SESSION 7

Paper (d)

MATCHING MACHINES IN SYSTEMS

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INTRODUCTION

The methods of harvesting of timber can be classified as shortwood, tree length, or full tree, depending on how much processing is carried out at the stump. Each method, however, can be carried out by a number of systems (Figs.1-3). According to the FRI Census of 1974, tree length is by far the most common method, and the most common system comprises bushman to fell and trim, skidders or tractors to extract, with bucking done manually at the skid. It is important to stress that manual labour is a major component of the normal logging system which must be kept in mind when trying to match up system elements.

The exercise of attempting to match elements in harvesting systems has at least two different, but related, aspects:

1. matching individual elements to each other;

2. matching systems to the working conditions.

Both aspects require that you know the individual element's limitations, production capacity, operating range, and cost. Wellburn lists other aspects of machinery that are important : (16)

a) Operating limits and optimum conditions; grades, adverse and favourable; tree size, carrying capacity.

b) Environmental impact. A general statement of the suitability of each machine to protect the environment.

c) Operating costs. Costs should include depreciation and an allowance for non-productive time. This will enable you to estimate the cost of doing a job directly from a time estimate.

d) Machine time distribution. How much time does a skidder spend loading and unloading and how much travelling? How much time does a feller-buncher spend moving?

e) Special requirements of each machine to operate within the system. Grapple skidders operate best where logs are bunched. Clam bunk skidders bring large loads into the landing, which adds to the limbing and bucking cost. Truck loading is often inefficient on cable logging operations.

It is, unfortunately, difficult to get a clear indication of a machine's capabilities. A good example of the kind of information required is supplied by Wells and Gordon (17) in their study of the

Fig. 1 FLOW CHART FOR SHORT WOOD HARVESTING SYSTEM

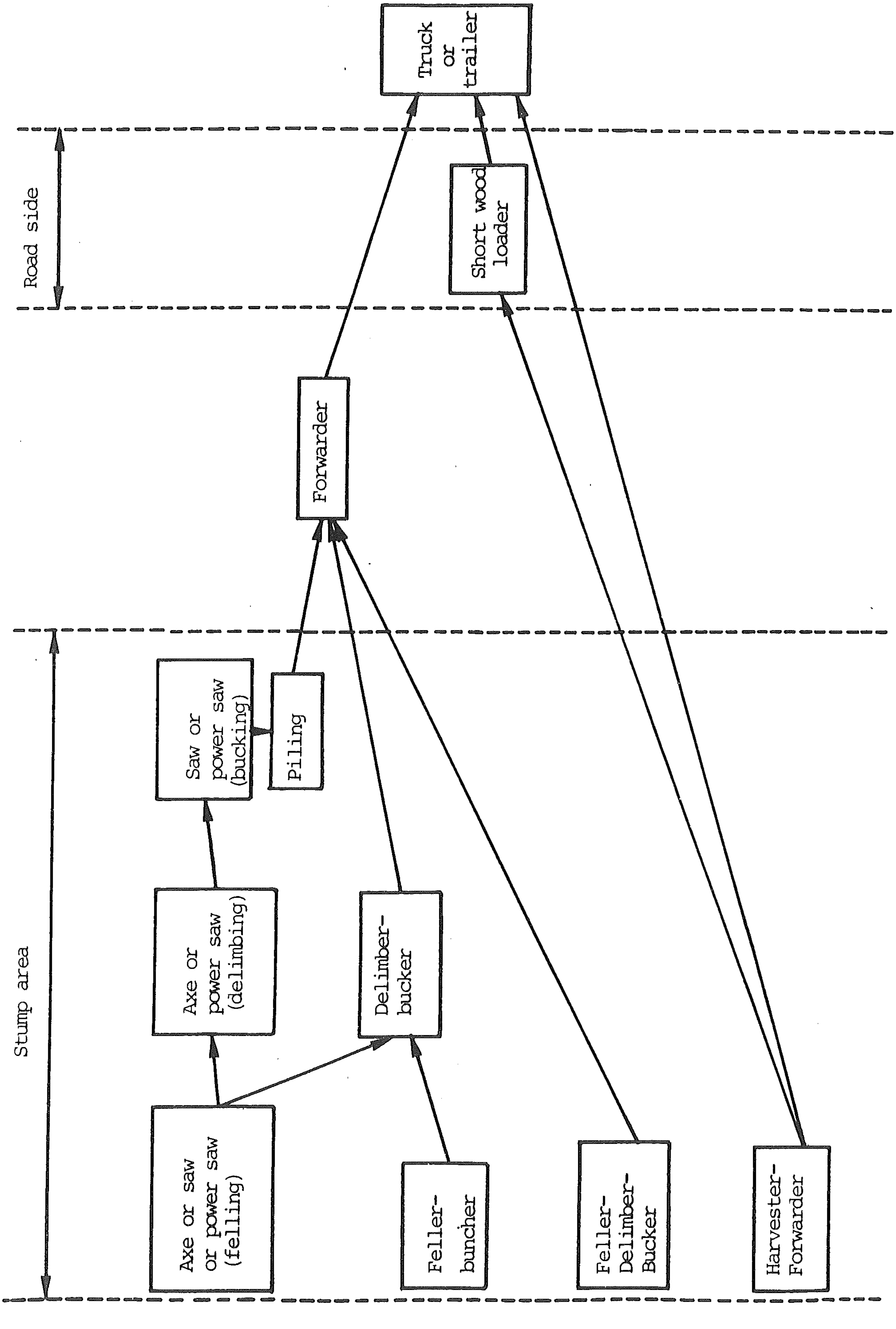


Fig. 2 FLOW CHART FOR TREE LENGTH HARVESTING SYSTEM

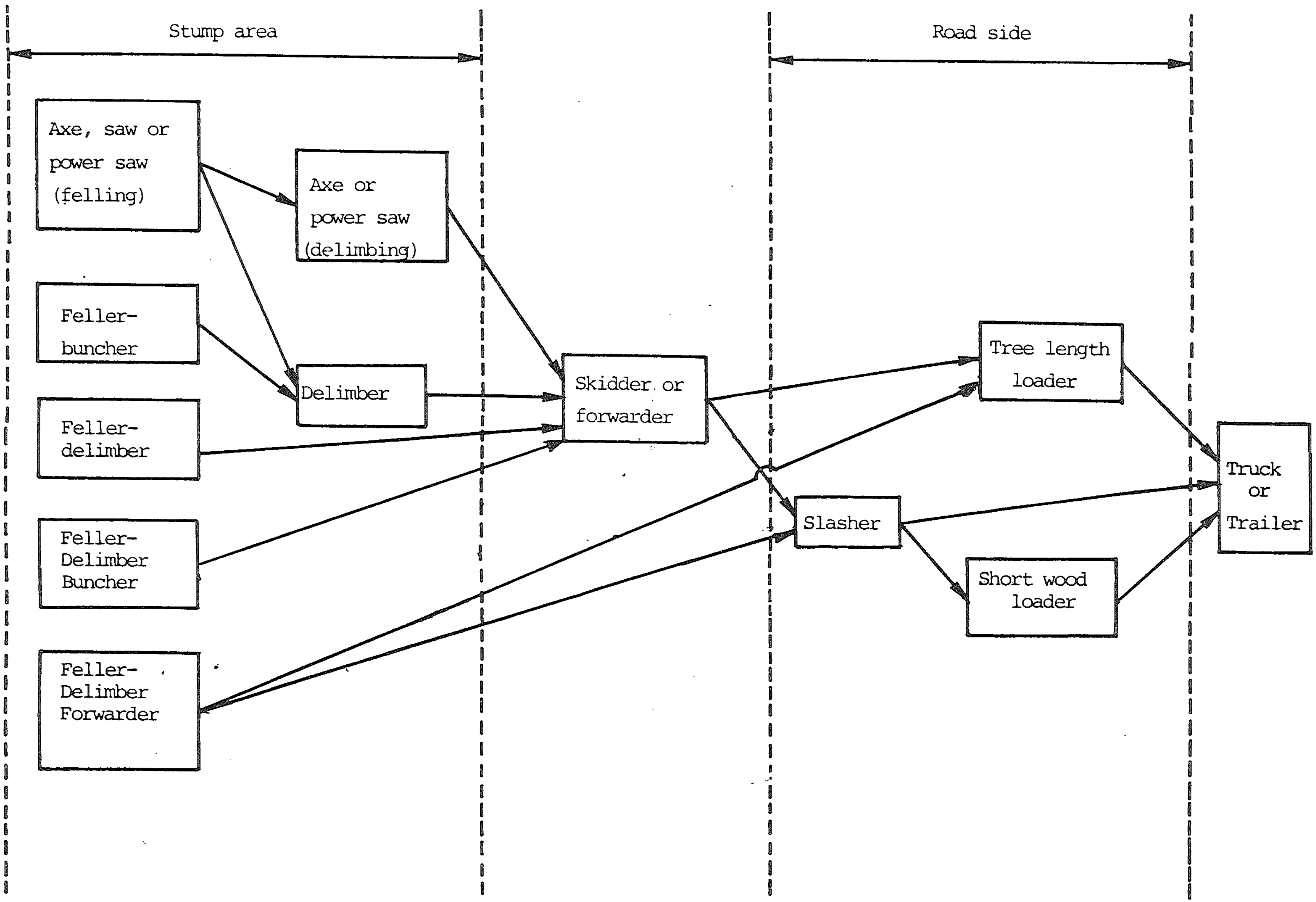
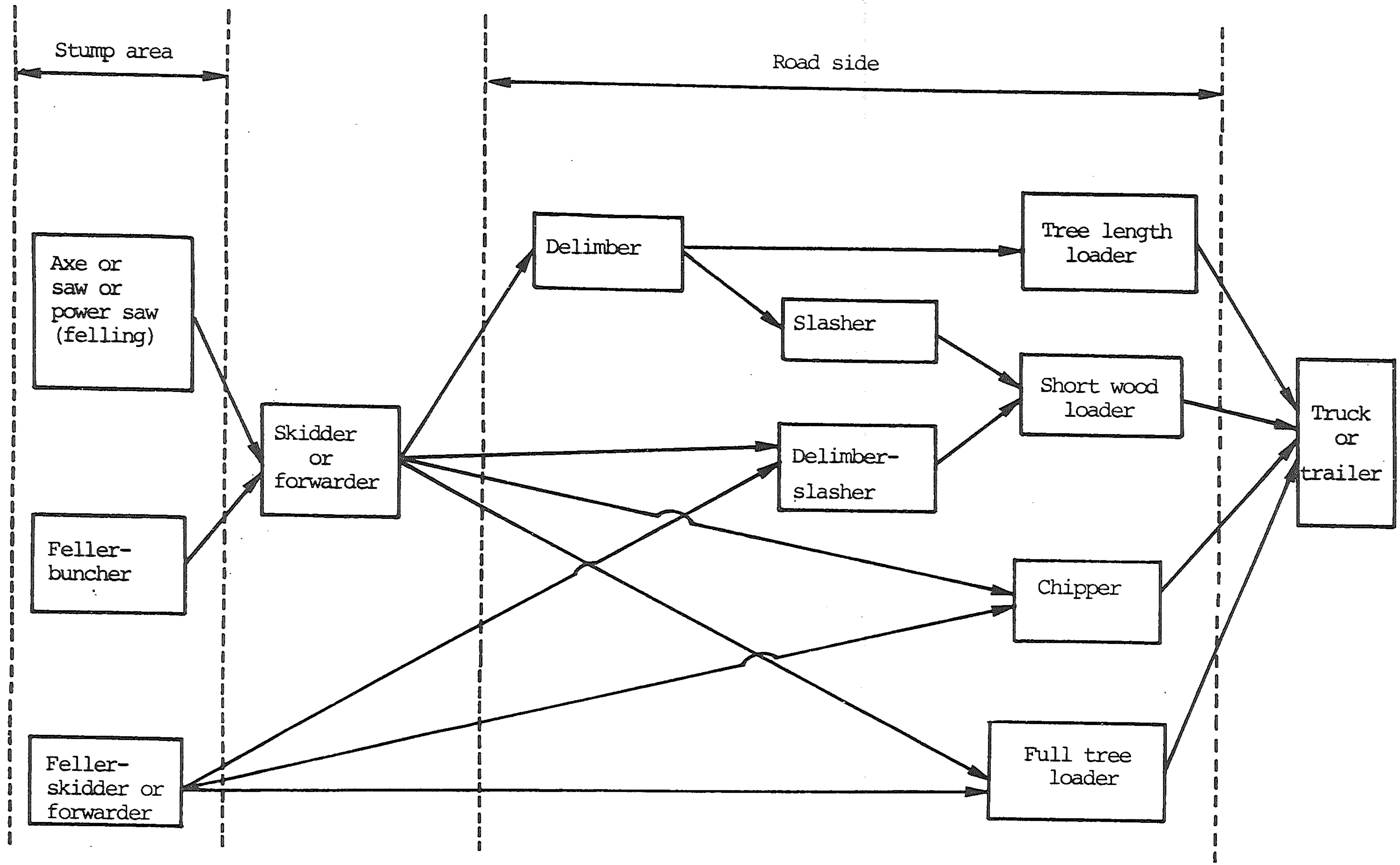


Fig. 3 FLOW CHART FOR FULL TREE HARVESTING SYSTEM



Iwafuji log skidder, Graph I.

MATCHING SYSTEMS TO THE WORKING CONDITIONS

In theory, and it is widely held and often quoted, one should try to match machine size to tree or piece size. Liley (6) gives a clear indication of the importance, not only of average piece size, tree length, and volume per hectare, but of the wide variation possible in these parameters (Appendix I). As well, there are a great number of other factors which influence the efficiency of logging systems, and these should be considered when choosing a system. Hoefle (5) lists some of these factors in Table I.

In practice, it is difficult to obtain a clear indication of any machine power/tree size relationship. What is clear, is the amount of variation in tree size and load size associated with individual harvesting operations - Table II. It may be that tree size is important only through its effect on load volume, becoming more important as the size of the tree approaches the optimum load size for the machine, i.e. one tree= one load.

Also, in reality, no logging system is worked in optimum conditions for any length of time; and many are expected to produce at the outer edges of their operating range, simply because that is where the trees are.

Thus, indicative and tactical planning may give a lead on what the long-term working conditions will be, and this may be useful in deciding on the appropriate system and method to be used, but conditions are sure to vary considerably. (For example, a contract is soon to be let to log 60,000 cubic metres per year for 10 years, on the East Coast, and the thinking is to have one gang do the logging. Imagine the range of working conditions that one system will experience!).

MATCHING INDIVIDUAL ELEMENTS TO EACH OTHER

Logging, as in most production systems, involves the flow of material from one processing station to the next. In order to accomplish a smooth regular flow of wood from station to station, the production line, and the elements within that line, must be in balance. Any line must be balanced in three respects. First, the output from the line must balance the output requirement. Second, the output from each station on the line must balance, or in other words be the same. If this were not so, there would be a continual build up of stock, or an accumulation of *lost time*. Finally, the labour loads on the different operators assigned to the line must be in approximate balance.

It is hardly necessary to say that for any one system, there will be only a very limited set of circumstances (if any), which will permit all stations in a logging production line to produce wood at the same rate. Also, this limited set of circumstances will not be present for any length of time over the operating life of any system. In fact, even for production systems in factories, perfect machine balance is impossible (Burbidge), and compared to factories, harvesting operations are tremendously more variable. One of the most important differences between factories and logging production lines is that in logging, the machine is taken to the raw material, not the raw material to the machine (Silversides). Studies have measured the variation in worker productivity (Bills and Whitely,Hamilton) the

Stands	Terrain	Opening-up	Factors of production (input)	Timber market	Environment
- size of cutting unit	- slope	- standard of:	- workers	- demand for timber	- scenery
- species composition	- bearing capacity	- roads	- capacity	- dimension	- recreation
- stability	- accessibility	- skidding lines	- qualification	- quality	- soil erosion
- dimension of trees		- cable lines	- efficiency	- amount	
- DBH		- distance of:	- machinery	- time and place of delivery	- water pollution
- height		- roads	- type		
		- skidding lines	- availability		
- quality of trees		- cable lines	- productivity		
- branchiness			- ergonomic evaluation		
		- landings			
- taper					
- volume per acre					
- type of cut					

Table I. *Factors influencing the choice and efficiency of harvesting systems* (from Hoefle, 1974).

Table II

RANGE OF LOADS REPORTED FOR SKIDDING OPERATIONS

Machine	Horsepower	Average load	Range	Source
C4	83	1.45 m^3	0.10 - 3.67	12
C5	97	1.95 m^3	0.75 - 3.53	13
Range	appr. 90	2.46 m^3	0.37 - 5.46	9
		4.30 m^3	0.31 - 14.80	9
		3.42 m^3	0.14 - 10.67	9
		3.42 m^3	0.57 - 12.54	9
		6.37 m^3	0.28 - 14.15	9

TABLE III

Drott 40LC Feller Buncher Production Rates

	Strip 1	Strip 2	Strip 3	Strip 4A	Strip4B
Stocking (stems per ha.)	204	236	608	1032	1032
Trees felled per hour	72.5	76.9	87.8	85.6	113.4

influence of tree size (Mackintosh), the importance of haul distance (Bartholomew et al.), and volume per unit area (Winer), all of which can vary greatly from hour to hour. McConchie and Terlesk(8) measured the influence of stocking (stems/ha) on feller-buncher productivity (Table III).

Burbidge (3) describes five ways that lines can be balanced in the factory (Appendix II). Translating these into a logging context they are:

1. Increase the number of men on machines doing the same operation, e.g. add another feller or trimmer.
2. Divide a long operation into two, e.g. add a breaker-out to allow the feller to carry on felling.
3. Change of method - pre-strop logs to allow for quicker turnaround times at the stump.
4. Method improvement - use Nordfor method of trimming to reduce time and fatigue.
5. De-rating - not a good idea - work machine at slower speed to achieve balance.
6. Add work. Let skidder do more sorting on the skids and keep skid site clean.

Another common way of achieving balance in the system is to allow for buffer stocks of wood between various operations, which will allow each element to work at its optimal capacity (Mellgren). This is, of course, very common at the loading stage, but it may also be applied all along the system.

WHAT TO LOOK FOR IF THE FLOW OF WOOD IS UNSATISFACTORY

Let's assume that, for one reason or another, you are unhappy with the flow of wood that your crew is achieving. Let's assume further that absenteeism, machine and men working time per day (utilization) and machine availability (downtime) are at satisfactory levels. (If they are not, they are pretty good starting points for improvement). A further assumption we'll make is that there are no queueing problems with either too many trucks or not enough trucks for the loader. (A situation which can cause problems for your crew, and which may be beyond your control, but you should know who to go to to rectify the situation). Also, you can't complain about the weather or ground conditions, so where should you start to look?

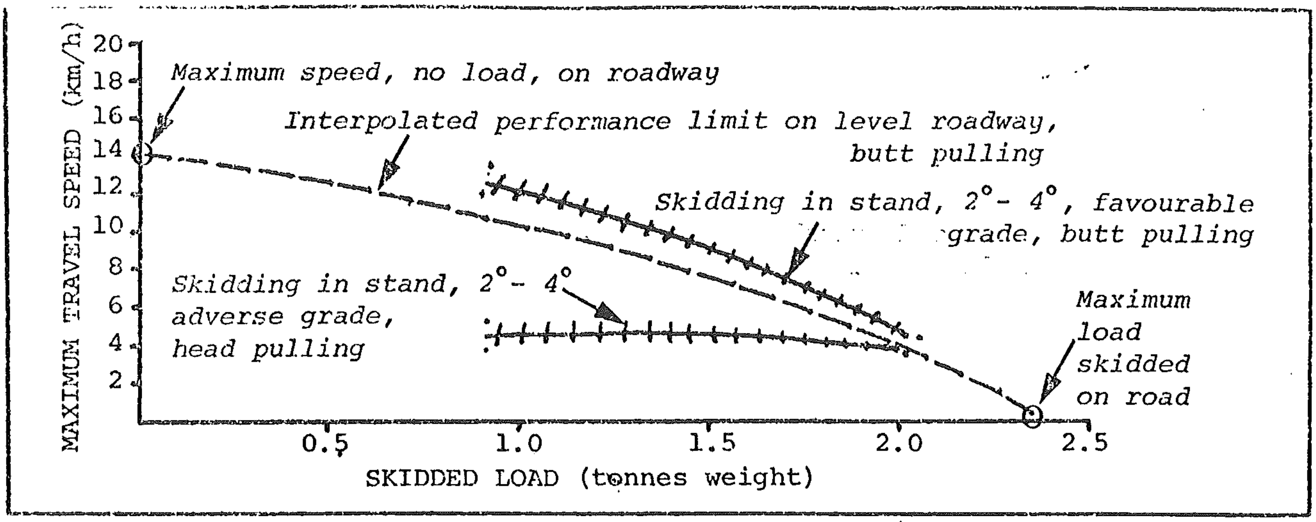
The first item to check on is the skidder load volumes. We have already seen the variation which occurs in load volume over a single operation, and it has been said that "the maintenance of optimum volume per load is often the key to improved productivity" (Winer). One study (14) showed that actual volumes were well below the theoretical maximum load for two machines (Graph II).

Thus a check on the number of trees and the volume per drag will indicate whether or not this is the problem. If it is, then the next step is to find out why load volume is not what you expect.

- Are enough trees ready at the bush end when the skidder arrives, or should there be another bushman (or two) felling and trimming?

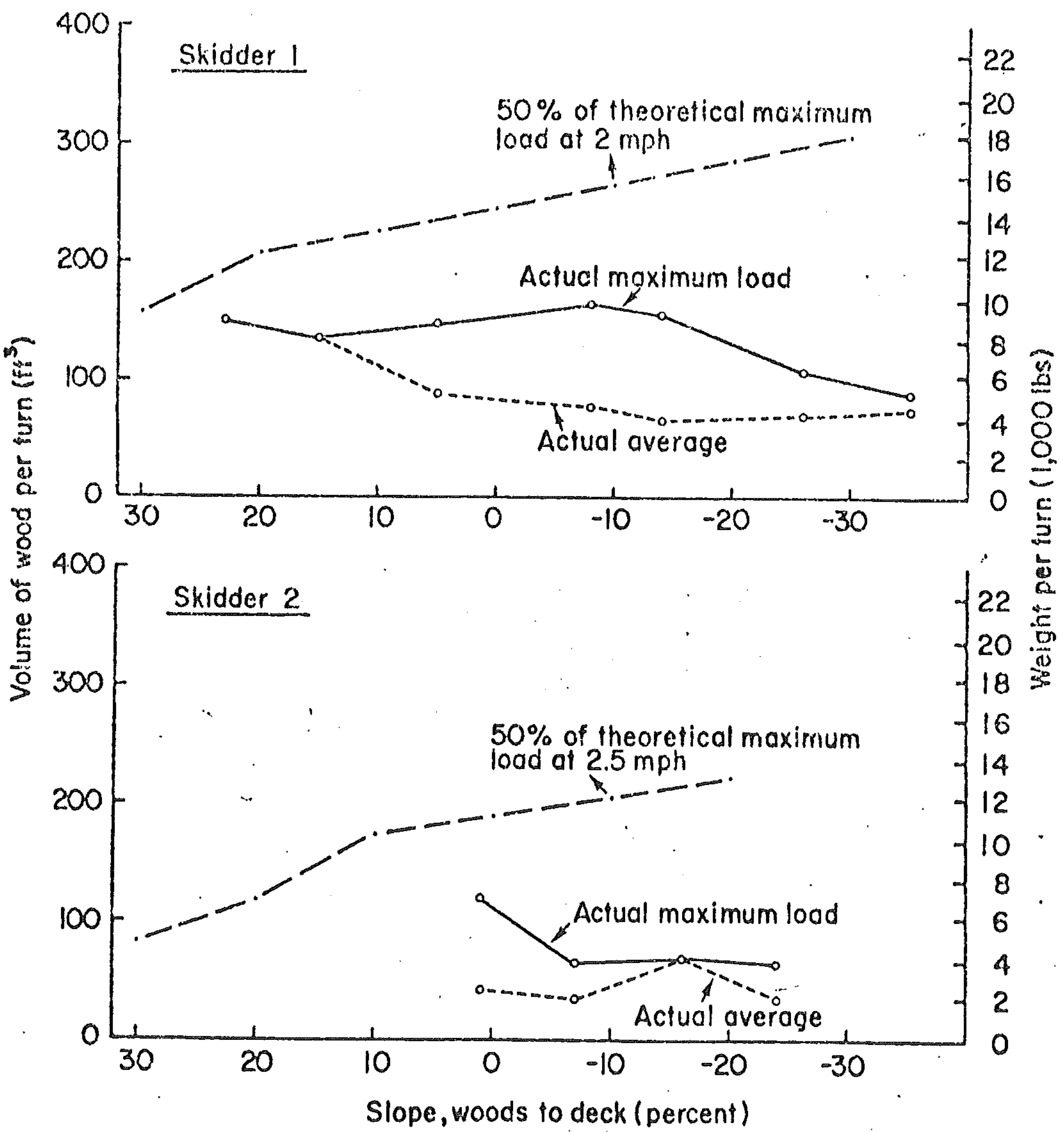
- Are there enough strops to ensure that a full load can be pulled, given the range of tree size that you are working in? Some gangs carry one or two strops more

GRAPH I



Performance limitations of the Iwafuji T20

GRAPH II



Loads per turn for two skidders, with theoretical maximum, actual maximum, and average volume by percent slope. (Sampson and Donnelly, 1977) than they normally can use, just for those occasions when extra small logs are available.

- Are the bushmen felling in such a way that it is difficult for the machine operator to break out a proper load? Felling should be done in order to make the extraction phase easier.

- Can bunching be done in undersize timber to collect a proper load for the prime mover? Nicolls (11) showed the following results from a bunching trial:

TABLE IV

	Normal Logging		Bunching Included	
	Trial 1	Trial 2	Trial 1	Trial 2
Pieces/day	8	9.4	12.75	12.0
Productivity tonnes/day	72	45.1	111.5	74.5
Cost/tonne	$7.21	$11.53	$6.64	$9.73

- Does the machine operator have a good idea of what the maximum load capacity of the machine is? Is he aware of the importance of optimum load size?

Another aspect to look at is the amount of time the prime mover is not pulling wood because of delays. Interference with the normal production cycle of the prime mover usually happens either at the bush site or skid site, or both. In a normal operation there will be some interference at the beginning when the haul distance is short, but this should quickly disappear as the hauls get longer. If it persists, find out why.

- Is the trimming required excessive? Would another bushman help?

- Is access a problem for the fellers? Can the tractor pre-crush any extreme undergrowth?

- Are there too many sorts on the skids, causing increased measuring and bucking time? Is the required quality of the job too high?

- Does the landing layout or the loading operation interfere with the skidder operation? Would it help to have two separate fleeting areas, to allow the extraction process to carry on while loading or bucking is being carried out?

A third point which may be investigated is the length of the haul itself. Much of logging is materials handling, and it follows that reducing the haul distance will result in higher output. Too often, I feel, very little thought is given to this aspect, and we accept without question the location and number of skid sites to be used. During the 1976 windthrow in Canterbury, Les Gilsenan somehow convinced the powers that be to put in skids further and further into the compartments as they were cleared, and this led to higher productivity. Later on, he eliminated skids altogether, and stored his processed logs in the compartment itself, thus reducing his haul length to 1½ tree lengths, and increasing his output 300%! The extra 500 metres or so that the truck had to travel did not affect the efficiency of the trucking operation, but the reduced haul distance had a major effect on logging productivity.

- Is there scope to reduce haul distance by locating another landing or two on the far side of the compartment?
- Can wood be "strung" along the roadside, as is done in some overseas operations, thus reducing haul length to half the compartment depth?
- Is it, in fact, possible to bring the truck to the wood instead of the wood to the truck?

These are just some ways of trying to improve the flow of wood. Perhaps you can suggest others!

APPENDIX I.

RECOGNITION OF THE TREE AND STAND CHARACTERISTICS IN PLANNING

All of the above is eminently useful information and represents crop constraints that the planner must recognise. Of most importance is the individual piece size. This determines machine sizes and power ratings, particularly where the logs are big and must be handled by a machine individually. With small piece sizes there is some capacity to vary load characteristics by varying the number of pieces in the drag.

Studies invariably show that there is a high correlation between piece size and productivity and hence logging cost.

The total live volume per hectare is a critical constraint in that it determines the rate at which areas must be logged if set rates of production are to be achieved. This in turn determines the rate at which new roads and landings must be constructed and the frequency of change in hauler settings or rope shifts.

The mean tree diameter affects chainsaw sizes, choker sizes and felling times. In 'mechanized' operations it is important to know diameters to determine such considerations as whether a felling head has sufficient jaw opening or whether delimbing knives can accept the full stem width.

The tree length may also be important in mechanized operations. Does, for instance, the delimbing boom have the capacity to reach the full utilizable length of the stem? In conjunction with piece size, tree length may be an important consideration in skyline operations - does the slung length of the tree beneath the skyline allow sufficient ground clearance?

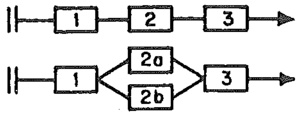
The average values for the stand parameters cannot be considered without also recognizing the levels of variation associated with them. A logging system may function cheaply and efficiently at mean piece sizes, or lengths, or diameters, but be inefficient or inoperable at extremes in the range. A wide variation in crop characteristics may require a single very flexible system, or perhaps a combination of systems such as seen where a small skidder based wood salvage crew follows a larger feller buncher operation.

APPENDIX II

METHODS OF LINE BALANCE

Machine minutes

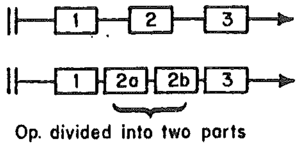
Station	1	2	3
Before	10	20	10
After	10	10 10	10



① Adding machines in parallel

Machine minutes

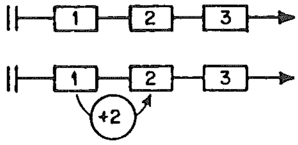
Station	1	2	3
Before	10	20	10
After	10	10 10	10



② Adding machines in series

Machine minutes

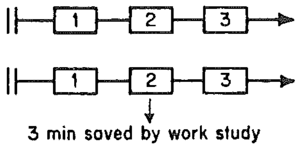
Station	1	2	3
Before	12	8	10
After	10	10	10



③ New method — redistribution of elements

Machine minutes

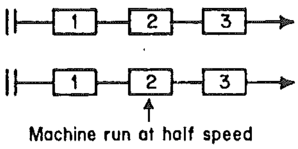
Station	1	2	3
Before	10	13	10
After	10	10	10



④ Method im- provement by work study, etc

Machine minutes

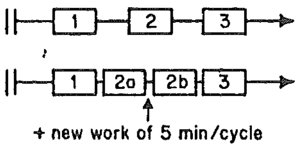
Station	1	2	3
Before	10	5	10
After	10	10	10



⑤ De-rating some machines

Machine minutes

Station	1	2	3
Before	10	5	10
After	10	10	10



⑥ Adding new work

1. Additional machines in parallel. With high output requirements balance can sometimes be improved by increasing the number of machines doing the same operation, at a station where the output is low due to a long operation time.

2. Additional machines in series. In the same instance, balance can be improved by splitting a long operation into two parts and adding a new machine station to the line.

3. Change of method. It is sometimes possible to improve balance by a change of method in which part of a long operation is transferred to another machine in the line, where the operation time is shorter.

APPENDIX II

4. Method improvement. Balance can be improved by applying Work Study to find ways of increasing the output at critical stations.

5. De-rating. Machines at stations with excessively high output rates can be slowed down to obtain balance and at the same time achieve the advantages of longer machine life and longer life between major repairs and maintenance.

6. Adding work. It is sometimes possible to take advantage of the spare capacity at an underloaded station by adding extra work which improves the quality or appearance of the product at no extra cost.

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