINE SYSTEM: Volvo 861 forwarder (6 wheel drive).

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Waratah delimber-feller-buncher → Waratah processor → Volvo 860 forwarder.

DESCRIPTION OF OPERATION: Thinning extraction, the forwarder extracted 2.6 meter bolts through the bush, onto a sand track and then out to the truck road, loading trucks directly.

DESCRIPTION OF SITE: Aupouri Forest, New Zealand. Flat sand country.

DESCRIPTION OF STAND: Radiata pine, 12 years old.
Total stocking 830 stems/ha.
Crop stocking 275 stems/ha.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Mean merch. length = 10.1 m.
Mean merch. LED = 20.4 cm.
Mean merch. volume = 0.17 m^3.

PRODUCTION DATA:

		No. of Observations	Mean Per cycle (min.)	% of Total Cycle	Haul Distance (m) Mean	Range
Return empty		7	5.76	11.2	575	10-916
Load		7	23.60	46.0	----	----
Move to load		7	3.29	6.4	120	63-212
Travel loaded		7	3.55	6.9	235	40-458
Run loaded		7	2.74	5.3	386	40-816
Unload		8	12.42	24.2	----	----
Total cycle (min)		8	51.36	100.0		
Total distance (metres)		7			1316	191-1,836
Forwarder Payload	- No. of pieces				222	195-261
	- tonnes				10.9	9.7-12.3

Productivity: 12.7 tonnes/PMH
Average haul distance: 658 metres

Loading Analysis:

		Mean	Range
Mean load time (min./cycle)		23.60	19.97 - 28.78
No. of grapple loads		31.3	27 - 36
Mean grapple load (pieces)		7.2	1 - 9
Mean grapple load (tonnes)		0.35	0.32 - 0.40
Loading Productivity:	(pieces/min.)	9.6	8.4 - 11.1
	(tonnes/min.)	0.47	0.41 - 0.54
Unloading Productivity:	(pieces/min.)	18.5	13.7 - 22.9
	(tonnes/min.)	0.90	0.67 - 1.12

Travel Speed:	m/min.	km/hr
Run empty (track)	149	8.9
Travel empty (bush)	87	5.2
Move while loading	36	2.2
Travel loaded (bush)	66	4.0
Run loaded (track)	141	8.5
Mean empty	100	6.0
Mean loaded	99	5.9

OTHER COMMENTS: Forwarder productivity was highly sensitive to haul distance and would have increased significantly if haul distances were reduced or if sand tracks were spaced at more regular intervals.

CITATION: Greene, W.D., B.L. Lanford and B.J. Stokes. 1984. PRODUCTIVITY OF THE VALMET 940 GP GRAPPLE PROCESSOR IN SOUTHERN PINE PLANTATION THINNING. COFE/IUFRO Joint Meeting Proceedings. pp. 105-108.

MACHINE SYSTEM: Valmet 940 GP multi-stem grapple processor was attached to a Cranab boom mounted on a Timberjack 385 skidder hydraulically powered bucking chainsaw. Maximum delimbing diameter = 40 cm.

OPERATOR RATING: The operator had operated the machine for several months.

DESCRIPTION OF SYSTEM:
Feller-Buncher → Processor → Forwarder

DESCRIPTION OF OPERATION: The Feller-Buncher built piles adjacent to an access corridor created by the removal of every 11th row of the stand. Bunches were oriented perpendicular to the direction of the row. The processor delimbed and bucked these bunches; the forwarder then hauled the bunches to the landing.

DESCRIPTION OF SITE: Central Alabama.

DESCRIPTION OF STAND: 12-year old loblolly pine plantation
Average DBH = 18 cm. Average tree height = 15 m . Stocking before thinning = 1,600 trees per ha. Residual stand = 701 trees/ha.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
2.3 meters in length and up to 7.5 cm top outside bark.

PRODUCTION DATA: Study Period: Two working days.

Productivity of the Valmet 940 GP Processor

Average No. of Trees/Bunch	16
Average Volume/Bunch (m^3)	2.5
Average Distance Between Bunches (m)	8

Productive Minutes Per Tree

Avg. Move Time Between Bunches	0.02
Avg. Processing Time Per Tree	0.40
Processing Time (12 cm tree)	0.24
Processing Time (20 cm tree)	0.61

(For each 5 cm increase in diameter, it took an additional 0.23 productive minutes to process.)

Total Processing Time for a 12 cm Tree	0.25
Total Processing Time for a 20 cm Tree	0.64

OTHER COMMENTS:

CITATION: Duggan, M. 1988. EVALUATION OF THE WARATAH PROCESSOR IN RADIATA THINNINGS. Logging Industry Research Association, New Zealand. Vol. 13, No. 12.

MACHINE SYSTEM: Prototype Waratah heavy duty grapple processor (max. tree dia. = 50 cm, min. = 7.5 cm), mounted on a wheeled Hitachi 073 excavator base fitted with a blade to clear slash.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: JD 440 D skidder
Motor manual thinning → Komatsu D37 Tractor → Waratah Processor
Timbermaster hauler

DESCRIPTION OF OPERATION: The fallers cut off the tops at 10 cm SED, and for head pulling, delimbed the first 1 meter. Trees were skidded to stacks at landing or roadside for delimbing/slashing by the Waratah.

DESCRIPTION OF SITE: Kinleith Forest, New Zealand. Moderate to steep terrain.

DESCRIPTION OF STAND: Radiata pine, 17 years old.
Total stocking = 886 trees/ha, yield stocking = 511 trees/ha.
Mean yield DBH = 24.5 cm. Mean yield volume = 0.3 m^3 (0.03 - 0.57 m^3).

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

	Mean time per cycle (min.)		
Cycle Element	Operator 1	Operator 2	Mean
Accumulate	0.05	0.09	
Pickup and return	0.14	0.15	
Position and delimb	0.27	0.30	
Cut to length	0.07	0.07	
Move along stack	0.01	0.03	
Move along road	0.04	0.04	
Restack	0.01	0.02	
Blade skid	0.08	0.08	
Total Cycle	0.67	0.78	0.73
Cycles Observed	248	220	
Trees/PMH	90	79	

OTHER COMMENTS: Trees with large branches (> 5cm) and/or malformation required 43% more processing time (1.12 min/tree). The piece size processed (0.3 m^3 average, range 0.03 - 0.57 m^3) was considered to be approaching the upper level of the Waratah's capabilities. The Waratah was able to process both head first and butt first without adversely affecting productivity.

CITATION: Raymond, K. and Moore, T. 1989. MECHANIZED PROCESSING AND EXTRACTION OF SHORTWOOD THINNING. Logging Industry Research Association, New Zealand. Vol. 14., No. 5.

MACHINE SYSTEM: Waratah Grapple Processor.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Waratah delimber-feller-buncher ==> Waratah Processor ==> Volvo 861 forwarder.

DESCRIPTION OF OPERATION: Thinning operation, Waratah DFB partially delimbs, fells and bunches trees. The Waratah processor follows, delimbs and produces stacks of 2.6 m bolts for forwarding to trucks at road.

DESCRIPTION OF SITE: Aupouri Forest, New Zealand. Flat sand country.

DESCRIPTION OF STAND: Radiata pine, 12 years old. Total stocking = 830 stems/ha. Crop stocking = 275 stems/ha.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: Mean merch. length = 10.1 m. Mean merch. LED = 20.4 cm. Mean merch. volume = 0.17 m^3.

PRODUCTION DATA:

Element	No. of Observations	Mean per Cycle (min)	+ 95% Conf. int.	% of Total Cycle
Pick up tree	476	0.165	0.005	18.1
Delimb and cut	476	0.588	0.028	64.8
Total: Process	476	0.753	0.027	82.9
Move	75	0.091	0.027	10.0
Clear	56	0.031	0.003	3.4
Op. delay	17	0.034	0.034	3.7
TOTAL CYCLE	476	0.909	0.043	100.0

Trees/PMH = 66.0
Tonnes/PMH = 12.5
Delimb time = 0.182 (no. of pieces) - 0.104 [R^2 = 0.35]

OTHER COMMENTS: The Waratah DFB delimbed an average of 7.8 meters, which allowed the Waratah processor to cut 3-2.6 meter lengths before further delimbing. The processor worked mostly as a merchandizer.

CITATION: Raymond, Keith. 1988. THE HARRICANA STROKE DELIMBER IN RADIATA THINNINGS, 1988. Logging Industry Research Association, New Zealand. Vol. 13, No. 1, pp. 1-8.

MACHINE SYSTEM: Harricana HM-1290-50 stroke-delimber mounted on a Caterpillar 215B Special Applications excavator base, with 85 hp engine, track unit. The delimber was on a 50 foot boom, with 2 chainsaws, and could handle up to 65 cm trees.

OPERATOR RATING: Two relatively inexperienced operators, with wide variation between operators working in the same direction.

DESCRIPTION OF SYSTEM: Four different approaches were tried to determine an efficient method of operation. The first three months involved the delimber working out of phase with the rest of the operation.

DESCRIPTION OF OPERATION: Thinning operation. Over the twelve day period of the study, data was collected on gross productivity, total PMH/day, and delays. Processing of delimber was timed for 200 merchantable trees.

DESCRIPTION OF SITE: Flat terrain.

DESCRIPTION OF STAND: Two stands of 18 and 19 year old radiata pine.
Stand 1: Total stocking = 600 SPH; Yield stocking = 350 SPH.
Stand 2: Total stocking = 1,100 SPH; Yield stocking = 850 SPH.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Stand 1: Avg. yield DBH = 28 cm; Avg. merch. vol. = 0.40 m^3.
Stand 2: Avg. yield DBH = 25 cm; Avg. merch. vol. = 0.36 m^3.

PRODUCTION DATA:

	Operator A		Operator B	
Element	Min/Cycl.	% of Tot.	Min/Cycl	% of Tot.
Pick up	0.24	30.1	0.33	27.1
Process	0.50	62.9	0.84	67.8
Clear	0.02	3.0	0.02	1.7
Sort	0.03	3.9	0.03	2.4
Stave	0.00	0.1	0.01	1.0
Total	0.79	100.0	1.23	100.0

Element	%
Productive Time	75.2
Mechanical Repair	13.0
Servicing & Maint.	3.17
Wait for Repair	1.76
Operational Delay	4.58
Personal Delay	2.29

On Job Time (hr/Day)	9.5
Available machine time (hr/Day)	7.8
Gross Productive machine time (hr/Day)	6.5
Mean productivity (Trees/PMH)	
Daily utilization (m^3)	54.0
Daily utilization (Tonnes)	
	153.0
	170.0

OTHER COMMENTS: Attention to the work organization is important. Stands of 0.35 m^3 piece size, or greater, best suites the delimber operation. This trial describes equipment and systems which are still in the state of development.

CITATION: Powell, L.H. 1972. EVALUATION OF NEW LOGGING MACHINES LOGMA T-310 LIMBER BUNCHER. Pulp and Paper Research Institute of Canada. Logging Research Report LRR/46.

MACHINE SYSTEM: Logma T-310 Limber-Buncher.

OPERATOR RATING: 4 months experience.

DESCRIPTION OF SYSTEM:
Drott Feller-Buncher → Logma T-310 Limber-Buncher → Hough 90 Payloader (Forwarder)

DESCRIPTION OF OPERATION: Partial cut. The felled and prebunched trees were limbed and bucked at the stump prior to forwarding to roadside.

DESCRIPTION OF SITE: Ontario, Canada, in December. Average of six inches of snow. Terrain was rolling with thin sandy soil, rocky outcrops and swampy depressions.

DESCRIPTION OF STAND: Jack pine and black spruce.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree length contained 10.2 cubic feet and ranged from 2.0 to 24.4 cubic feet (SD = 4.7 Ft^3). The operation was integrated and produced both sawlogs and pulp wood.

PRODUCTION DATA:

Time Per Merchantable Tree:

$$\text{Time (cmin)} = 27 + 9200/TA + .7VT + .3VT \times B2 + .5VT \times B3 \quad [R^2 = 0.25]$$

	Variables	Avg.	SD	Range	Time Distribution
	Time/Tree (cmin)	56	12	30-111	Moving = 21%
TA=	Merch. Trees/acre	453	88	290-616	Processing = 70%
VT=	Vol/Tree (Cu.Ft.)	10.2	4.7	2.0-24.4	Delays = 9%
B2=	1 when branchiness class is 66%, otherwise BL = 0				
B3=	1 when branchiness class is 100%, otherwise B3 = 0				

Average productivity when using average time and average tree is equal to 10.9 cunits/productive hour.

OTHER COMMENTS:

CITATION: Raymond, K.A. 1988. PRELIMINARY TRIALS WITH THE HARRICANA STROKE DELIMBER. Logging Industry Research Association, New Zealand. Project Report P.R. 35.

MACHINE SYSTEM: Harricana HM-1290-50 stroke-delimber mounted on a Caterpillar 215B special applications excavator base.

OPERATOR RATING: Not highly experienced.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Thinning operation, trees processed at road side (Ponderosa) and at landings (Radiata) in "Hot Deck" and "Cold Deck" operations for long length pulpwood.

DESCRIPTION OF SITE: Ponderosa pine trial: Tasman Forest, New Zealand. Radiata pine trial: Kaingarda Forest, New Zealand.

DESCRIPTION OF STAND: Ponderosa pine: average tree size = 0.36 Tonnes.

Radiata Pine stands:

	Stand 1	Stand 2
Stand Age	18	19
Total stocking (trees/ha)	600	1,100
Yield stocking (trees/ha)	350	850
Yield mean DBH (cm)	28	25
Mean merch. volume (m^3)	0.40	0.36

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Ponderosa Pine trial:

Element	Operator 1 Min.	Operator 1 %	Operator 2 Min.	Operator 2 %
Pick up	0.232	26.3	0.227	31.7
Process	0.493	55.8	0.394	55.0
Clear slash	0.054	6.1	0.016	2.2
Stack	0.026	3.0	0.013	1.8
Move	0.021	2.4	0.009	1.3
Sort	0.057	6.4	0.057	8.0
Total Cycle (min.)	0.883	100%	0.716	100%
Productivity trees/hour	68.0 (64-73)		83.8 (77-91)	

		Operator 1		Operator 2	
Radiata Pine trial:	Element	Min.	%	Min.	%
	Pick up	0.240	30.1	0.332	27.1
	Process	0.501	62.9	0.831	67.8
	Clear	0.024	3.0	0.020	1.7
	Sort	0.031	3.9	0.028	2.4
	Stack	0.001	0.1	0.011	1.0
		0.797 min. ±0.072 min.	100.0%	1.222 min. ±0.092 min.	100.0%
	Trees/PMH (95% conf. int.)	75.3 (69.0 - 82.7)		48.6 (45.2 - 52.5)	

OTHER COMMENTS: Fluctuation in daily production rates for individual operations ranged up to 23% due to operator inexperience and periods of fatigue. Over duration of the trial, weighted mean productivity was 54 trees/PMH.

CITATION: Thompson, M.A. and J.A. Sturos. 1984. BUNCHING WITH LOW-INVESTMENT SYSTEMS IN NORHTERN HARDWOOD POLE THINNINGS. American Society of Agricultural Engineers. Winter Meeting. New Orleans, Louisiana. December 11-14, 1984. Paper No. 84-1599.

MACHINE SYSTEM: Radio Horse 9 sled-mounted winches. It was a radio controlled winch with a 6.7 kW diesel engine. Gafner 4501F Iron Mule forwarder. Bunk capacity = 24 m3.

OPERATOR RATING: Winch operator was relatively inexperienced.

DESCRIPTION OF SYSTEM:
1. Sled-mounted winches → forwarder.
2. Forwarder forwarding unbunched wood.

DESCRIPTION OF OPERATION: Thinning. Manually felled wood was winched to trailside by the radio horse 9, bucked and piled and then forwarded to roadside. On an adjacent site, the marked trees were felled, delimbed and piled at the stump for later forwarding.

DESCRIPTION OF SITE: Northern Wisconsin. Ground is flat and well drained with sandy loam soil.

DESCRIPTION OF STAND: Red oak, red maple, and basswood.
Average stand DBH = 16.5 cm.
Initial basal area = 32 m^2/ha.
Residual basal area = 20 m^2/ha.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Study Period: Summer 1982

Time study - Sled Mounted Winches	
Pull cable and hook	22.8
Winch (%)	16.8
Unhook (%)	5.8
Total Productive Time (%)	45.4
Non Productive Time (%)	54.6
Avg Piece Size (m^3)	0.19
Avg skid distance (m)	17.4
Productivity (m^3/SH)	3.6
Observed Total Time (hr)	15.8

Productivity - Forwarder

Productive Elements	% of Total Time Bunched	Unbunched
Travel	29	44
Preparation	16	5
Load	21	23
Unload	17	14
Total	83	86
Unproductive		
Total	17	14

	Bunched	Unbunched
Observed Productive Time (hr)	13.1	11.6
Observed Total Time (hr)	15.8	13.5
Total Number of Cycles	22	17
Total Volume (m^3)	123.7	89.3

OTHER COMMENTS: The average forwarding distance for the unbunched wood was about half that for the bunched wood.

CITATION: Arvidsson, A. and M. Spahr. THE MAKERI THINNING SYSTEM - AN EVALUATION OF THE MAKERI HARVESTER AND MAKERI FORWARDER IN THINNING. Swedish University of Agricultural Sciences, College of Forestry.

MACHINE SYSTEM:
Makeri harvester → Makeri forwarder

OPERATOR RATING:

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: A low thinning with corridors spaced on 15 meter centers. The harvester would cut the stem, back out to the corridor edge and then limb, buck and deck the stem. The forwarder would then haul the processed wood to the landing.

DESCRIPTION OF SITE: Western Dalarna Province, Sweden. The slopes averaged 7%.

DESCRIPTION OF STAND: An average of 612 trees per acre with the average tree being 5.1 inches DBH (OD) and 41 feet tall. Volume per acre was 16.3 cunits/acre, consisting of pine and spruce.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY: The stems were processed into 3 meter pulp sticks. The average tree harvested was 4.5 inches DBH (OD) and 37 feet tall. 5.04 cunits/acre were removed during the thinning.

PRODUCTION DATA:

Harvester

$T = 41.9 + 2.3\ Avst + 6.2\ DBH + 2.0\ BIT$

Where T = Total Time in cmin/tree
Avst = Distance (meters) between cut tree and corridor center
Dbh = DBH (centimeters) of tree harvested
BIT = Total number of 3 m, sticks per tree

- Total time/tree averaged 123.5 cm (without pauses)
- Avst averaged 3.1 meters
- DBH averaged 11.5 cm
- BIT averaged 2.75 3 meter sticks/tree
- Harvester cut and processed an average of 48.6 trees of 88 cubic feet per PMH.

Forwarder

N = 12 turns.
Forwarder hauled an average of 62 Ft^3/turn, and averaged 185.9 Ft^3/PMH. The average cycle time was 22 minutes for an average forwarding distance of 265 feet.

Harvester Time Distribution

Work Element	Total Time/Tree
Travel, Empty (%)	20.0
Position and Shear (%)	16.7
Travel with Tree (%)	14.7
Process (Limb, buck, bunch) (%)	48.6

Forwarder Time Distribution

Travel, Empty (%)	7.6
Loading (%)	43.7
Driving while loading (%)	13.9
Travel, loading (%)	5.8
Unloading (%)	19.2
Interruptions (%) (less than 15 min.)	9.8

OTHER COMMENTS: The system attempts to match resource dimensions with investment level.

CITATION: Biltonen, F.E., et.al. 1976. MECHANIZED THINNING OF NORTHERN HARDWOOD POLE STANDS: METHODS AND ECONOMICS. USDA Forest Service, North Central Forest Experiment Station. Research Paper NC-137.

MACHINE SYSTEM:
Rome grapple shear on a JD S44 Loader → Clark Ranger 667 GS grapple skidder → Barko Loader → Trelan D-60 W.T. Chipper → 2 tractors and 4 vans

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Trees were felled with the feller-buncher, placed in piles and skidded to the landing with the grapple skidder. The loader passed whole trees to the chipper.

DESCRIPTION OF OPERATION: 4 Thinning Treatments.
1) Strip - 10 foot wide strips on 30 ft. centers.
2) Shelterwood - Residual BA of 59 Ft^2/acres.
3) Selective - Residual BA of 67 Ft^2/acre.
4) 10 foot wide corridors cut on 80 foot centers. Residual BA of 57 Ft^2/acre.

DESCRIPTION OF SITE: Michigan upper Peninsula. Sandy loam soil. Topography was flat with minor changes in elevation.

DESCRIPTION OF STAND: Pole-sized stand of mixed hardwood with a few sawlog trees. The stand contained 13 cords of hardwood pulpwood and 2,700 bd.ft. of small sawtimber per acre. There were 216 trees per acre with diameters ranging from 2" to 28" DBH. Basal area was 99.96 Ft^2/acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:
Grapple skidder[1] operating rates by treatment

Treatment	Skids	Average distance per skid		Average stems	Average weight per	Total time per skid	
		Road	Woods	per skid	skid	Without delay;	Actual
	No.	*feet*		*No.*	*Tons*	*Minutes*	
Strip	214	517	638	9.1	1.67	4.5	6.25
Shelterwood	200	1,368	622	11.1	2.43	5.0	9.35
Selective	173	1,186	711	11.2	2.61	4.7	10.98
Strip with selective	219	518	625	10.7	2.42	4.5	8.56

[1]Clark Ranger 667.

Feller-buncher[1] operating rates by treatment

Treatment	Felling cycles	Stems per cycle	Stems per skidder bunch	Stems per hour without delays	Actual
Strip	672	2.90	9.1	139.2	88.8
Shelterwood	858	2.90	11.1	133.8	87.0
Selective	709	2.95	11.2	137.4	80.0
Strip with selective	933	2.70	10.7	128.4	85.2

[1]John Deere 544 with Rome Shear.

Chipper[1] operating rates for entire study

Vans	Stems	Chipping cycles	Stems per cycles	Stems per van	Minutes per van without Delays	Actual	Tons per hour without delays	Actual
	--------No.--------							
73,75	8,570	5,336	1.6	116.2	41.35	83.82	34.82	17.18

[1]Trelan.

	Time Distribution		
	F-B	Skidder	Chipper & Loader
Productive Time (%)	67	62	49
Repair/Maint. (%)	5	9	15
Interference Delay (%)	3	16	28
Other Non Productive (%)	25	13	8

OTHER COMMENTS: Strip thinning was considered to be the best option.

CITATION: Williamson, C.K. III. 1975. A STUDY OF FACTORS AFFECTING PRODUCTIVITY AND COST OF WHOLE-TREE CHIPPING IN SOUTHERN PINE PLANTATIONS. Masters Thesis. Agricultural and Mechanical College. Louisiana State University.

MACHINE SYSTEM: Model 75 Morbark Metro Chiparvestor equipped with a hydraulic knuckle-boom loader. 75-inch chipper disc. Chipping capacity = 21 inches diameter. (2) John Deere "544-B" feller-bunchers, (1) John Deere "T40" grapple skidder, (5) Diesel haul trucks with 40-foot chip vans.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-bunchers → grapple skidder → chipper → trucks (chip vans)

DESCRIPTION OF OPERATION: First thinning of planted loblolly pine, clear-cutting alternate strips 16 feet wide. The system produced whole tree chips.

DESCRIPTION OF SITE: Five miles southeast of Jena, Louisiana. Rolling terrain and well-drained sandy loam.

DESCRIPTION OF STAND: 18 year old loblolly pine plantation. Average diameter = 5.5 inches. Average tree height = 35 feet.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Study Period: February 1975

Productivity of Model 75 Morbark Chiparvestor

Total time period (min.)	1,317.38
Productive time (%)	42.22
Delay time (%)	57.78
Loading & processing time/load (min.)	19.58 to 39.85
Loading & processing time/tree (min.)	0.10 to 0.21
Average tree diameter (inches)	5.74
Average tree height (ft)	36.52
Avg. Volume (cords/van load)	10.46
Avg. no. of trees/load	197
Overall production (cords/hr)	9.53

Summary of Individual Productive Capacities

	Trees/ Hour	Cords/ Hour
Felling and Bunching (two feller-bunchers)	338.4	17.26
Skidding (1 grapple skidder)	204.0	10.41
Chipping and Loading (75-inch chipper)	358.2	18.27
Hauling (5 trucks/40-Ft. Vans)	330.0	16.85

OTHER COMMENTS:

CITATION: Williamson, C.K. III. 1975. A STUDY OF FACTORS AFFECTING PRODUCTIVITY AND COST OF WHOLE-TREE CHIPPING IN SOUTHERN PINE PLANTATIONS. Masters Thesis. Agricultural and Mechanical College, Louisiana State University.

MACHINE SYSTEM: Model 18 Morbark Metro Chiparvester (58-inch chipper disc) 18 inch chipping capacity. Telescopic loader (1) John Deere 544-B feller-buncher, (2) Clark Ranger 664 grapple skidders, (4) Diesel haul trucks with 35-foot chip vans.

OPERATOR RATING: Inexperienced crew.

DESCRIPTION OF SYSTEM:
Feller-buncher → Grapple skidders → Chipper → Trucks (chip vans)

DESCRIPTION OF OPERATION: First thinning of planted loblolly pine. Clear-cutting alternate strips 16 feet wide. Produced whole tree "total chip".

DESCRIPTION OF SITE: Five miles southeast of Jena, Louisiana. Rolling terrain and well-drained sandy loam .

DESCRIPTION OF STAND: 18 years old loblolly pine plantation. Average diameter = 55 inches. Average tree height = 35 feet.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Study Period: February 1975

Productivity of Model 18 Morbark Chiparvestor	
Total time period (min.)	1,894.29
Productive time (%)	32.22
Delay time (%)	67.78
Loading & processing time/load (min.)	27.07 to 40.96
Loading & processing time/tree (min.)	0.11 to 0.31
Average tree diameter (inches)	5.33
Average tree height (ft)	34.28
Avg. Volume (cords/van load)	9.20
Avg. no. of trees/load	187
Overall production (cords/hr)	5.42

Summary of Individual Productive Capacities

	Trees/ Hour	Cords/ Hour
Felling and Bunching (two feller-bunchers)	169.2	8.63
Skidding (1 grapple skidder)	192.4	9.82
Chipping and Loading (75-inch chipper)	311.4	15.88
Hauling (5 trucks/40-Ft. Vans)	200.0	10.20

OTHER COMMENTS: Other than truck delays, there were no major delay problems associated with this operation.

CITATION: Corwin, M.L. 1988. A DOCUMENTATION AND ANALYSIS OF THE PHYSICAL, OPERATING AND BUSINESS ENVIRONMENTS FOR SMALL TREE HANDLING AND HARVESTING SYSTEMS. MS Thesis, Department of Forestry, Virginia Polytechnic Institute and State University.

MACHINE SYSTEM:
(1) Feller-Buncher → (2) Grapple Skidder → (1) Mobile Chipper → set out trucks.

OPERATOR RATING: The experience of the 7 man crew ranged from 8 to 38 years.

DESCRIPTION OF SYSTEM:
(1) Hydrop Ax 411B feller-buncher with 16 inch head → (2) Timberjack 450 grapple skidders with parallelogram archs → (1) Morebark 22 Total Chiparvestor.

DESCRIPTION OF OPERATION: Prelogging operation producing whole-tree chips. All pine and hardwoods less than 8 inches in diameter were felled and chipped. Most brushy material was removed during felling and much of it was sent through to chipper.

DESCRIPTION OF SITE: Coastal plain of Alabama.

DESCRIPTION OF STAND: A 20 year old natural stand of mixed pine and hardwood.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:
Skidder Productivity

Time per Turn Interval Midpoint (Minutes)	Relative Freq.		Cumulative Relative Freqency			Times per Bunch Class Minimum	Relative Frequency	Cumulative Relative Frequency
Skidder No. →	1	2	1	2				
2	.04	.05	.04	.05		18	.12	.12
3	.07	---	.11	.05		20	.12	.24
4	.07	.18	.18	.23		22	.08	.32
5	.43	---	.61	.23		24	.20	.52
6	.14	.27	.75	.50		26	.12	.64
7	.04	.18	.79	.68		28	.08	.72
8	.11	.09	.90	.77		30	---	.72
9	.04	.14	.94	.91		32	.04	.76
10	---	.05	.94	.96		34	.12	.88
11	.04	---	.98	.96		36	.08	.96
12	---	---	.98	.96		>36[1]	.04	1.00
13	---	.05	.98	1.01				
14	.04		1.02					

* Skidder 1: 28 cycles recorded.
Skidder 2: 22 cycles recorded.
25 skidder bunches tallied.

Feller-Buncher Productivity

Time per Bunch Interval Midpoint (Minutes)	Relative Freq.	Cumulative Relative Freqency	Times per Bunch	Relative Frequency	Cumulative Relative Frequency
.25	.05	.05	2	.09	.09
.50	.05	.10	3	---	.09
.75	---	.10	4	.05	.14
1.00	.27	.37	5	.05	.19
1.25	.14	.51	6	.09	.28
1.50	.23	.74	7	.14	.42
1.75	.18	.92	8	.14	.56
2.00	.05	.97	9	.18	.74
2.25	.05	1.02	10	.05	.79
			11	.05	.84
			12	.05	.89
			13	.09	.98
			14	---	.98
			15	---	.98
			16	---	.98
			17	---	.98
			18	.05	1.03

Chipper productivity (in terms of truck loads)

Load Number	Time to Load (Minutes)	Load Weight (Tons)	Number of Skidder Bunches	Trees per Ton[1]
1	28.75	22.08	11	13.45
2	39.25	22.20	10	12.16
3	35.00	22.14	12	14.63
4	23.25	23.15	13	15.16
5	29.32	21.04	10	12.83
6	26.25	21.38	10	12.63
Mean	30.30	22.00	11	13.48

[1] Assuming 27 trees per skidder bunch.

OTHER COMMENTS:

CITATION: Moore, G. 1980. MULTIPLE-STEM LOGGING SYSTEMS: HYDRO-AX 411 FELLER BUNCHER AND CHAIN FLAIL DELIMBER. American Pulpwood Association. 82-P-3.

MACHINE SYSTEM: Hydro-Ax 411 feller-buncher. Head capacity = 16" D.O.B. at base. It can be tilted fore and aft but not sideways. Hydro-Ax 411 chain flail delimber. 8 chains, maximum RPM = 400. Effective delimber width = 2 inches. Clarke 667 grapple skidder.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Method 1: Feller-Buncher → Flail Delimber → (Manual delimbing and topping) → Grapple Skidder → Loader.
Method 2: Feller-Buncher → Flail Delimber (1 pass) → Grapple Skidder → Flail Delimber → Knuckle Boom Loader.

DESCRIPTION OF OPERATION: Thinning. For outrows, the machine sheared and accumulated trees as it went. When the accumulator was full, the bunch was placed in the outrow. For selective thinning, the operator layed bunches in the outrow or in the residual stand.

DESCRIPTION OF SITE: Slash pine sites at Beerburrum State Forest and Radiata pine sites at Stockdale Tree Farm in Victoria, Australia. The terrain of all sites was flat except for one site where slopes of up to 18% were encountered. Conditions were dry.

DESCRIPTION OF STAND: Slash pine. Radiata pine plantation.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Summary of Feller-Buncher Productivity

Species	Age (Yrs.)	Average Stem Volume (m^3)	Thinning Prescription	No. of Trees	No. of Machine Bunches	Total Time (min)	Production (m^3/Hour)
P. Elliottii	14	0.16	Outrow & Select	150	79	55.6	26.1
P. Elliottii	14	0.18	Outrow	281	131	78.7	38.5
P. Radiata	11	0.12	Outrow	610	120	148.6	30.8
P. Radiata	14	0.12	Select	35	12	17.0	14.7
P. Radiata	22	0.30	Select	53	---	26.0	37.3
P. Radiata	11	0.22	Outrow	55	---	39.6	18.4

Chain Flail Delimber Productivity

Species	Age	Average Stem Volume (m^3)	Production (m^3/hr)	Speed (km/hr)
P. Elliottii	14	0.18	82.0	1.15
P. Radiata	11	0.12	40.8	1.00
P. Radiata	14	0.12	23.6	1.20
P. Radiata	22	0.30	33.5	1.26
P. Radiata	11	0.12	~50	Combined productivity 1st and 2nd pass

OTHER COMMENTS: When the feller-buncher is working across slopes, the lack of side tilting capacity of the head led to some tangling between the tops of the trees in the head, and the residual trees in the plantation. In steeper country traction was a problem when backing uphill with trees in the head.

CITATION: Stokes, B.J. and B.L. Lanford. 1985. PREBUNCHING AND SKIDDING FUNCTIONS IN THINNINGS. Transactions of the ASAE. ASAE Paper No. 85-1594.

MACHINE SYSTEM:
Mor-Bell Logger → Cat 518 grapple skidder

OPERATOR RATING:

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Trees were skidded with the More-Bell Logger using narrow 3 meter corridors. The trees were consolidated into large bundles for removal with a grapple skidder using wider (>5m) corridors. Thinning.

DESCRIPTION OF SITE: Alabama.

DESCRIPTION OF STAND: 15 year old loblolly pine stand containing 335 trees per acre. The average tree was 5.4 inches in diameter at breast height.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Summary of prebunching data

Element	Unit	Obs.	Mean	Std. Dev.	Range
Travel empty	min/cycle	24	0.27	0.08	0.09 - 0.86
Empty distance	(m)	24	13.6	8.8	2.7 - 36.9
	(ft)		(44.5)	(29.0)	(9.0 - 121.0)
Travel loaded	min/cycle	40	0.29	0.15	0.09 - 0.64
Loaded distance	(m)	40	11.9	7.1	2.7 - 28.1
	(ft)		(38.9)	(23.2)	(9.0 - 92.0)
Pick-up load	min/cycle	40	0.28	0.13	0.08 - 0.80
Bunches/cycle		40	1.2	0.4	1 - 2
Stems/cycle		40	6.6	2.7	2 - 13
Volume/cycle	(m^3)	40	0.58	0.24	0.18 - 1.20
	(Ft^3)		(20.9)	(8.5)	(6.6 - 42.7)
Basal area/cycle	(m^2)	40	0.09	0.04	0.03 - 0.19
	(Ft^2)		(1.01)	(0.40)	(0.34 - 2.00)
Drop load	min/cycle	40	0.11	0.04	0.05 - 0.21
Delays					
Time/delay	(min)	4	0.55	0.41	0.19 - 0.97
Turn/cycle	(min)	40	0.05	0.01	0.0 - 0.97

Summary of skidding data

Element	Unit	Obs.	Mean	Std. Dev.	Range
Travel empty	min/cycle	23	0.99	0.29	0.57 - 1.52
Empty distance	(m)	23	86.8	35.6	30.8 - 155.2
	(ft)		(284.7)	(116.7)	(101.0 - 509.0)
Travel loaded	min/cycle	18	0.92	0.39	0.458 - 1.82
Loaded distance	(m)	23	89.0	39.3	30.8 - 155.2
	(ft)		(291.8)	(128.9)	(101.0 - 509.0)
Pick-up load	min/cycle	21	0.60	0.29	0.17 - 1.51
Bunches/cycle		21	1.4	0.5	1 - 2
Stems/cycle		21	12.1	8.1	2 - 26
Volume/cycle	(m^3)	21	1.04	0.68	0.15 - 2.32
	(Ft^3)		(37.2)	(24.3)	(5.5 - 83.0)
Basal area/cycle	(m^2)	21	0.17	0.11	0.03 - 0.37
	(Ft^2)		(1.80)	(1.16)	(0.28 - 3.96)
Gate delimbing	min/cycle	11	2.39	1.44	0.56 - 4.64
Drop load	min/cycle	21	0.23	0.08	0.09 - 0.36
Landing maintenance	min/cycle	19	0.34	0.18	0.10 - 0.83

OTHER COMMENTS:

CITATION: Corwin, M.L. 1988. A DOCUMENTATION AND ANALYSIS OF THE PHYSICAL, OPERATING AND BUSINESS ENVIRONMENTS FOR SMALL-TREE HANDLING AND HARVESTING SYSTEM. MS Thesis, Department of Forestry, Virginia Polytechnic Institute and State University.

MACHINE SYSTEM:
(1) Feller-Buncher → (1) Grapple Skidder → Gate Delimbing → Grapple Loader

OPERATOR RATING: Feller-Buncher & Loader - 3.5 years. Skidder - 5 years.

DESCRIPTION OF SYSTEM: 2 man crew.
Morbell Mark IV = 15 inch Morbark shear → Franklin 170 grapple skidder → trailer-mounted Prentice 210 loader → contract trucking.

DESCRIPTION OF OPERATION: Prelogging tree length pulpwood. Feller-buncher cut swath through the stand, starting at the deck and moving outwards radially. The bunches were positioned with the butts facing the landing. The bunches were skidded to the deck and gate delimbed.

DESCRIPTION OF SITE: Upper coastal plain of Virginia.

DESCRIPTION OF STAND: 30 year old natural stand of loblolly pine. Volume estimated to be 11 cords of pulpwood and 1,200 bd.ft. of sawtimber per acre. DBH ranged from 4 to 8 inches.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Skidder (N = 28)

Time per Turn Interval Midpoint (Minutes)	Relative Freq.	Cumulative Relative Freqency		Trees per Turn	Relative Frequency	Cumulative Relative Frequency
2	.07	.07		6	.18	.18
3	.07	.14		7	.04	.22
4	.43	.57		8	.11	.33
5	.36	.93		9	.18	.51
6	.07	1.00		10	.21	.72
				11	.11	.83
				12	.11	.94
				13	.07	1.01

Feller Buncher (N = 45)

Time per Bunch Interval Midpoint (Minutes)	Relative Freq.	Cumulative Relative Freqency		Times per Bunch	Relative Frequency	Cumulative Relative Frequency
.25	.04	.04		1	.31	.31
.50	.16	.20		2	.24	.55
.75	.24	.44		3	.36	.91
1.00	.22	.66		4	.04	.95
1.25	.16	.82		5	---	.95
1.50	.16	.98		6	.04	.99
1.75	.02	1.00				

Loader (N = 5)

Load Number	Time to Load (Minutes)	Number of Trees	Load Weight (Tons)	Trees per Ton
1	43.25	90	18.69	4.82
2	60.00	96	19.38	4.95
3	44.50	100	19.28	5.12
4	40.00	93	17.39	5.35
5	32.00	121	20.62	5.87
Mean	43.95	100	19.07	5.22

OTHER COMMENTS:

CITATION: Corwin, M.L. 1988. A DOCUMENTATION AND ANALYSIS OF THE PHYSICAL, OPERATING AND BUSINESS ENVIRONMENTS FOR SMALL-TREE HANDLING AND HARVESTING SYSTEMS. MS Thesis, Department of Forestry, Virginia Polytechnic Institute and State University.

MACHINE SYSTEM:
Feller-buncher → grapple skidder → gate delimbing → grapple loader

OPERATOR RATING: Experience ranged from 6 years to 1/2 year.

DESCRIPTION OF SYSTEM: 5 man crew.
(1) Caterpillar 910 with Fleco 15 in. accumulating head → Caterpillar 518 grapple skidder → Prentice 150 loader → (1) tractor (2) trailers.

DESCRIPTION OF OPERATION: Thinning tree-length pine pulpwood. First the main skid trail was cleared, then parallel corridors were cut on 60 foot centers. Next, the feller-buncher thinned in between the corridors, depositing the trees in bunches with the butts near the edge of the corridor. The bunches were skidded to the landing where they were gate-delimbed and dropped at the landing.

DESCRIPTION OF SITE: Piedmont of Virginia.

DESCRIPTION OF STAND: 19 year old loblolly pine plantation. Average tree was 8.3 inches in DBH.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Feller-Buncher (N = 29)

Time per Bunch Interval Midpoint (Minutes)	Relative Freq.	Cumulative Relative Freqency		Trees per Bunch	Relative Frequency	Cumulative Relative Frequency
.25	.03	.03		1	.10	.10
.50	.14	.17		2	.17	.27
.75	.14	.31		3	.14	.41
1.00	.14	.45		4	.24	.65
1.25	.17	.62		5	.24	.89
1.50	.14	.76		6	.10	.99
1.75	.10	.86				
2.00	.10	.96				
2.25	.03	.99				

Skidder (N = 21)

Time per Turn Interval Midpoint (Minutes)	Relative Freq.	Cumulative Relative Freqency		Tree per Turn	Relative Frequency	Cumulative Relative Frequency
3	.14	.14		2	.05	.05
4	.19	.33		3	---	.05
5	.24	.57		4	.05	.10
6	.19	.76		5	---	.10
7	.10	.86		6	.10	.20
8	.05	.91		7	.10	.30
9	---	.91		8	.19	.49
10	.05	.96		9	.14	.63
11	---	.96		10	.05	.68
12	.05	1.01		11	.14	.82
				12	.10	.92
				13	.05	.97
				14	.05	1.02

Loader (N = 4)

Load Number	Time to Load (Minutes)	Number of Trees	Load Weight (Tons)	Trees per Ton
1	37.87	182	29.32	6.21
2	43.25	226	30.63	7.38
3	38.90	200	29.13	6.87
4	54.42	246	32.43	7.59
Mean	43.61	214	30.38	7.01

OTHER COMMENTS:

CITATION: Corwin, M.L. 1988. A DOCUMENTATION AND ANALYSIS OF THE PHYSICAL, OPERATING AND BUSINESS ENVIRONMENTS FOR SMALL TREE HANDLING AND HARVESTING SYSTEMS. MS Thesis, Department of Forestry, Virginia Polytechnic Institute and State University.

MACHINE SYSTEM:
(2) Feller-Buncher → Manual Delimbing → (2) Grapple skidders → (1) Slasher → (1) Loader

OPERATOR RATING: Experience of 8 man crew ranged from 9 to 20 years.

DESCRIPTION OF SYSTEM:
(2) Franklin 105 feller-bunchers (one with a 14-inch Tidewater head, the other with a Morbark 14-inch Rapid buncher) → Manual Delimbing → (1) Franklin 170 and (1) Clark 665D Skidder

DESCRIPTION OF OPERATION: A shortwood thinning operation. Every 5th row was removed by one feller-buncher while the other thinned in between rows. The bunches were manually delimbed and then skidded to the deck where they were bucked into 5 foot lengths by the slasher and then loaded.

DESCRIPTION OF SITE: Upper coastal plain of Virginia & North Carolina.

DESCRIPTION OF STAND: A loblolly pine plantation with a fair amount of hardwoods. The tract contained 15 cords/acre, with the average tree DBH = 6.5 inches.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Observed Feller-Buncher Productivity Data
#1, N = 10
#2, N = 24

Time per Turn Interval Midpoint (Minutes)	Relative Freq.		Cumulative Relative Freqency			Trees per Bunch	Relative Frequency		Cumulative Relative Frequency	
Feller-buncher No. →	1	2	1	2			1	2	1	2
.75	---	.04	---	.04		2	---	.08	---	.08
1.00	.20	---	.20	.04		3	---	.04	---	.12
1.25	.40	.04	.60	.08		4	.20	.25	.20	.37
1.50	.10	.04	.70	.12		5	.30	.33	.50	.70
1.75	.20	.08	.90	.20		6	.10	.17	.60	.87
2.00	.10	.13	1.00	.33		7	.40	---	1.00	.87
2.25		.13		.46		8		.08		.95
2.50		.08		.54		9		---		.95
2.75		.08		.62		10		.04		.99
3.00		.08		.70						
3.25		.08		.78						
3.50		.08		.86						
3.75		---		.86						
4.00		---		.86						
4.25		.04		.90						
4.50		---		.90						
4.75		.04		.94						
5.00		.04		.98						

Skidder Productivity
#1, N = 22
#2, N = 21

Time per Turn Interval Midpoint (Minutes)	Relative Freq.		Cumulative Relative Freqency			Trees per Turn	Relative Frequency		Cumulative Relative Frequency	
2	.05	---	.05	---		5	.05	---	.05	---
3	.09	.10	.14	.10		6	---	.05	.05	.05
4	.14	.05	.28	.15		7	.05	---	.10	.05
5	.18	.05	.46	.20		8	---	---	.10	.05
6	.18	.19	.64	.39		9	.05	---	.15	.05
7	.09	.19	.73	.58		10	.05	.05	.20	.10
8	.05	---	.78	.58		11	.09	.19	.29	.29
9	.09	.05	.87	.63		12	.09	.10	.38	.39
10	---	.05	.87	.68		13	.05	.10	.43	.49
11	.05	.05	.92	.73		14	.05	.05	.48	.54
12	.05	.14	.97	.87		15	.18	.10	.66	.64
13	---	.05	.97	.92		16	---	.05	.66	.69
14	---	---	.97	.92		17	.14	.14	.80	.83
15	---	---	.97	.92		18	.05	.05	.85	.88
16	---	.05	.97	.97		19	---	---	.85	.88
17	.05	---	1.02	.97		20	.14	---	.99	.88
18		---		.97		21	.05	.05	1.04	.93
19		---		.97		22		---		.93
20		.05		1.02		23		---		.93
						24		.05		.98
						>24 (39)		.05		1.03

Loader Productivity Data (N = 6)

Load Number	Time to Load (Minutes)	Number of Trees	Load Weight (Tons)	Trees per Ton
1	62.73	232	25.04	9.27
2	70.90	270	25.16	10.73
3	72.62	222	24.17	9.18
4	60.70	218	24.58	8.87
5	73.90	188	22.20	8.47
6	66.45	215	25.33	8.49
Mean	67.88	224	24.41	9.17

OTHER COMMENTS:

CITATION: Corwin, M.L. 1988. A DOCUMENTATION AND ANALYSIS OF THE PHYSICAL, OPERATING AND BUSINESS ENVIRONMENTS FOR SMALL TREE HANDLING AND HARVESTING SYSTEM. MS Thesis, Department of Forestry, Virginia Polytechnic Institute and State University.

MACHINE SYSTEM:
(2) Feller-bunchers → (2) grapple skidders → Manual limbing and topping → Skidder swing to main deck → grapple loader → set-out trailers

OPERATOR RATING: The experience of the 8 man crew ranged from 1/2 to 17 years.

DESCRIPTION OF SYSTEM:
(2) Franklin 105 feller-bunchers with 12 inch Tidewater heads → (2) Franklin 105 grapple skidders → Manual limbing and topping → Skidder swing → Barko 160 grapple loader → Fiat Allis 10B dozer for set out.

DESCRIPTION OF OPERATION: Prelogging operation producing tree-length pine pulpwood which removed 62% of the stand volume. Prelogging operations began at the deck and moved radially outward. Each skidder followed a feller-buncher and dragged felled material to the intermediate deck for delimbing. After dropping an unlimbed bunch at the intermediate deck, the skidder picked up a limbed bunch and dragged it to the main deck.

DESCRIPTION OF SITE: Upper coastal plain of Virginia.

DESCRIPTION OF STAND: Part natural and part seeded loblolly pine. The stand contained 17.9 cords per acre of pine and 2.7 cords per acre of hardwood. The average pine DBH = 7.4 inches. The average hardwood DBH = 8.8 inches.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Skidder Production (#1, N = 14, #2, N = 16)

Time per Turn Interval Midpoint (Minutes)	Relative Freq.		Cumulative Relative Freqency			Trees per Turn	Relative Frequency		Cumulative Relative Frequency	
Skidder No. →	1	2	1	2			1	2	1	2
3	---	.06	---	.06		8	.07	---	.07	---
4	.07	---	.07	.06		9	---	---	.07	---
5	.14	.06	.21	.12		10	.07	---	.14	---
6	.14	.06	.35	.18		11	.07	---	.21	---
7	.14	.31	.49	.49		12	.14	.25	.35	.25
8	---	.06	.49	.55		13	---	.06	.35	.31
9	.14	---	.63	.55		14	.07	.06	.42	.37
10	.14	.06	.77	.61		15	.21	.25	.63	.62
11	.07	.19	.84	.80		16	.14	.06	.77	.68
12	.07	.06	.91	.86		17	.07	.13	.84	.81
13	---	.13	.91	.99		18	.14	.06	.98	.87
14	---		.91			19		.06		.93
15	---		.91			20		---		.93
16	.07		.98			21		.06		.99

Feller-Buncher Production (#1, N = 15, #2, N = 15)

Time per Bunch Interval Midpoint (Minutes)	Relative Freq.		Cumulative Relative Freqency			Trees per Bunch	Relative Frequency		Cumulative Relative Frequency	
Feller-buncher No. →	1	2	1	2			1	2	1	2
.50	.07	---	.07	---		1	.07	---	.07	---
.75	.07	.15	.14	.15		2	.07	---	.14	---
1.00	.20	.27	.34	.42		3	.33	.33	.47	.33
1.25	.15	.33	.49	.75		4	.40	.33	.87	.66
1.50	.33	.07	.82	.82		5	---	.33	.87	.99
1.75	.15	.15	.97	.97		6	.07	---	.94	
2.00	---	.07	.97	1.04		7	.07		1.01	
2.25	.07		1.04							

Loader productivity

Load Number	Time to Load (Minutes)	Number of Trees	Load Weight (Tons)	Trees per Ton
1	40.94	128	25.41	5.04
2	43.84	137	28.08	4.88
3	41.33	130	26.68	4.87
4	42.01	140	26.53	5.28
5	35.44	148	27.54	5.37
Mean	40.71	137	26.85	5.09

OTHER COMMENTS:

CITATION: Stokes, B.J., B.L. Lanford and D.L. Sirois. 1982. MOR-BELL THINNING SYSTEM: FELLER BUNCHER, SKIDDER AND LOADER. Transactions of the ASAE. ASAE Paper No. 82-1590.

MACHINE SYSTEM:
Mor-Bell Thinning System: Mor-Bell feller-buncher, Mor-Bell Logger.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
1) Mor-Bell feller-buncher → 1) Mor-Bell skidder-loader → gate delimbing → Loaded on truck by Mor-Bell skidder-loader

DESCRIPTION OF OPERATION: Initial thinning where about 60% of the pine was removed. Select thinning was applied to the stands by using narrow access corridors on 66 foot spacing.

DESCRIPTION OF SITE: South Alabama, summer. Slopes ranged from 0-21%, and averaged 7%.

DESCRIPTION OF STAND: 14 year old loblolly pine plantation consisting of 85% loblolly pine and 15% mixed hardwood. Stand contained an average of 677 trees per acre.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree was 5.5 inches DBH, ranging from 1.2 to 11.9 inches.
Average tree was 42 feet tall, ranging from 13.4 to 73.3 feet.
Average tree contained 6.5 cubic feet.

PRODUCTION DATA:

	Feller-Buncher		Skidder-Loader	
Sample size	362 trees		57 turns	
	Avg.	SD	Avg.	SD
Cycle time (min)	0.71	0.49	4.92	2.29
Stems/cycle	2.9	1.4	5.6	2.4
Vol./stem (Ft^3)	6.5	2.8	---	---
Bunches/cycle	---	---	1.2	0.5
Vol./cycle (Ft^3)	18.85	---	21.2	7.1
Prod./PMH (Ft^3)	1,593	---	258	---
Skidding distance (ft)	---	---	284	151

* Cycle time for skidder loader includes gate delimbing and loading.

OTHER COMMENTS:

CITATION: Anon. 1978. CAT 235 HYDRAULIC LOG LOADER. Machinery Evaluation. Logging Industry Research Association, New Zealand. Volume 3, No. 4.

MACHINE SYSTEM: Harricana RA-150-XS log grapple mounted on a Cat 235 excavator. Modifications included an electrically controlled hydraulic system, extension of the track gauge and extra guarding.

OPERATOR RATING: 2 operators: one with experience, the other without experience.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Second thinning.

DESCRIPTION OF SITE: Kinleith Forest, New Zealand.

DESCRIPTION OF STAND: Radiata pine.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average log weight was 0.4 tonnes. The logs were classified as either short (2.4 m to 6 m), or longs (6 m to 12 m).

PRODUCTION DATA: Study Duration: 2 days

Operator	Unload Trailer		Load Truck		Loading Time
	(min)	(%)	(min)	(%)	(min/tonne)
Inexperienced	2.85	10	26.17	90	0.87
Experienced	1.58	7	19.60	93	0.65

Average truck load = 27.2 tonnes
Machine availabilty = 61%

OTHER COMMENTS:

CITATION: Deal, E.L. 1982. STEEP SLOPE FELLING AND BUNCHING IN SMALL TIMBER. *IN* Proceedings: "The Small Tree Resource: A Material Handling Challenge." Forest Products Research Society. Portland, Oregon. April 19-21, 1982. pp. 111-128.

MACHINE SYSTEM: Kockums 880 Tree King feller-buncher. Equipped with a chainsaw feller-buncher head capable of cutting hardwoods up to 22 inches ground line diameter. Line skidder.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-buncher → Line skidder

DESCRIPTION OF OPERATION: Thinning. The 880 felled and bunched timber for subsequent skidding by a line skidder.

DESCRIPTION OF SITE: Near Morganston, North Carolina. Slopes: 0 to 100%. Heavy rain during the study period.

DESCRIPTION OF STAND: Mixture of upper piedmont and mountain species.
DBH = 2 to 28 inches. Tree height = 30 to 100 feet.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average DBH = 9.23 in.

PRODUCTION DATA:

Productivity by Diameter Class, Based on Average Slope of 35%

DBH (in)	Vol/tree (lbs)	Trees/ton	Time/Tree*(min)	Time/Ton (min)	Tons/Hour
2	19.72	101.40	0.53	53.74	1.12
4	107.8	18.55	0.57	10.57	5.68
6	245.87	8.13	0.60	4.88	12.30
8	475.00	4.21	0.62	2.61	22.99
10	1,088.71	1.84	0.65	1.20	50.00
12	1,747.02	1.15	0.73	0.84	71.42
14	2,390.18	0.83	0.80	0.66	90.91
16	3,242.96	0.62	0.87	0.54	111.11
18	4,120.56	0.48	0.99	0.48	125.00

*Time/Tree (min) assumes 60 percent utilization.

OTHER COMMENTS: The 880 felled and bunched on slopes up to 63% on firm soils and 60% on loose soil.

CITATION: Holmes, R. 1986. LOKOMO 933C: MINOR FLAWS ON MIGHTY MACHINE. Canadian Forest Industries. 106(11):B16-B18.

MACHINE SYSTEM: Lokomo 933C Clambunk Skidder.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Feller-Buncher → Clambunk Skidder

DESCRIPTION OF OPERATION: Clearcutting.

DESCRIPTION OF SITE: Lac St. Jean, Quebec. Terrain is rough with slopes occasionally exceeding 30%.

DESCRIPTION OF STAND: Black spruce with average DBH of 8 to 10 inches.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Trees average 0.111 m^3 each.

PRODUCTION DATA: Study Duration: One month

Availability (%)	85
Utilization (%)	81.4
Avg. Trees/SMH	178
Avg. Trees/PMH	219
Avg. Forwarding Distance (ft)	1,264

OTHER COMMENTS:

CITATION: Reymond, Keith. 1988. FORWARDER OPERATIONS IN AUSTRALIA. Logging Industry Research Association, New Zealand. Vol. 13, No. 27.

MACHINE SYSTEM: 1/2 year old Kockums forwarder 85-35, with six wheels, engine power of 132 kW, and a load capacity of 15 tonnes.

OPERATOR RATING: The operator was highly skilled with approximately five years experience in forwarder operation.

DESCRIPTION OF SYSTEM: System consisted of a Timbco 2518 feller-buncher, a Kockums 85-41 Logma delimber, a Valmet 902 harvester and two Kockums six wheel forwarders.

DESCRIPTION OF OPERATION: The Timbco feller-buncher felled the outrow, thinned the two adjacent rows on each side and bunched the wood for further processing. The forwarder then hauled wood to the landings.

DESCRIPTION OF SITE: Ground conditions were dry, the soil was a hard packed loam, and slopes ranged from 0-19 degrees. Maximum slope for thinnings operations was 20 degrees. Outrows were cut directly up the slope.

DESCRIPTION OF STAND: First thinnings of radiata pine, planted in 1963. Average extracted log size (5.4 m length) was 0.08 m^3.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Table 1. Work Cycle of the Kockums 85-35 Forwarder (N = 10)

Element	Mean per Cycle (min)	% of Total Cycle
Travel Empty	3.18	11.9
Load	13.16	49.3
Move (while loading)	1.36	5.1
Travel Loaded	2.54	9.5
Position	0.16	0.6
Unload (to roadside)	6.28	23.6
Total Cycle (net of delays)	26.68	100.0
Empty Distance (m)	188	
Loaded Distance (m)	146	
No. of Pieces Loaded	112	
Volume per load (tonnes)	9.0	

OTHER COMMENTS: The disadvantages of forwarders are their high capital cost, instability on excessive sideslopes and inability for extraction from inaccessible areas.

CITATION: Hochrein, P.H. 1986. PREBUNCHING VERSUS FULL-CYCLE YARDING IN DIFFERENT THINNING INTENSITIES. MF Paper, Department of Forest Engineering, Oregon State University.

MACHINE SYSTEM:
Prebunch with a Koller K300 → Swing with a Madill 071 (with MSP carriage)

OPERATOR RATING: Experienced.

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: 12 foot wide corridors were layed out prior to harvesting. The cutters used the corridors to directionally fall the timber. The Koller prebunched the timber in the corridor prior to swing-yarding with the Madill.

DESCRIPTION OF SITE: Willamette National Forest, Oregon. Slopes ranged from 0-85%, and averaged about 42%.

DESCRIPTION OF STAND: 65 year old second growth Douglas fir stand containing 350 trees per acre. The average diameter at breast height was 11.3 inches. Volume was estimated to be 21.5 MBF/acre of trees greater than or equal to 8 inches DBH.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Mostly 34 foot lengths.
Average log size was 15.0 cubic feet (64.9 board feet)

PRODUCTION DATA:

		Prebunch		Swing	
Variable	Explanation	Average	Range	Average	Range
Volume/hour	(Board feet)	537	147-1,432	1,085	252-3,288
Time/turn	(minutes)	4.62	1.44-13.86	5.04	2.47-11.23
SYD (ft)	Slope yarding distance	481	60-1,005	434	70-1,000
LYD (ft)	Lateral yarding distance	64	18-135	3	0-20
Logs/turn		2.53	1-5	5.79	1-19
Slope (%)	Ground slope where logs were hooked	41	19-85	42	0-75
YUM	Number of unmerch. logs yarded			0.74	0-6

Delay Free Regression Models*

Prebunching with Koller -

Cunits/Hour = 730.9 - 0.3121 (SYD) - 2.008 (LYD) + 136.8 (LOGS) - 6.327 (SLOPE) [no R^2]

Time/Turn (min) = -1.206 + 0.002334 (SYD) + 0.01057 (LYD) + 0.6446 (LOGS) + 0.05662 (SLOPE) [$R^2 = 0.63$]

Swing with Madill -

Cunits/Hour = 586.7 - 06681 (SYD) + 140.2 (LOGS) - 43.5 (YUM) [$R^2 = 0.62$]

Time/Turn (min) = 2.936 + 0.003521 (SYD) + 0.09862 (LOGS)

* Approximately 18 percent of the time was spent in delay for both the prebunching and swing operation.

OTHER COMMENTS:

CITATION: Kellogg, L.D. and E. Aulerich. 1977. PREBUNCH AND SWING TECHNIQUE MAY REDUCE YOUR THINNING COSTS. Forest Industries. 104(2):30-32.

MACHINE SYSTEM: Prebunching machine. Modern logging equipment, Gearmatic 9 winch powered by a 47 HP Volkswagon engine. Yarder - Schield Bantam T-350 rigged as a slack line system with a Maki carriage.

OPERATOR RATING:

DESCRIPTION OF SYSTEM: Prebunching was done with the winch. The operator pulled the line to the logs, hooked a turn and then winched the log to the corridor. Bunches were then swung to the landing using the yarder.

DESCRIPTION OF OPERATION: Thinning operation, removing 36% of volume.

DESCRIPTION OF SITE: Average slope was 25%.

DESCRIPTION OF STAND: A 35 to 40 year old Douglas-fir stand containing 29 MBF (Scribner) per acre. Average diameter at breast height was 12 inches.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Average Yarding Conditions

	Single Drum (prebunching)	Mobile yarder (swinging)
Yarding distance (ft)	---	178
Lateral distance (ft)	76	---
No. Logs/turn	1.3	2.8
Vol/turn (bd.ft. (Ft^3))	124 (20.7)	254 (42.3)
No. chokers	1.4	2
Lead angle (deg.)	28.3	110.8
Time/turn (min)	6.10	3.42
Vol/hour (bd.ft.)	1,222	4,452

Prebunching:

Total Turn Time (min) = 2.890 + 0.029 (slope distance) + 0.011 (lead angle) + 0.037 (turn volume in cu. ft.) + 2.110 (number of chokers) + 1.78[a]

a = delay and moving time constant [$R^2 = 0.39$]

Swinging:

Total Turn Time (min) = 1.094 + 0.004 (slope distance) + 0.005 (lead angle of decks to skyline) + 0.009 (turn volume in cubic feet) + 0.64[b]

b = delay and moving carriage stop [$R^2 = 0.34$]

OTHER COMMENTS:

1) When logs were prebunched in corridor, the turn time was reduced by 35% and production per day more than doubled.
2) Prebunching can reduce yarding cost by as much as 24%.

CITATION: Zelinsky, C.R. 1980. OPERATIONAL PREBUNCHING, A LOGGERS APPLICATION TO REDUCE SKYLINE THINNING COSTS. MF Paper, Department of Forest Engineering, Oregon State University.

MACHINE SYSTEM: Prebunching machine: 2 speed Skagit GO-10 drumset mounted on a dump truck. Swing machine: Madill 071 yarder with a Danebo S-40 MSP carriage.

OPERATOR RATING: Crew members had at least 2 years of experience.

DESCRIPTION OF SYSTEM:
Prebunch with Skagit → Swing with Madill → Deck and load with a Bantam C-366 loader with a Danebo heel-boom.

DESCRIPTION OF OPERATION: Thinning. The fellers did not use directional falling, and bucked the trees at the stump into 35 and 41 foot logs. The skagit yarded the logs into a deck near the prebunching spar in the corridor. Swinging was then performed with the Madill 071.

DESCRIPTION OF SITE: Linn county, Oregon. Slopes ranged from 25 to 70%.

DESCRIPTION OF STAND: 60 to 90 year old Douglas fir and western hemlock. The stand contained an average of 93.75 cunits/acre and 70 stems/acre. The average DBH = 17 inches. 6.25 cunits/acre were marked for thinning.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA: Study Period: August 9 to September 30, 1979.

Summary of Volume Production for Prebunching

Crew	Delay-free production (cunits/hour)	Production with operating delays (cunits/hour)	Production with all delays (cunits/hour)
With owner/operator as a chokersetter	9.50	5.75	5.19
Without owner/operator as a chokersetter	6.56	4.27	3.37
Combination	8.15	5.09	4.32

Summary of Observed Time per Unit Volume
Required for Prebunching
Spar Changes and Corridor Changes

Crew	Delay-free time (min./cunit)	Time with operating delays (min./cunit)	Time with all delays (cunits/hour)
With owner/operator as a chokersetter	0.12	0.20	0.22
Without owner/operator as a chokersetter	0.18	0.28	0.36
Combination	0.14	0.23	0.27

Swing Cycle Production Summary

Delay-free production (cunits/hr)	Production with operating delays (cunits/hr)	Production with all delays (cunits/hr)
16.23	14.4	13.22

Yarding System Mechanical Availability and Utilization

		Time: Minutes per Turn					
		Productive		Delays			
Machines (Crew)	No. of Shifts	Regular Cycle	Change Yarding roads and/or blocks	Mechanical	Other non-mechanical	Mechanical Availability (percent)	Utilization (percent)
GU-10 with owner/operator	5	4.60	1.14	0	0.62	100	90
GU-10 without owner/operator	2	6.03	1.21	0	1.93	100	79
GU-10 Combination	7	5.15	1.17	0	1.13	100	85
Madill 071	5	5.50	0.60	0	0.55	100	92

<u>Prebunching Yarding Cycle - Regression Equations</u>

Outhaul	= 0.4157 + 0.0035 (LATSD) + 0.0729 (CREW)	[R^2 = 0.1599 N = 151]
Hook	= 1.0289 + 0.6078 (CREW)	[R^2 = 0.1965 N = 151]
Inhaul	= 0.2842 + 0.0050 (LATSD)	[R^2 = 0.2781 N = 151]
DF Time	= 1.242 + 0.0154 (LATSD) + 0.00157 (SDIST) + 0.9976 (CREW)	[R^2 = 0.4332 N = 151]

Outhaul = Outhaul time (min.)
Hook = Hook time (min.)
Inhaul = Inhaul time (min.)
DF Time = Relay-free time (min.)

LATSD = Lateral Slope Distance, Ft.
CREW = zero-one dummy variable. Zero when the owner/operator was the chokersetter and one when he was not
SDIST = The slope distance down the corridor to the prebunching spar from the yarder.

OTHER COMMENTS: The main contributor to non-operating delay time was the re-rigging time associated with breaking the prebunching line.

CITATION: Miyata, E.S., et. al. 1984. FIELD EVALUATION OF MENZI-MUCK FELLER-BUNCHER ON DIFFICULT TERRAIN IN S.E. ALASKA. *IN* Proceedings of Mountain Logging Symposium, West Virginia University. June 5-7, 1984. pp. 263-280.

MACHINE SYSTEM: 5000 T2 Menzi Muck with 54 hp diesel engine. Maching was fitted with a 12-inch shear without accumulator.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:

DESCRIPTION OF OPERATION: Partial cut. Thinning method consisted of clearcutting 16-18 ft. wide corridors for later cable yarding and selectively thinning the areas between corridors.

DESCRIPTION OF SITE: S.E. Alaska. Soft, wet soils with slopes ranging to 63 percent. The area was logged 40 years ago, and there was a lot of logging debris.

DESCRIPTION OF STAND: Dense, even-aged stand of western hemlock and sitka spruce. The stand contained 447 stems per acre of trees greater than 5 inches DBH, and 2,275 stems per acre of trees 1 to 4.9 inches DBH.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:

PRODUCTION DATA:

Total trees sheared	455
Scheduled hours	17.7
Productive hours	9.8
Productivity/SMH	26 stems
Productivity/PMH	46 stems

OTHER COMMENTS:

CITATION: Massey, G.F. 1978. LOGMA LIMBER-BUNCHER INTRODUCED INTO AUSTRALIA. Australian Forest Industries Journal. January 1978. pp. 49, 50, 52, 54.

MACHINE SYSTEM: Logma T-310 limber-buncher with telescopic boom. The boom grips, delimbs and bucks. Case 850 feller-buncher.

OPERATOR RATING:

DESCRIPTION OF SYSTEM:
Feller-buncher → Limber-buncher
Fallers → Limber-buncher

DESCRIPTION OF OPERATION: A thinning operation producing sawlogs and pulpwood from a softwood plantation.

DESCRIPTION OF SITE: Morwell, Victoria, Australia. Terrain varying from 15° to 19° in slope.

DESCRIPTION OF STAND: 7 ft. x 7 ft. radiata pine plantation.

MATERIAL SIZE DISTRIBUTIONS AND LANDING INVENTORY:
Average tree volume = 0.275 m^3 (thinning site).

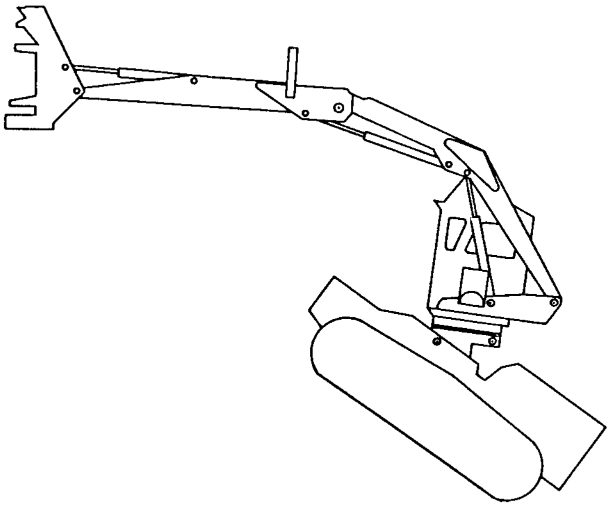
PRODUCTION DATA: Third Thinning

	Logma Production				
Avg. Tree (m^3)	0.3	0.3	0.45	0.45	0.49
Production/machine hour (m^3)	11	18	17	18.1	16
Slope	0°-10°	0°-10°	10°-15°	10°-15°	15°-19°
Falling type	Manual	Mech.	Mech.	Mech.	Mech.

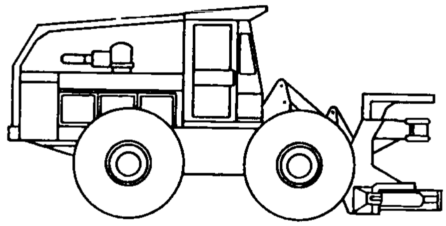
OTHER COMMENTS:

APPENDIX A. DEFINITIONS AND ILLUSTRATIONS OF TYPICAL MACHINERY

FELLER-BUNCHER



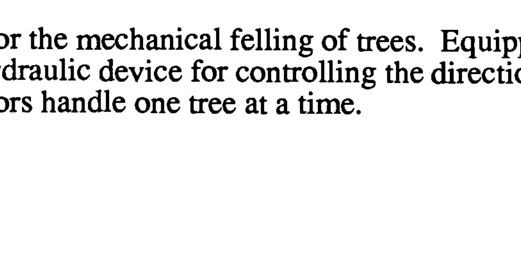
Leveling, swing-boom



Fixed-shear

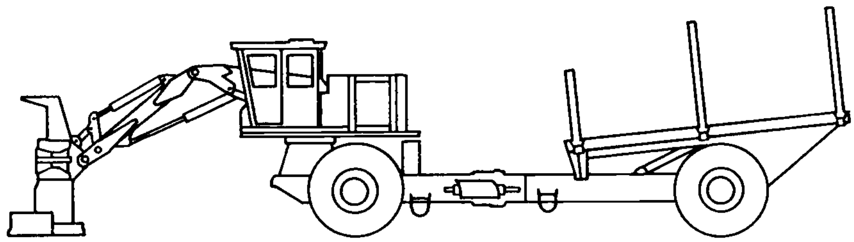
A machine with a shear or saw device for the mechanical felling of trees. Feller-bunchers accumulate several small trees in a bunch and place them in a selected position. Configurations include rubber-tired and tracked, tree-to-tree machines; tracked, swing-boom machines; and tracked, self-leveling, swing-boom machines.

FELLER-DIRECTOR



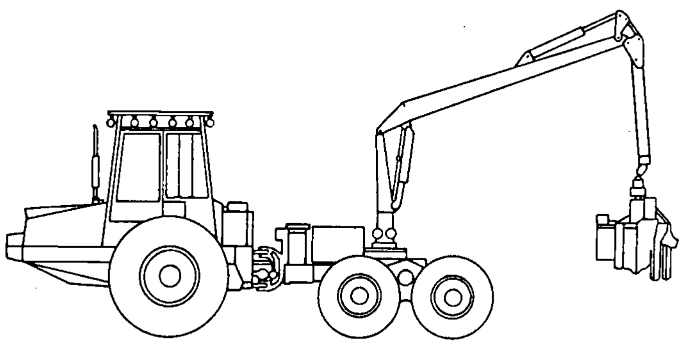
A machine for the mechanical felling of trees. Equipped with a shear or saw and a hydraulic device for controlling the direction of the tree's fall. Feller-directors handle one tree at a time.

FELLER-FORWARDER

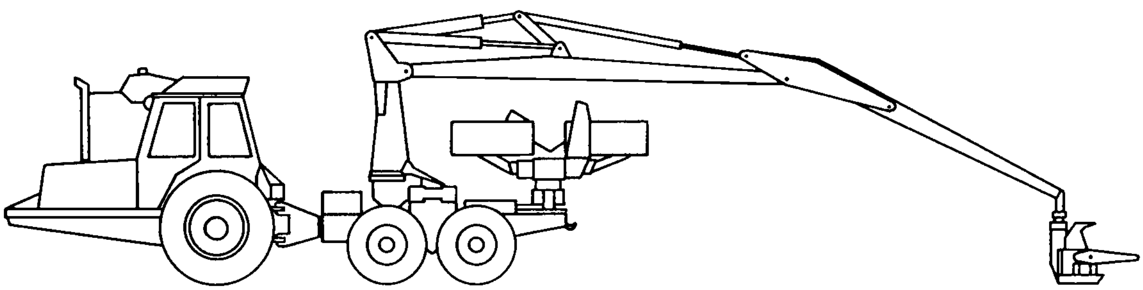


A machine for felling trees and transporting whole-trees clear off the ground. Equipped with a felling device (shear or saw).

MULTI-FUNCTION HARVESTER



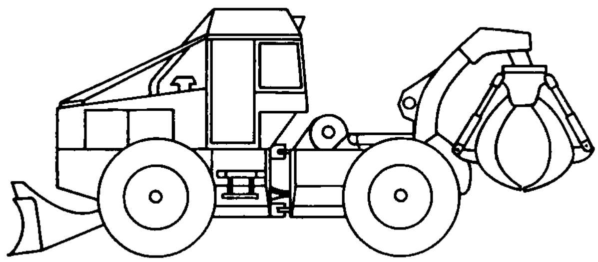
Single-grip harvester



Double-grip harvester

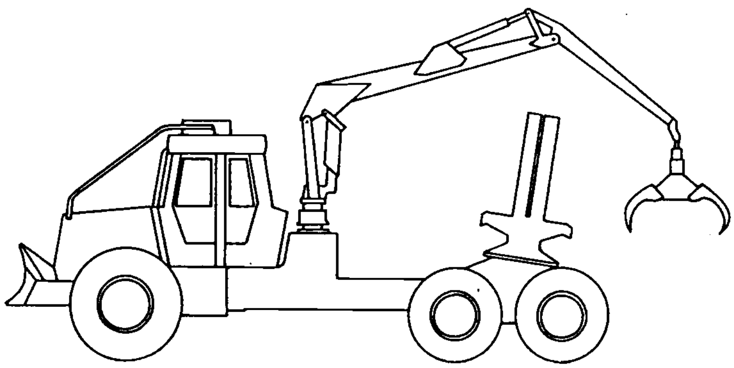
A machine that fells, delimbs, tops, and bucks the tree at the stump area. Multi-function harvesters usually are equipped with a boom-mounted felling device. Configurations include single-grip and double-grip machines. Single-grip machines handle felling and processing with a single, boom-mounted felling and processing unit. Double-grip machines handle felling with a boom-mounted felling unit that works in combination with a bunk-mounted processing unit.

GRAPPLE SKIDDER



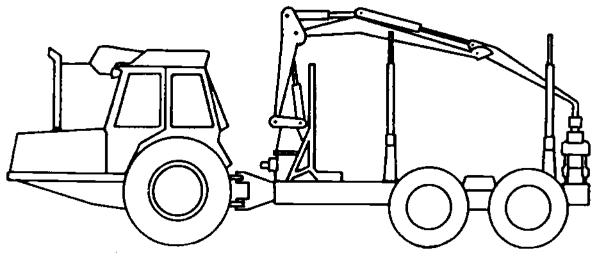
An articulated, rubber-tired vehicle or tracked vehicle for transporting whole-tree material in a grapple that lifts the butt end of the load clear off the ground.

CLAMBUNK SKIDDER



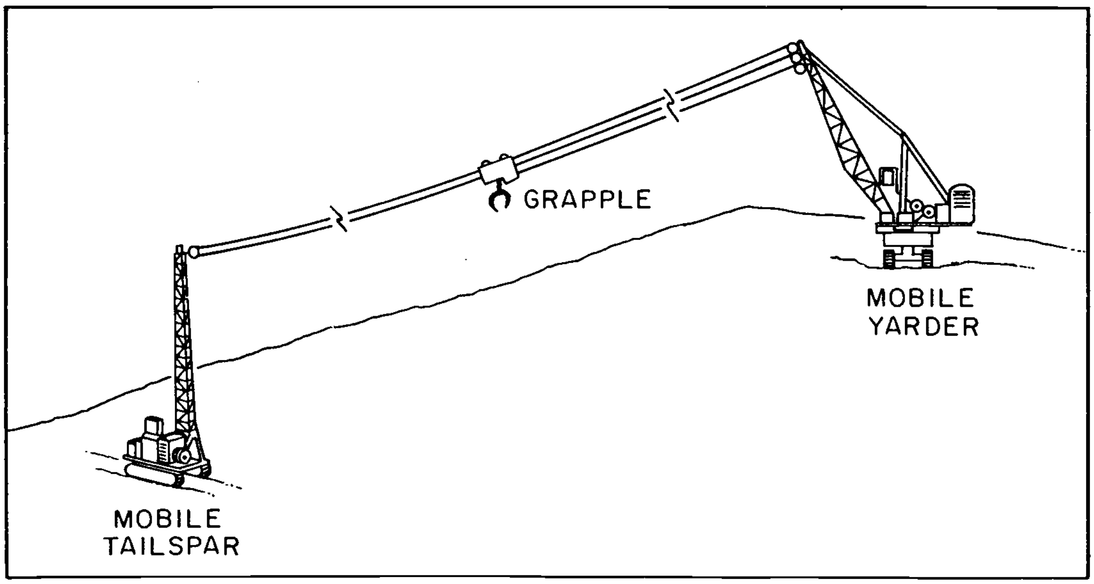
An articulated, rubber-tired vehicle or tracked vehicle for transporting whole-tree material in a top-opening bunk (inverted grapple) that supports the butt end of the load clear off the ground. Clambunk skidders are equipped with a grapple loader for self-loading.

FORWARDER



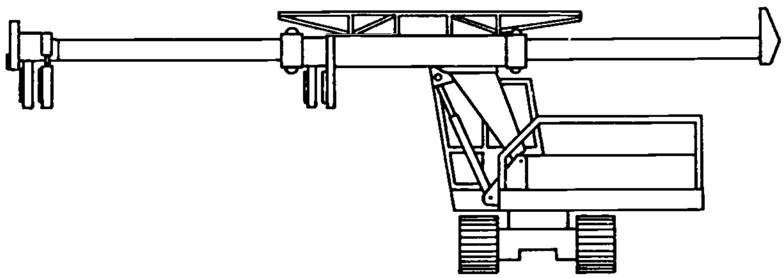
A rubber-tired, articulated vehicle typically used for transporting short-wood clear off the ground. Equipped with a grapple loader for loading and unloading.

GRAPPLE YARDER



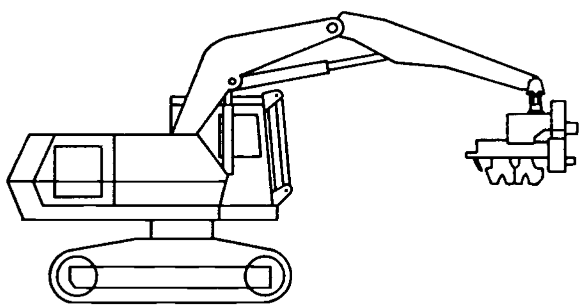
A mobile yarder typically rigged in a running skyline configuration with a grapple carriage.

STROKE-BOOM DELIMBER



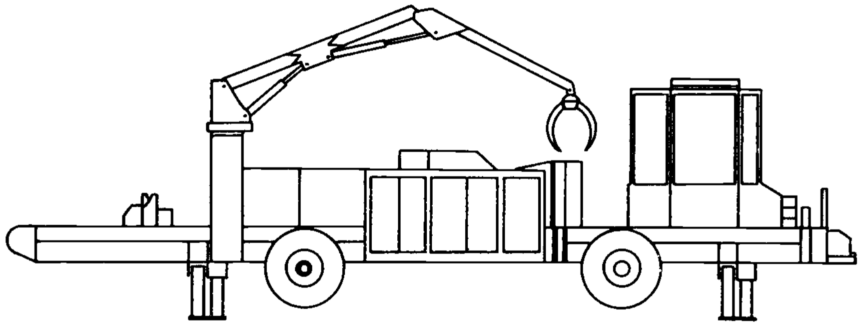
A machine that delimbs, tops, and bucks whole-trees typically at the landing or at the roadside. Stroke-boom delimbers process a tree by holding it overhead in stationary holding arms while pushing a knife-edged, sliding grapple along the stem. Configurations include one-piece and telescopic booms. Equipped with length-measuring devices.

GRAPPLE PROCESSOR



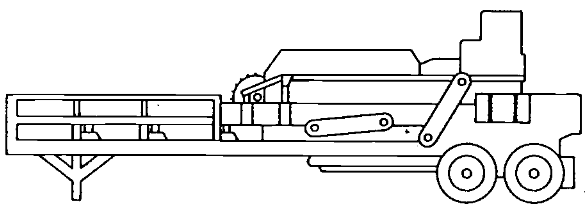
A machine that delimbs, tops, and bucks whole-trees typically at the landing or at roadside. Grapple processors support the tree in a boom-mounted processor, with a roller or chain-feed mechanism that pulls the tree through stationary delimbing knives. Equipped with devices that measure length and diameter.

STROKE-DECK DELIMBER



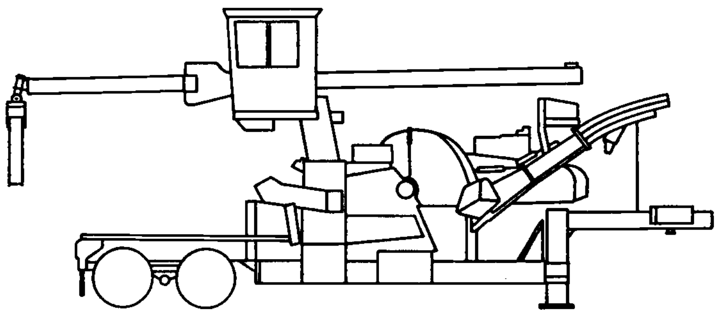
A machine that delimbs, tops, and bucks trees at the landing or at the roadside. Stroke-deck delimbers support the tree on a deck while a delimbing grapple is pulled along the stem. Equipped with devices that measure length and diameter.

CHAIN-FLAIL DELIMBER/DEBARKER



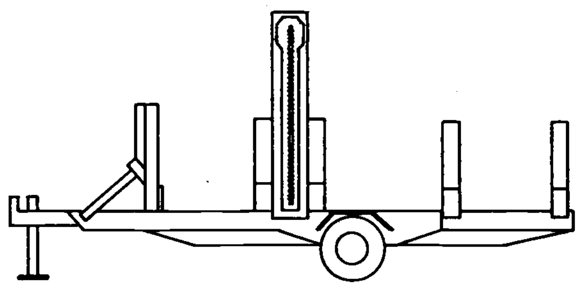
A machine that delimbs and debarks trees at the landing or at the roadside. Chain flail delimber/debarkers remove limbs and bark with the impact and scraping action of rows of short chains attached to rotating drums.

PORTABLE CHIPPERS



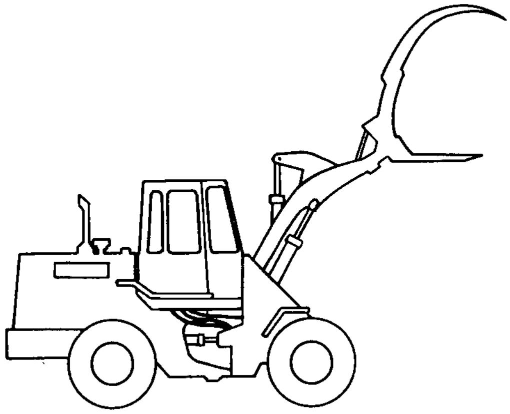
A machine equipped with rotating, disk-mounted knives that mechanically reduce logs or whole trees to small pieces. Usually equipped with a grapple for self-loading.

SLASHER



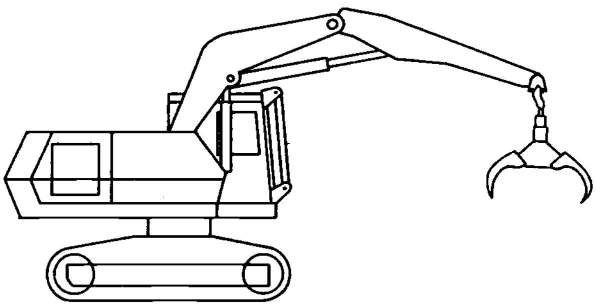
A machine for bucking tree lengths into logs or pulpwood. Tree lengths may be slashed singly or in multiples. Usually equipped with a grapple for self loading.

FRONT-END LOADER



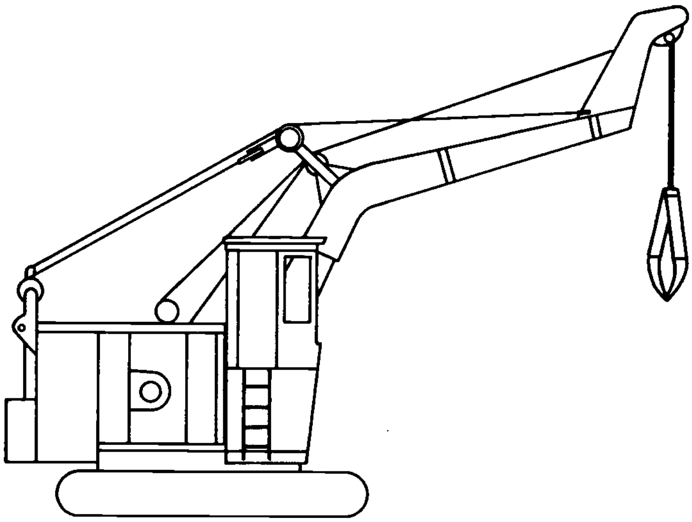
A machine capable of lifting a log or load of logs clear off the ground for the purpose of loading the material on trucks at the landing.

HYDRAULIC GRAPPLE LOADER



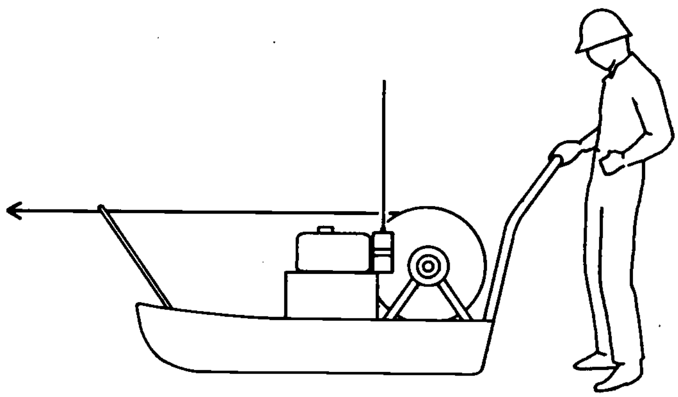
A loading device with a boom and hydraulic grapple mounted on a mobile carrier that is capable of continuous rotation.

WIRE ROPE CRANE LOADER



A loading device mounted on a mobile carrier. It is similar to the hydraulic grapple loader, except that the grapple mechanism is cable controlled.

WINCHES



A powered drum used to yard small timber to a central location.

APPENDIX B. TABLE OF EQUIVALENTS

AREA

1 Hectare (ha)	x	2.4711	=	Acres
1 Square Meter (m^3)	x	10.7639	=	Square Feet

AREA (PROPORTION)

1 Cubic Meter / Hectare (m^3/ha)	x	0.1429	=	Cunits/Acre
1 (Any Unit) / Hectare	x	0.4047	=	(Any Unit)/Acre

LENGTH

1 Centimeter (cm)	x	0.3937	=	Inches
1 Meter (m)	x	3.2808	=	Feet
1 Kilometer (km)	x	0.6214	=	Miles

POWER

1 Kilowatt (kW)	x	1.3405	=	Horsepower

PRODUCTIVITY (PROPORTION)

$$\text{Production / Productive Machine Hour (PMH)} = \frac{\text{Unit Volume Produced}}{\text{Productive Hours}}$$

$$\text{Production / Scheduled Machine Hour (SMH)} = \frac{\text{Unit Volume Produced}}{\text{Scheduled Hours}}$$

TIME

1 Centiminute	x	100	=	Minutes

TIME (PROPORTION)

$$\text{Utilization (\%)} = \frac{\text{Productive Hours}}{\text{Scheduled Hours}}$$

$$\text{Availability (\%)} = \frac{\text{Mechanically Available Hours}}{\text{Scheduled Hours}}$$

VOLUME

1 Cunit	x	100	=	Cubic Feet
1 Cubic Meter (m^3)	x	0.3531	=	Cunits

1 Cubic Foot (Ft^3) = Approximately 3-4 Board Feet (bf) for small timber (less than 12 inches dbh)

= Approximately 5-6 Board Feet (bf) for medium timber (greater than 12, but less than 20 inches dbh) and large timber (greater than 20 inches dbh)

1 Cord = Approximately 90 Cubic Feet of Wood and Bark (stacked)

WEIGHT

1 Metric Ton (tonne)	x	1.1023	=	Tons
1 Kilogram (kg)	x	2.2046	=	Pounds

Examples Using Equivalents

Problem 1

Suppose the user wishes to calculate feller-buncher productivity in cubic feet, trees, and board feet per productive machine hour (PMH) using the following regression equation and average values (Gingrass, 1988):

Cubic Meters / PMH = -28.9 + 0.0059 (Stand Density) + 3.12 (Average dbh)

Given: Stand Density = 1,240 Trees / Hectare
Average dbh = 18 Centimeters
Average Tree Volume = 0.19 Cubic Meters

Solution

1) Solve the equation using the variables in the original units of measure:

$$m^3 / PMH = -28.9 + 0.0059\ (1{,}240) + 3.12\ (18)$$
$$m^3 / PMH = 34.57$$

2) Convert cubic meters into cunits:

$$34.57\ m^3/PMH \times 0.3531 = 12.21\ Cunits/PMH$$

3) Convert cubic meters into trees:

$$\frac{34.57\ m^3}{PMH} \times \frac{1\ Tree}{0.19\ m^3} = 181.9\ Trees/PMH$$

4) Convert cunits into board feet using the small tree factor of three board feet to one cubic foot:

$$\frac{12.21 \text{ Cunits}}{\text{PMH}} \quad x \quad \frac{100 \text{ Ft}^3}{1 \text{ Cunit}} \quad x \quad \frac{3 \text{ Bd Ft}}{1 \text{ Ft}^3} \quad = \quad \frac{3{,}663 \text{ Bd Ft}}{\text{PMH}}$$

Problem 2

Further suppose that the user needs to express board feet per productive machine hour (Bd Ft/PMH) in terms of scheduled machine hours (SMH).

Given: Utilization = 80%
Bd Ft/PMH = 3,663

Solution

Use the following relationships:

$$\text{Production/PMH} = \frac{\text{Production/SMH}}{\text{Utilization}}$$

$$\text{Production/SMH} = \text{Production/PMH x Utilization}$$

Then solve:

$$\begin{aligned} \text{Bd Ft/SMH} &= \text{Bd Ft/PMH x Utilization} \\ &= \text{3,363 Bd Ft/PMH x 0.80} \\ &= \text{2,930.4} \end{aligned}$$