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BASIC PRINCIPLES IN SELECTING LOGGING EQUIPMENT*

by

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Introduction

One should not be overwhelmed by the numbers and types of a specific piece of equipment which has been designed to do a specific task, even though all or some may do the work in a different manner using different mechanical techniques. There are several methods you can take to help you select what you need.

You can take a guess, buy from the most convincing salesman, copy from yourneighbour, analyse the merits of each system or piece of equipment, if you are qualified, or hire the expertise to help you make the choice. Before you choose your method you should take a rational look at the situation. I hope that this talk will assist you in a rationalisation of your thinking about your choice or method of choosing. It is not intended to go into the mechanics of estimating production and costs but to outline some of the factors which affect productivity, and thus costs, in order that you know what you need to know so that you can make a good effort at selecting the correct system or equipment for your operation.

For the most part, equipment manufacturers are responsible, reliable, well-meaning people, trying to produce a product which will fit a specific job and produce at the lowest unit cost. Many of these manufacturers will design, or modify slightly, their equipment to suit your particular needs, and again many offer services which will ensure that you get the proper piece of equipment. For instance, many truck manufacturers will install certain components such as the drive train to fit your roads and loads. This may entail travel and expenses, but the results, especially if the operation is large, should pay off by dependable service and savings.

Again, many manufacturers have been in the business long enough to provide reliable and productive equipment for any job anywhere in the world. They design based on experience and get continuous feedback from their dealers or sub-offices. The work which has been put into a great deal of equipment should not be ignored. Where some manufacturers fall down is in not producing impartial case studies of their equipment in actual producing operations, or if they do, they confine their studies to fit the existing big markets of the developed countries. Such studies do not necessarily fit conditions in developing countries.

Some manufacturers provide operator training and some run maintenance courses for mechanics. The size of your order may determine the cost of these services to you. In any case you can see that manufacturers generally want to provide a product to meet your needs, which in turn will benefit them in the long term. Still, someone may inadvertently recommend a good, reliable piece of equipment or a system which is not suitable for your job. Whichever method you choose, hopefully not by guessing, you must take a close look at the situation at both ends of your logging operation. This is rationalization and must not be ignored.

For any independent logger, you must also know where your product, the log, is going to. You must also know what logging equipment will produce a product to fit the needs of the industry you will be selling to. Industry cannot be divorced from logging. The forest industry starts with the tree, whether it be from a natural or planted forest.

Now that we have put the logging sector into a bit of perspective, we should carry on and talk about how we go about rationalizing our method of selection and logging equipment.

The primary objective in selecting equipment should be an economic one, which earns the most money for you, always bearing in mind and giving due consideration to the environment and to government policy. For social reasons a government may wish to proceed with a venture even though it is not financially feasible; however, the goal of economic viability through efficiency should not be forgotten.

Essentially, the problem is to select an appropriate, or the most appropriate, logging system. Then the equipment selection problem is almost solved.

Certain preliminary steps must be taken before one can start the selection of a system. For ease of detailing the process from start to finish, the various steps can be broken down into sections, each with at least a major heading.

1. The basic preliminary steps

Prior to embarking on any venture whether it be logging or a completely integrated industry, the potential entrepreneur must look at:

- the forest resources and natural conditions;
- the market; and
- the financing to marry the two.

These three can be furtner broken down into numerous sub-factors, not all of which can be investigated by one type of expertise. The sub-factors will be listed and follows by a short discourse on the positive aspects and the pitfalls which may ensue if not carried out, or carried out properly.

It must be remembered that each step cannot be divorced from the other and although the factors are listed in sequence each must always be borne in mind when making an evaluation.

1.1 Inventory

An inventory of the forest must be carried out and this requires special skills. In most countries, forest services are capable of carrying out an inventory. However, they may not put the correct emphasis, from your point of view, into their work. For instance, many people spend a great deal of time gathering very precise volumetric detail when the most important aspect may be species - for often that is where the money lies. Similarly, defect and breakage studies must accompany an inventory which will be used as the basis for planning a forest industry. Remember even a simple logging/sawmill unit can run into some US$ 10 million. A modest 150 000 m3 log/saw/ply unit can run to US$ 30 million. For such production, some US$ 5 million may be needed for the logging component alone.

The results of an inventory complete with volume, decay, breakage and species detail may be sufficient to stop a project if it is being analysed in financial terms alone. And rightly so.

The inventory is the most important preliminary step, but this must be accompanied by a correct and detailed analysis. Again, more skills than those of just an inventory man are generally required.

The inventory results must be analysed for loggable volumes; species, which must also yield details of weight (green for loading, hauling or floating) bark thickness, susceptibility to insect and fungus attack, in addition to marketability and the determination of market value. Much of this detail is already available, such as green and dry weights, and susceptibility. However, if these are not available the inventory required to gather this information will be more complex.

The logger is interested in unit merchantable volumes which can be used to estimate logging costs and road density, among other things. The pulp mill man will usually want to know the total recoverable volumes down to a lower diameter limit than a sawmiller and he may want more details as to the colour of the wood and silica content.

Although planning and equipment purchases are normally carried out on the basis of a forest inventory, an operational cruise (enumeration) can be extremely useful, and since it must soon be executed, it can be very useful to conduct the first year's cruise prior to equipment selection.

Inventory crews and expertise are not always available - however, the expertise may be readily hired from numerous consulting firms, although the potential entrepreneur must know what will be enough to suit his needs, before he can properly direct the people he hires.

In many cases FAO could provide much of the expertise needed through one or more of its service programmes. However, this assistance is normally limited to governments of member countries. Thus, state-run enterprises may qualify through requests made through their governments.

1.2 Natural conditions

The operational efficiency of most logging equipment is heavily affected by the natural conditions and forces one finds in the forest area. Thus, such factors as terrain, soil, availability of road surfacing material and precipitation must be determined prior to system and equipment selection.

For instance, fragile soils liable to erosion in a high rainfall area, on steep and broken terrain, may rule out the use of a skidder/tractor system and similarly soils in which compaction may be detrimental to growth of the next crop may necessitate the use of low ground-pressure equipment or cable systems.

In order to get this information further work must be carried out and another set of specialists will be required.

Terrain conditions can be obtained with reasonable accuracy from topographic maps made from aerial photographs. However, a dense tropical forest canopy normally hides minor variations such as low steep-sided hills which often become a costly embarrassment when road construction is started. For such areas, topographic maps constructed from details gathered by a topographical crew (which can operate with the operational cruise crews) is much better; however, this system is more expensive.

Regardless of cost, topographic maps, or terrain information, are usually a necessity for proper planning and for equipment selection. For instance, steep terrain may necessitate the use of a cable system.

Soil conditions and soil typing can be a relatively low-cost venture, provided only mechanical qualities are required. However, if growth capabilities are also needed the costs will be much higher. Soil-bearing tests provide extremely useful information as to the amount of gravel required for a road, and thus the number of trucks, loaders and spreaders which will be required can be estimated. The need for a large amount of gravel will influence the size of the gravel and logging trucks as well as the number required.

The availability of gravel or other suitable road surfacing material (laterite, rock, coral) or the lack of it, will influence the transport mode (road, river) and shorten or lengthen skidding distances.

Similarly, a complete absence of gravel in a high rainfall area, and thus excessive road construction/hauling costs, may force the decision to use a cable system with a minimal number of roads, provided the silvicultural system will tolerate its use. If the silvicultural prescription cannot be changed then the problem becomes social and/or environmental and subsidies may be required or the enterprise abandoned.

Soil seriously affected by rain and the churning effect of ground working equipment can soon be in such a state that equipment cannot continue to work. Often long halts are required with resultant lost productivity and high unit production costs. Not only is the fixed cost of equipment which continues to pile up the culprit, but the large overhead charges usually also continue. Similarly, if workers are laid off, social damage results.

Another fact which is often overlooked is the effect of rain (and snow) on the productivity of the workers. In some countries work ceases when rain starts. Rain couses slower work through reduced vision and resultant poor footing, especially in steep terrain.

1.3 Environmental considerations

Precipitation and the effects of runoff, especially when forced into unnatural channels by roads and skid trails, are already well known.

High precipitation coupled with certain types of logging and road construction equipment can prove disastrous to downstream areas and habitats. Careful planning and road layout and construction methods can often alleviate much or all of this so called "logging problem".

Rainfall data and stream flow data, along with a knowledge of downstream users are as important for environmental reasons as for system selection and as a matter of fact the effect on environment should have a bearing on system selection. The entrepreneur should begin to gather any additional data as soon as the idea to industrialize is conceived.

Similarly, the flora and fauna must be considered, and this requires more expertise if these are to be preserved. Logging disturbs the animals, but depending on its intensity they may return as logging moves on. However, some animals need an undisturbed primary forest. A major factor is to determine what havoc logging is playing with the food source and its capacity to renew itself.

Environmental considerations may dictate that a forest is left untouched, as has happened in some countries. However, in your particular circumstances government policy will prevail and logging for social reasons may be justified, in which case the logger must find the least damaging solution. In some countries logging by balloons and helicopters is done for precisely this reason. Similarly, more costly road construction techniques are sometimes used to lessen the environmental impact.

The logger should ensure, or take steps to ensure, that he leaves the forest in a state in which it will produce another crop in addition to the other benefits which may be gained from it, provided that it is intended that it remain in forest, and is not being logged prior to clearance for agriculture or a dam flood basin.

1.4 Government policy

The type and size of an operation will often be governed by Government policy. In richer countries the need to harvest the forests may not be as great as in poorer countries which need the employment and revenue. Similarly, countries well endowed with forests can better afford to harvest the standing wealth than one less endowed.

In any case, most governments keep the control of their forests in their hands and will lay down the rules for their use. In order to change the rules, entrepreneurs must be able to show (prove) that their proposed type of operation will be advantageous to the country as a whole. This requires know-how and knowledge of your proposed equipment and its productivity.

1.5 Silvicultural system

The system laid down by silviculturalists to ensure a continuation of the growing capacity of a forest is one of the most important factors governing the unit volume recoverable and thus the harvesting system and type of equipment to be used.

For instance, an inventory in a tropical rain forest might indicate volumes ranging from 45 to 150 m3 per hectare of sizes suitable for industry. However, the silvicultural prescription designed to ensure another crop and the presence of presently unwanted species,

singly or together, may lower this volume to 20 to 30 m3 per hectare. These lowered volumes indicate a whole new ball game with regards to operating costs and road spacing.

A country would have to be in dire circumstances or be well endowed with forests to disregard such a prescription. Until the silviculturalist can find another solution or works from a better data base, the logger will have to adapt. In order to adapt he must be knowledgeable or he must hire trained personnel to help pick the equipment which will do the job economically.

1.6 The industry to be fed

Loggers make a product for use in industry, therefore, they must know their log market. Similarly the industry must know the market for its products.

For integrated enterprises the industrial planner bases his unit on the market to be served. He sometimes overlooks the logging end, thus making the combination of machines required to produce the log input volumes uneven or mismatched, with some equipment remaining idle and some being overworked. This is particularly evident in intermediate phases such as loading and unloading where only one of few units are needed relative to the other items.

For too long planners have assumed that anyone can log, simply because "even our forefathers did it with their backs and with oxen". The real situation is quite the contrary: the industrial organizer must ensure that he hires or buys the best expertise. In round figures, a log has cost more than double that paid for it in cold cash when it enters the mill because of the conversion factor, to which must be added the milling cost which is normally lower than the price of the log before conversion. The cost of the log is usually the single biggest cost factor in a mechanical wood based industry.

1.7 Financing

Without the necessary funds neither the logger nor the integrated enterprise can get started. If they start under-funded and cash flows do not materialise as expected, the enterprise will fold, or someone else's money will have to be pumped in to save it. If you are lucky,

(or unlucky, depending on how you feel about government assistance) public moneys may be fed in for social reasons.

The logger can only get financing by proving his plan, ideas and capability. In order to do this he must have the know-how to draw up a plan, complete with equipment lists and production costs. Some enterprises or governments have the expertise to do this, but when they do not, consultant firms or individuals can be hired to do the job.

However, special knowledge of logging systems, equipment and its productivity and overall planning are a prerequisite to performing such studies. FAO through its programmes can provide assistance in this field, to the prefeasibility level, to Member Countries. It can also act as a neutral monitor for these governments when feasibility studies have been completed by third parties.

A rule not to be forgotten is not to go in under-funded. Thus, reasonably accurate equipment prices must be used in estimates. Similarly, equipment operating costs must be reasonably estimated, otherwise costs may be up and profits down, thus affecting the availability of operating funds.

One pitfall to avoid is buying the lowest priced equipment when money is in short supply, for sometimes the equipment is not suitable and you are soon back in financial trouble.

Government policy with regard to foreign exchange is an extremely important factor for some countries and in extreme cases, after the initial purchase has been financed, there are no foreign funds available when spare parts are needed. This can be disastrous.

2. The logging system

There are many ways and many machines that can be used to log a tract of timber and many of these can be grouped or linked together in the process of logging to form a so-called logging system. However, its purpose is to fit into the chain of events to produce logs, at the lowest possible cost. There are certain machines which

do not readily match up with others to form a system, and yet in certain circumstances they may be an aid to the apparently incompatible system. Simple examples of this latter are a tractor cleaning out difficult corners for a cable system, or being used as a mobile tailhold for a skyline cable system, or feeding logs to a skyline system.

A "system", therefore, as the word implies, is a planned method of logging, from standing tree to final delivery point of the log. Since a system implies planning, the role of pre-planning, inventories and engineering surveys are or should be a part of the system. This paper will confine itself to the production equipment portion of logging systems, bearing in mind that the preliminary steps enumerated earlier are a prerequisite to any system and eventually to equipment selection.

Since the groupings required to form a system are very complex we will confine ourselves to the major systems of extraction and transport, both of which form the most important equipment component of a system, and follow up with the ancillary or auxillary functions which are also extremely important but in most cases fit into any major extraction and transport system.

There are inumerable extraction systems which if fully discussed could fill many a book. We will, therefore, confine ourselves to the - until recently - more standard systems which for the most part will be appropriate for indigenous tropical rain forests. However, some of these systems are also suitable for the tropical and sub-tropical plantations which are now reaching maturity and ready for logging. The latest and most highly sophisticated systems now in use in the northern temperate coniferous forests, and aerial logging, will not be discussed. Basically long distance transport is part of a system, but since it can fit with any extraction system it will be treated separately.

2.1 Major extraction systems

Some people break their major systems down to the length of log or tree which is to be produced. However, we will stick to the major extraction methods. These are basically: cable (off, or partly off the ground), tractor/skidder (often called ground skidding), semi-

mechanical light equipment (such as the winch lorry of South East Asia, farm tractors with or without forestry attachments) and manual/animal (swamp logging in some countries).

At this point it must be remembered that the extraction system cannot be divorced from the transport system and the auxiliary functions such as felling and loading. Each can or will have an effect on the extraction system.

The basic problem of the planner/investor who has little experience to fall back on is how to pick the system which will provide logs at the lowest cost and still be compatible with silvicultural and environmental needs as well as adhering to government or company policies (employment, foreign exchange). The problem is amplified for those who have little or no experience to guide them. These three basic points, jointly or singly, will or may force a decision into the use of a certain system or method and in any case they will, or should, provide some of the answers to the handling of other criteria (unit volumes, soil considerations) which must then be brought into the selection system to form our guidelines.

Each of the systems mentioned above are affected by certain basic criteria which differentiates it from the other. The effects of some of these criteria show up on the balance sheet once the wrong system has been tested. Similarly, a selection which eliminates their bad effects or utilizes them to advantage has a positive effect on profits.

The preliminary data, gathered in the initial stage, is where the conditions and/or numbers necessary for an evaluation are obtained.

The basic criteria which will influence the choice of systems are:

- topographical conditions;
- weather (precipitation, heat);
- soils;
- silvicultural systems;
- volume per area;
- volume per log.

and these are variables which must be considered when attempting to rationalize a choice, for each system is sensitive to one or more of the criteria.

Other criteria which enter into the calculation are:

- availability of manpower;
- mechanical capability of personnel;
- operational capability of personnel;
- present experience of personnel;
- animal power, availability/experience;
- accessibility/infrastructure.

The latter are essentially self-explanatory. One would normally choose the most sophisticated (and expensive) equipment if the available people are not mechanically inclined, unless for some policy reason the operator is willing to forego immediate profits until a training programme has remedied the situation. Normally, in such cases one starts off with the less sophisticated system, where feasible, and works upwards as experience is gained and as original equipment wears out or where special circumstances dictate, such as a dwindling supply of workers. Similarly, accessibility is easily understood as a concept but can become a major problem in fitting it in as a factor affecting the selection of a transport system.

The major criteria defy a simple system of evaluation which will show the relative effect of each as merits or demerits in or upon each system, or between systems. In order to show this, the interlinkages and variations within criteria must all be defined and would be the subject of a special book, let alone this paper. The delineation is not so severe for one piece of equipment or system, but is excessive when briding systems. Perhaps the best manner in which to point out the effects of criteria would be to handle them system by system and then let the reader draw his own conclusions for his particular circumstances.

2.1.1. Cable system(s)

There are many cable methods of logging. The primary ones may be called "high lead" and "skyline" with inumerable variations, especially in the skyline method. This paper is too short to describe them all, but suffice it to say that there are the heavy duty systems in use in the West Coast of North America, the Philippines and Borneo, and the lighter cable systems used in swampy ground in southern U.S.A., as well as the numerous lighter skyline methods

used predominantly in the mountainous regions of Europe and in a few developing countries in Latin America, Asia and Africa.

Topographic conditions such as steep slopes and broken terrain are not a serious factor in cable logging - let us say not as serious as in tractor logging. The major problem which such conditions impose on the systems is mostly to do with labour which must be well trained and which can be very unproductive in difficult terrain.

Cable systems have been used on slopes which vary from flat to steep. However, level ground, especially for the heavier systems, is not always the best on which to use cables, unless soil conditions dictate its use. Because cable logging requires very well trained and skilled operators it should be limited, if possible, to forest areas where no other extraction system can work satisfactorily.

Rainfall and snowfall are not excessively detrimental to the systems, but the effect on the loggers can drastically reduce production. Rainfall and its effects on soil are negligible with regard to movement of the log, since the heavy machinery is stationery. Improper planning in the high lead system can of course lead to serious erosion.

Similarly, excessive heat can have an effect on labour productivity, but this is common to any system.

The silvicultural system prescribed can be a limiting factor to the use of cables. If as in many tropical forests a diameter limit selection system is imposed, not only will the volume possibly be lowered to the point where cable logging can be uneconomical but the attempt to try to selectively log a few trees from among many standing ones without damaging or destroying the residual stand is a difficult task. Some prescription as to damage to residuals, if rigidly enforced, could preclude the use of high lead cable logging and some skyline systems.

In some areas where the forests are rich and heavy volumes are to be removed and regeneration is assured, the system(s) can be used effectively. Essentially, cable logging is best suited to clear felling operations.

The size of log dictates the size of the cable system. However, since in many cases the fixed machine costs plus the fixed cost of lost time in setting up are very high, the size of the area to be logged (setting) and the unit volumes per unit area are very critical. The critical unit volume varies with regions and experience of the logging crews. The new, larger and costly (some now over US$ 500,000) West Coast USA portable systems have considerably reduced the moving and set-up time, but the volume over which these items must be written off is still a factor to be reckoned with.

The following is presented to give some idea of the volumes some companies are logging with high lead systems in South East Asia on tropical hill forests: One operator high-leads on volumes of some 130 m3 per hectare and roughly 2,000 m3 per setting, while another stopped high leading with approximately the same unit volumes but smaller total volume per setting, due to the broken terrain which reduced the area per setting. He found he could log cheaper with tractors. At another location one operator is high leading in some 50 m3 per hectare of forest on terrain which is not too steep, with an average volume in the order of 1, [illegible]3 per setting.

One report from the early 1970's indicates that certain Philippine loggers are high leading in stands which yield between 80 m3 to 100 m3 per hectare and with average setting sizes as small as 15 hectares. Some or many operators use two or more systems and therefore can afford certain high cost operations which are necessary due to the terrain conditions and still reach an acceptable average delivered cost.

From the above, you can see that the spread is wide, and it must be noted that the tropical forests of South East Asia are the richest in the world.

The selling price of the log will determine how low a unit volume can be logged, but if you can choose a lower cost system which is capable of efficient logging in low volume forest, the higher your profits will be.

Manpower requires special training for use of the system, and experienced supervision is very essential if the best techniques (tricks of the trade) are to be used effectively. Some companies have gone broke trying cables in Asia.

For plantations, skyline systems can be very effective and the light equipment of alpine Europe with their multi-span skylines can assure longer set-ups and substantially reduce the amount of road required. On gentle, easy terrain, however, a skidder/crawler system is likely to prove to be a cheaper method.

For single span skylines the shape of the slopes to be logged is very important and without the deflection obtained by a concave shape the system cannot be used, which indicates the need for accurate topographical maps.

The best advice one can give on cable logging is to bring in experienced loggers and forest engineers as assessors. They can be obtained from the Philippines, where high lead logging in tropical forests has been going on for a long time, and from temperate countries for logging plantations.

2.1.2. Tractor/skidder system

A term often applied to this system is "ground skidding". The fact that the skidding machine runs over the ground, dragging one end of the logs, gives one the picture of the effects of some of the major criteria on the system.

Tractors (crawler tractors) can be used alone or they can be used in combination with another machine, the articulated four-wheel drive skidder. As a matter of fact they make an effective combination and in most cases the skidder cannot be used without the assistance of a crawler tractor. The ratio of crawlers to skidders generally varies with the terrain and log size, these vary from 1 : 1 to 1 : 3 as a rule. A 1 to 2 ratio logging unit can now cost in the order of US$ 300,000 or even more.

Both machines (and therefore the system) are very sensitive to terrain conditions. The crawler is limited to slopes of 40 % to 60 % but the upper limit should not be considered a norm, and the adverse

grades must be limited to some 15 % to 20 % and only for short distances which do not occur too frequently. I have seen large crawlers working on steep slopes skidding logs up skid trails in the order of 40 % but production was low.

The skidder is normally only effective on slopes to 30 % - 40 % with the upper limit being considered only occasionally. This machine which is intended for fast hauling is very sensitive to adverse grades since the lost time (or smaller load) trying to skid or winch a turn up the adverse grades defeats the purpose of the machine (high productivity through its speed); thus broken terrain becomes an important consideration for its use. Similarly the advantage to be gained by fast skidding over long distances is lost in adverse terrain and a consequence is that more high-class truck roads will be required. The introduction of the skidder to the ground kidding system did lower the amount of truck road required per area logged. These machine limits have been presented here to indicate the effect of terrain on the ground skidding system.

Soil types and the effect of water on them is equally as serious to efficient skidding. Good, apparently firm soils, sometimes become quagmires when wet. In areas of high precipitation a careful look must be taken at both these criteria and their possible combination. Extremely wet conditions can either slow production per day or can stop operations over days and periods of time. Limiting the number of days a machine works (or machines in combination) raises the fixed charges and machine inventory carrying costs, sometimes to the point of making the operation unprofitable.

A new skidding machine has recently come on the market which may help overcome the detrimental effects of water on skid ways and improve the adverse skidding capability of skidders while retaining the advantage of skidder speed, thus enhancing the chances of using a ground skidding system. The machine is now in use in some places in the tropics. Essentially, without going into great detail, the machine is a high speed tracked vehicle capable of operating in muddy conditions and on slopes to 35 %. It has an added advantage in that it exerts relatively low unit pressure on the ground.

Conventional ground skidding does bear a lot of soil and can lead to serious erosion problems, but careful layout and training of operators can lessen this.

The effect of the silvicultural prescription on this system is not as serious as for the high lead cable system the machines can manoeuvre amongst the standing trees. However, the use of machines which are too cumbersome along with improper supervision, can play havoc with the residual stand. These problems can be overcome with careful planning and supervision.

Crawler/skidder logging can be carried out profitably often at low unit volumes, but the high value of many tropical trees is a great help. There are virgin forests now being logged from which only 15 m3 per hectare are being harvested. Some rich forests of South East Asia yield over 100 m3 per hectare. Generally the minimum volumes which can be logged or the point at which one takes another careful look at all the other factors to see if they will alleviate the possible high costs, is in the order of 30 m3 per hectare.

The size of tree and/or log dictates which size of tractors/skidders you should choose but not necessarily the system, for crawlers and skidders come in many sizes.

The ground skidding system has been in use around the world for a long time and the use of crawler tractors is common in other fields, therefore, the chances are quite good that in most countries there are export crawler tractor operators. They may, however, have to change their outlook and methods to effectively skid logs. Skidder operators will be more rare and require special training even though they had previously operated crawlers.

2.1.3. Semi-mechanical/light mechanical systems

The heading for this section may appear to be wrong; however, it is intended to convey the idea that there are many pieces of equipment other than highly specialized and costly units which function very well under specific circumstances. These systems have a distinct advantage in that the components are not too sophisticated,

nor are they usually too expensive, plus the fact that they require more labour input which often meets a critical social need.

Normally these systems are not adequate to supply logs for large operations since their relatively low productivity makes the logistics problem enormous. They can, however, often be an arm of a large operation, producing in special areas and at a low cost.

Two systems which come to mind and are worth discussing are the winch lorry system of South East Asia and the farm tractor ground skidding adaptation.

The winch lorry system has been in use for some 30 years and performed very effectively in the easier terrain types. However, with the move to the mountains which was required as the forests receded, the system adapted and went along. Originally a tractor was only used to build the crude roads, but in the stage and often rugged terrain the tractor became the prime mover, bringing the log to the winch lorry at the road. The ratio of winch lorries to tractors is in the range of from 3 to 7.1. The system is still in use in Malaysia and Indonesia. It is believed that the Philippine version called the "Bataan Logger" is still in use but to a limited extent.

Terrain conditions are a limiting factor with normal winch lorry roads being limited to 30 % grades, but I have seen them hauling down slopes of 50 %. In one case the logger used logs as a drogue.

Adverse grades naturally also slow the lorry but since most winch lorry roads are crude the normal speed is slow. Adverse grades of 35 % have been measured.

Soil and the effect of water on it is important, but the 6-wheel drive feature permits the operation to start up soon after the rains stop. Production is definitely a lot lower during the monsoon months. The fact that the machines are operated on contract or through a contractual system and since they are relatively cheap, down time is not as important as for expensive machinery being operated by daily paid workers.

The system can function on very low unit volumes, as low as 8 m3 per hectare, and has been particularly effective in re-logging, as market trends for species change. With a prebuilt rudimentary road net work I have seen an operator logging an area (third time over) and bringing out less than 5 m3 per hectare.

The system is unsophisticated and drivers and crew soon learn to repair all but the engine of the lorry; the tractor being as in any other system. It is labour-intensive and production costs are usually lower than the major systems. As old machines wear out and higher priced trucks are needed, the system may lose a bit of its low price advantage; however, it is believed that costs of other equipment are accelerating at the same rate. The system works very well with medium sized to large logs and is used very effectively in some plantations of South Australia.

2.1.4. Manual/animal labour operations

While this section may be of little interest to some it must, however, be mentioned because it could be one of the choices available to you, and it may remind you that you do not always have to buy motor driven equipment to move logs from the stump to the carrier or dump.

An excellent example of this is the Kuda-Kuda system of Borneo, where it is used to harvest the freshwater swamp forests. Until recently even the tree was felled by hand saws and axes. The sole concession to power other than human, is a miniature railroad with skeleton cars pulled by a small, used mine diesel locomotive.

Many push/pull, slide/roll logging operations still exist and produce logs cheaper than we normally do with our high geared machinery. Manufacturers make sleds, chutes and pans pulled by radio controlled winches and the like, over and above axes, wedges, levers and jacks.

Animal pulling power has only recently left some of the temperate areas and today Malawi is in the process of training oxen for log skidding. Elephants are still used very extensively in Asia.

The manual systems are not dead yet, and you may yet find areas where they fit the bill. The big problem is that as people get more sophisticated they want change, and everyone likes to do work which is less physically demanding. The logistics of supplying a large industrial complex can be an enormous headache using these systems.

Now that we have reviewed the basic, but not all extraction systems, you are probably as unsure about what system to use as you were at the start. You really should not be, because the basic limiting criteria have been pointed out. With a knowledge of your forest and its environs you should at least be able to assess the most probably suitable system to use. Individual pieces of equipment within a system is essentially only a matter of numbers, sizes and configurations and thus will be covered in a general way later on.

One thing which should be evident from the above is that ground and cable systems are not readily comparable because they are different systems designed to operate under different conditions. Therefore, one cannot say which is the best. Many loggers under actual operating conditions soon determine which is the best as far as they are concerned, but they may be biased to their earlier training, and governed by the particular circumstances or physical criteria of their particular forest or the original forest they started in. One thing is sure - training followed by experience, is the surest way to find the right way for your operation.

2.2 Major transport modes

The other very major phase of any logging system is transport. Each of the transport systems listed below can be used with any of the extraction systems enumerated earlier. However, we must choose the appropriate one. Sometimes we have no choice but one, and its use is obvious.

Basically there are three ways to move logs over long distances, and these are: by truck, by rail and by water. The basic criteria examined for extraction methods also apply to transport, but as is evident, accessibility and availability of infrastructure and waterways becomes a key issue in transport.

One thinks twice before going in to log an area which is very remote. If there are no public or private roads (or a railroad) within economic hauling distance from the forest then the extra cost of construction of a lengthy access road often deters the investor. The presence of good, usable public roads often changes the picture, for instance logs are being hauled from 3,000 to 4,000 km in Brazil, albeit they are of selected species and at back haul rates. Wood hungry industries in parts of Asia haul logs from 160 to 500 km.

Basic data collection therefore must include information on public road, rail and waterways which may include coastal and seagoing movement. Therefore, occasionally other information is often required on port capabilities, rules, shipping and handling rates.

The major basic method of transport has now become trucking, for the accessible forests have almost completely disappeared from the vicinity of coasts and rivers. Occasionally all three methods will be used to move the same log. Some logs are trucked to rail, railed to water and floated to mills, generally, however, two systems in combination is the norm for a combined system. In most parts of the world where water transport is used, the logs must first be trucked. Basic data yields the information required to tell what other method can also be utilized to lower costs. Certain parts of Amazonia are still producing large quantities of logs without the use of trucks.

Railroads are a cheap method of moving logs, but the logging railroad almost became extinct because of its inflexibility with regards to terrain, and public railroads do not often go to or through the forest. Where available, railroad haulage can be cost effective.

The problem with most forests, as said earlier, is that they are no longer accessible to a waterway. Therefore, the logs must be trucked and once loaded it is a simple matter to hook on to a public road and deliver directly from the forest to the mill yard (so-called door-to-door delivery) provided the distance is not excessive. The movement is positive, logged today and at the mill

today or tomorrow. Tacking on another mode involves extra handling and delays and the manager often loses some control over his log for periods of time.

Of the three modes, especially for long distance movement, it can be said that the cost per unit of log, runs in the ratio of approximately 1 : 1.5 to 2.5 : 3.5 to 5, for water, rail and truck respectively, naturally with great variations for efficiency and ratio of fixed time (loading, unloading, terminal costs), to hauling time which is essentially a function of dead time to haul time, plus load factors affected by regulations and road conditions, stowage and service. Hauling costs are sometimes higher on inefficient railways than by truck. Road, spur and loading facility costs are extra in all cases.

The various factors which affect costs are time, distance, terrain and weight (volume). One can readily see the interplay between these items. For instance, a road with poor alignment and a low carrying capacity due to difficult terrain conditions and lack of surfacing material will require low speeds (time) and less will be carried per trip (weight/volume).

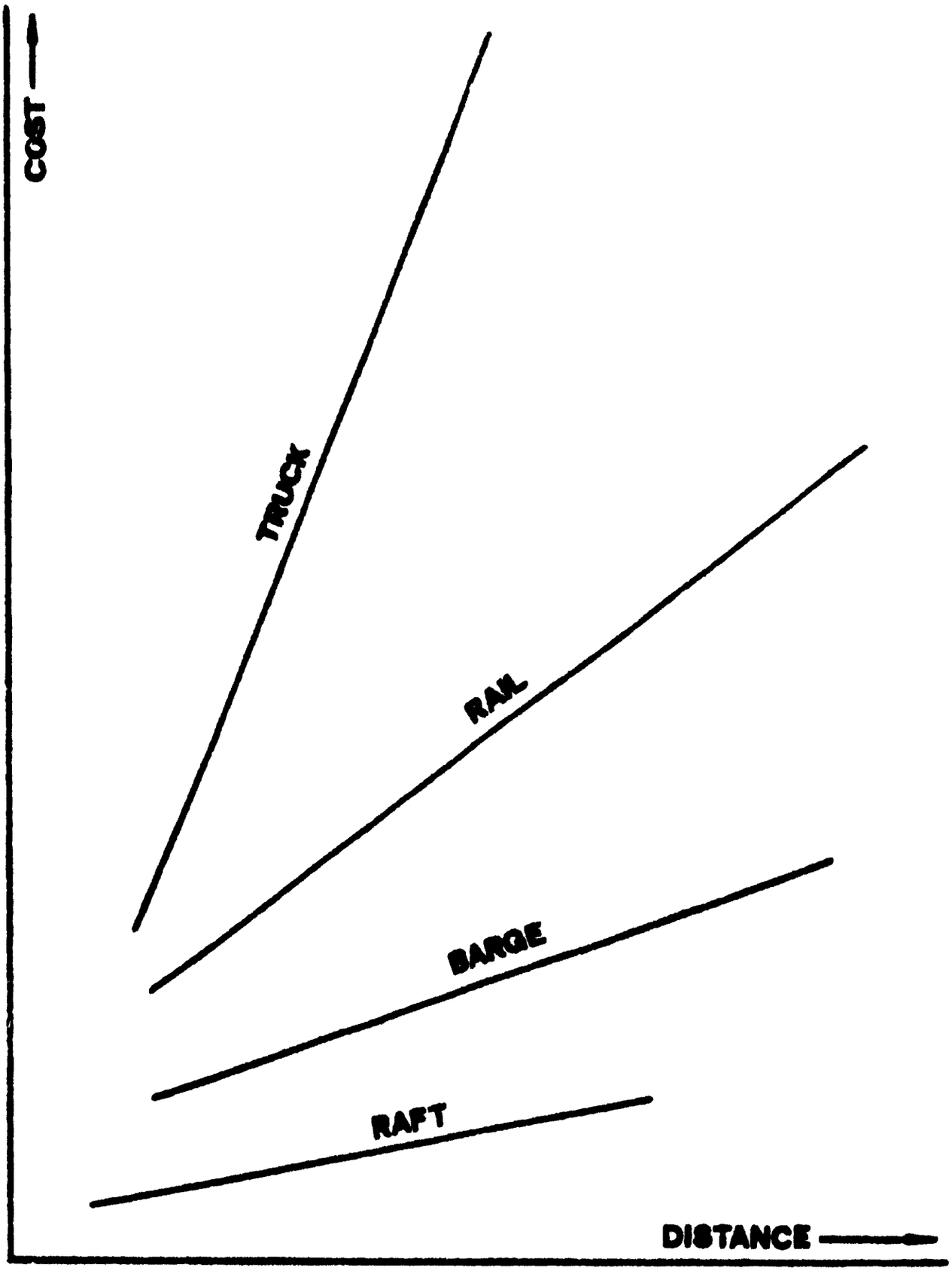
Similarly, on a winding serpentine river, barges will travel slower and costs will be higher than on a straight river.

However, these factors need not affect each transport mode to the same degree provided one knows the relationships of each. For instance on a twisting road or river you may be able to increase the load size, partially lowering the increased unit costs due to time.

If one were to calculate the unit cost per m3 of transport for the three modes over varying distances, he would be able to plot a graph of these which would look somewhat similar to the one shown in Figure. 1. One must remember that there can be great variations.

Truck hauling is very sensitive to soils and water, and thus to the availability of surfacing material in order to allow for all-weather haulage. The truck is much more versatile than rail in difficult terrain conditions. Thus to hauling costs, the cost of forest roads and their maintenance must be added. In most cases, however, roads are necessary for a first move.

LOG TRANSPORT COST RELATIONSHIPS



Trucks come in many sizes and configurations. The system is so prevalent that many firms manufacture trucks and trailers just for logging. These are generally in the heavy duty range and cost of one unit can run to US$ 100,000. Trucks in the medium and light duty range are usually assembly line units with perhaps some special features such as beefed-up frames, heavier suspensions and axles.

A careful look must be taken at the units to be purchased for trucking, once it is decided trucking is necessary and/or desirable. The size of the operations and the operational periods and shifts are basic to any calculation; however, load size, affected by the green weight of logs, (and bark), and load limits on public roads (and on some private) are equally important in the final selection. Some trucks, without load, weigh as much as permissible gross vehicle weights on the lower standard roads, which are often found out near forest areas. Some manufacturers use light weight materials to increase the payload. Furthermore, a system of trailers, one or two pups, can increase the payload, but a careful look must be taken before this is adopted.

The driving capability of the crew will often govern the accessories (automatic, power shift, and power steering) and size since huge trucks are difficult to manoeuvre for some inexperienced personnel. Similarly, low forest road standards may indicate the need for front-wheel drive and load limits are usually higher for more axles.

The loading and unloading methods can also be critical. A small operation cannot always afford to employ or buy a fast mechanical loader, therefore, loading can take up to 4 or 5 hours. It is rather pointless or costly to have a huge expensive truck standing around waiting to be loaded. Another example is the use of a pole trailer which is normally loaded for the return trip, which cannot be loaded or unloaded for lack of a sufficiently strong loader. In many parts of the developing world logs are loaded manually or semi-manually, or at least without the benefit of separate special loaders. Many systems are in use, but the truck should be bought to fit into the system.

Truck hauling is often the highest cost phase of logging. Thus it seems only natural that special attention is taken in the selection of trucks and their configuration. One should remember that expertise is available, not only for the initial selection but also for the effective operation of hauling. Some companies employ full-time transport superintendants. As stated earlier most truck manufacturers will provide the expertise to supply the truck to do your job, but remember you must know your basic requirements and have the basic data at hand.

You must know the terrain to determine the type of road you will build; sharp curves and steep grades will require certain specific equipment including trailers. The size of log required by industry and the size of your trees will perhaps require special features capable of handling say, long logs, and here the size of truck and the extraction equipment must be well matched for the best overall performance.

Highway hauls require that you know all the regulations, not only those pertaining to speed and gross weights but also as to size, such as overall length, width and height. Quite often you will find antiquated rules which no longer fit the situation. By presenting a well outlined and calculated case you may be able to assist the authorities in up-dating their regulations or get special hauling permits that will save you money.

Beyond a certain distance hauling by rail is usually cheaper than truck hauling, however, in many cases the rail haul involves a truck haul at both ends, therefore, a careful look must be taken into these added costs which must include rehandling.

In some countries rail hauling on public systems is not as efficient as truck hauling, and private railroads into the forest area are usually not on because of the difficult terrain found in most remaining forests. Because of this it is doubtful that anyone still extracts directly to a railroad, an exception being the mini-railways of the swamp forests of S.E. Asia, which are the only ground haul methods suitable and which usually only haul short distances to the nearest river.

With th now increased and cont nually increasing rice of fuel it is possible that more companies will look into the possibility of putting in rail for their long hauls. Similarly, remote areas far in the hinterlands will probably best be served by rail which is put in for another purpose, say for mining. In all public rail hauls the logger is at the mercy of the railroad and generally railroaders have not given much time or effort to help solve the loggers' transport problems. Railroaders often claim the logger is inconsistent. Perhaps it is the loggers own fault for his inconsistency, or perhaps he is inconsistent as a result of the government's forest licencing policy.

The rate structure on public railroads is usually very complex. Railways play a prominent part in the overall economic policy of some countries and often these policies are reflected in the rates for certain goods or commodities. Of course, the same can apply to internal water transport, and to some extent trucking on public roads, where rates are applied to meet a specific need or encourage/discourage certain activities, often as a market regulatory tool. Before investing in equipment, a logger who must rely on rail for his long haul, should ensure that he has a long-term agreement with procedures laid down on how to handle any rate alterations.

Rail transport requires very special expertise if one is to operate a private road. On public roads the numbers can readily be obtained but during preliminary discussions one must ask all the questions. Railways people tend to assume that you know as much as they do. Some unmentioned items can be costly and are the public railways willing to put into service special cars (wagons) which will handle logs most effectively? Often, they will not. One skeleton car can cost in the order of US$ 20,000 and they sit idle for a good part of the time in addition to which you may have to pay dead heading charges.

Public railways (as public roads) have set load limits which must be carefully looked into when calculating. Green weights and bark can make a haul expensive, especially if the wrong cars are used and load configuration (pyramid) is regulated.

Until recently at least, road transport has cut into the railway business so badly (other commodities) that many were unprofitable. However, where rail service is available a careful look should be taken into its use, especially for long hauls. Similarly, if a logger must build private roads over great distances served by a railroad the rail haul will win out unless service is too unreliable.

Water transport has always been the most economical method of moving logs, but the water system is not always available in the forest and trucking must be resorted to.

Ocean transport is a specialized business and implies moving logs out for manufacture in another country, therefore, it will not be covered here; however, one should mention that Indonesia, the Philippines and Brazil, for instance, have vast distances which can be covered within their territorial waters. A look into these would be the subject of a complete transport study.

Traditional water transport normally entails floating the logs in controlled groups on rivers without use of equipment or towing log rafts and/or bundles and barges with tugs.

The former is gradually disappearing along with the river drives of the northern coniferous forests. Rafting and barging are still quite common though mostly restricted to countries well endowed with rivers to tidewater ocean shipping points or mills. Similarly, most logs in Amazonian Brazil move on the Amazon or its tributaries.

For obvious reasons a logger must know the green weights of his timbers and the conditions of his rivers or the sea. Remote forest areas can appear accessible until one observes the river flows during the often prolonged dry season. Fast river flows can preclude towing upstream or raise costs considerably.

Tugs used for towing or pushing must be especially designed for a particular application. Although one sees "any old boat" towing log rafts and barges in many countries, they are not often the most efficient. The main advantage is that they are already owned or that the owner who has a lot of time will charter out at low rate.

Tugs used for moving logs come in all sizes, and power sources range from less than 100 hp to big barge puller/pushers of over 1,500 hp, depending on the application. Costs can run over US$ 1 million. Initial capital outlay for a barge/tug system can run into a sizeable amount, for instance the cost of a tug (towing/pushing) and two 2,000 ton capacity barges can run one into an expenditure of US$ 1.5 million, depending on the country of construction. A between-decks or welled barge will not usually handle as many logs in volume as say a flat decked deck-loaded scow, and loading is simpler on an open deck.

Thus, it can be seen that it is important to have a tug with the correct features, one of which is the power source and the correct barge. Regardless of these high figures quoted, if you have a floatable/navigable river it is essential that you investigate its use. But while you are investigating, be sure to check on boat crew staffing and manning regulations. The rules sometimes force an operator into more capital (and operating) outlay than he envisaged and thus higher costs. For coastal or deep sea shipping, a person is forced to use water but sometimes he can negotiate or force lower rates.

In areas with good rivers and coastal waters along with a forest which supplies floater-type logs, simple rafting systems are most often the answer. The surest and fastest method is to tow the flat or bundled rafts of logs, and again, specially designed tow boats are the most efficient.

Forest roads form an important part of the truck transport system, and in general it can be said that the factors which affect cost of extraction by crawler will have a similar effect on road subgrade construction equipment, where crawlers predominate. A tendency which has come in of late is the use of power shovels and back hoes for subgrade construction in some temperate countries. This method could well be the answer in some problematic soils in the tropics and could also help to alleviate environmental problems associated with or caused by the crawler method of construction.

Surfacing and grading equipment are basically standard. However, the size of gravel trucks may cause a minor selection problem in order to balance out the loading. If gravel is only applied lightly and over a short period of time, the trucks might stand idle unless they can be turned to other use. In such circumstances an operator might be better to hire (or contract) his trucks and loader for the requisite period, if he can.

Road construction is a specialized task requiring a lot of supervision so much so that most large, well run companies employ a road foreman.

3. Ancillary production functions

Although these items have been listed as being subordinate in this paper they are by no means insignificant, and if not properly carried out can disrupt an operation to the point where production is lowered drastically or costs are raised unnecessarily.

The same basic criteria affects these functions as for the major phases. We can discuss these in the order in which they normally take place in an operation

3.1. Felling and crosscutting

Today most of the world's industrial timber is felled by means of chain (power) saws. These are simple (relatively low-cost) little machines which are easily serviced by the operator or owner. However, they are a high production machine and have increased a workers output many times over the manual axe/saw methods.

Because they are fast they can also cause a worker to perform his task in an unsafe manner. In addition to picking the correct saw (horsepower, blade length and safety features) fellers should be given careful training on their use and proper felling techniques.

In addition to safety, the manner in which the trees are felled can make the extraction easier, thus lowering extraction cycle time, thus the importance of training. Similarly, it does not take many broken trees of a valuable species before you wish your fellers were trained.

Hand felling and sawing is still used in some countries, especially for fuelwood and small tree felling. Axes are wasteful and this becomes a serious matter in wood deficit areas.

Productivity in felling is also affected by terrain and weather. The size of the tree may cause a feller to work longer on one tree but if the height is good he will make up in volume.

One could not begin to name all the brands of chainsaws on the market, but suffice it to say that the market is big and competition amongst manufacturers ensures that they put out a good product and most have a large research and development staff to ensure that they put out better products in the future.

Associated with felling are the supposedly still more minor items such as clothing (helmets), hand tools, files and repair tools and jacks to name a few. These may seem minor but they are essential.

3.2 Debarking

Debarking is still done manually in the forest in most developing countries where logs are generally barked before entering the mill or where logs are exported. A logger must decide whether to do this in the field, manually, or let the miller do it either manually or mechanically at the mill. The logger's main concern is labour availability and whether or not the weight of the bark will affect the load size which he can haul and of course he must be reimbursed for his work. Tools are simple and readily available.

3.3 Loading

Loading normally entails the loading of logs at a forest landing on to a truck but can also be required for rail and barge hauls and can be carried out at the stump for pulpwood. Rail and barge loading does not normally have the same urgency to mesh in with other functions such as extraction and hauling, since these two transport modes are normally fed from a stockpile as and when the wagons and barges are ready. When, however, barges and wagons are available, the loading process must be fast and efficient.

In truck hauling the most difficult piece of equipment to fit into the overall scheme is usually the loader. This is especially so in small operations where quite often the logs are big but a big piece of equipment needed to load big logs on trucks is over-productive and thus would be under-utilized. Many small operators do without, and devise makeshift systems or use self-loading trucks, all of which are usually slow compared to mechanised loaders, and tie up the truck for long periods, thus high priced powerful trucks also become redundant. Similarly, under-production loaders hold up trucks thus raising hauling costs.

Mostly, all loaders are now mobile. Boom loading in cable operation is still practised but its use is declining. Especially mobile loaders can be said to be front-end loaders, mounted on wheels (rubber) or tracks, heel boom hydraulic loaders also on wheels or tracks and the hydraulic knuckle boom grapples used for loading smaller trees or logs are and usually to be where the logs are they must be mobile.

The decision as to size of loader depends on the size of logs, which has been decided in the extraction and/or transport phase or by mill requirements. The decision as to whether to use wheel or track mounted machines depends on how mobile it must be, which is essentially the distance to be travelled between loading points and the soil and water conditions. For some special loaders the adaptation to rubber wheeled mount can raise the cost considerably, even in the order of 40 per cent over and above the cost of a track mounted model. Front-end loaders mounted on rubber cannot always function on wet, soft landings - they soon slip and slide and bog down. Track mounted machines move slower and their weight is better distributed, thus they do not churn up the loading so much and are not so vulnerable to soil and rain conditions.

Thus, for certain soil conditions a track mounted (rubber if the road surface is wide enough) heel boom loader, loading from logs piled (windrowed) beside the road is sometimes the best solution. This of course entails being able to place the extracted logs in windrows. Clear felled forests being logged with a portable skyline

system lends itself very well to this loading unit. Ground skidding in a selection system could also use this method and thus prevent the clearing of large areas for landings with resultant extreme disturbance and compaction of the soil.

On some big operations where loading time is a significant part of a truck's total available time, some operators preload trailers and thus the truck (tractor) which is the expensive part of the unit is more or less moving continuously. The preloading of course must be foreseeen to be much faster than normal loading in order to make the extra investment pay off. Preloading also requires more space and better landings than those required for direct loading.

Rail and barge loading usually require special loading points and depending on the facilities provided, the loading equipment or method is chosen. A key factor is to be able to manoeuvre the logs so that they take the least space in the barge or wagon. Some railway companies charge by the wagon with weight limits, and naturally according to distance, thus a logger must ensure that he loads the maximum allowable. The same principle applies to barges.

Because loading is such a critical function to select equipment for, spare capacity in marginal situations should be allowed for. This could entail the cost of another machine standing idle for possibly most of the time. One solution is to try to order log unloading and gravel loading equipment which can be brought into play as required.

3.4 Unloading

As for loading, the object is to get the truck back on the road as fast as possible. Often the mill takes over this function and the logger loses control of his truck, which, if the mill employees are not conscientious, can be costly.

Logs are unloaded by a myriad of methods and systems, and a logger has to find the cheapest method which will also ensure that his truck is not held up unduly. Essentially the same mechanical

methods as loading are available but the front end rubber mounted loader appears to be the favourite. One must remember that log yards are surfaced and/or compacted and soil conditions do not effect this operation as is the case for loading in the forest.

An integrated operation can buy unloading equipment which will unload trucks, sort the logs for size and species, stockpile them and feed the mill. Thus the cost of the machine to the logging operation can be minimal. Big yard machines, which can often lift a whole load are costly and one capable of lifting 20 tons costs in the order of US$ 225,000.

Loggers delivering to water can employ "A" frame unloaders which are cheap and efficient, provided the truck is suited, but sinkers, which are common in tropical forests, may prevent this. Some operators use "A" frames or parbuckle their logs on to the ground, get the truck back on the road and move the deposited logs with a smaller front-end loader.

3.5 Overhead equipment

This heading covers all the non-producing items, although listed with the production functions, and is so important that it has been included here. The numbers and pieces of this equipment are large and their prices are usually relatively smaller than production items, however, no operation can function without some or all of them. They form a part of any system.

For instance, an operation cannot be supervised properly without a supervisor and he must have transport. Similarly, the crews must get to and from the job. The state of the roads and the job to be done dictate the type of truck required. An example of this is four-wheel drive versus two-wheel drive.

On scattered operations and long truck hauls a radio dispatch system can pay for itself in no time. A mobile workshop will reduce machine down time on any operation.

We know that we must ensure that equipment suppliers provide good maintenance and spare parts service. Similarly we must have a good repair depot. Shop equipment is a must and can run into a considerable sum when you add up the cost of all the bits and pieces. We must also stock the essential, most often needed, spare parts.

And since we want cost control on our operation, and each piece of equipment and its major components (tyres, wire rope), we need an office and the equipment to go with it, like power (plant), telephone, and office equipment. Housing and other such infrastructure can add up to a lot of money.

1. Individual considerations

Once a choice has been made as to which system to use the equipment choice has almost been made. The only problem confronting the operator now is which individual machine fits his particular terrain, weather and forest conditions. In other words if he has chosen a crawler/skidder combination he must determine the ratio of one to the other and the size or pulling power of each. The previous section has covered much of what could be said here but as said earlier one cannot divorce one part from another in a good operation and it is just as difficult here in a short paper.

Skidders generally come in three sizes within narrow limits and crawler tractors, suitable for logging, in about five. The selection of individuals entails a productivity analysis based on draw-bar pull and relevant speed of each machine as given by the manufacturers, and the load you expect to pull. It will be obvious in some cases that certain machines are not suitable, for instance a 75 hp tractor would not be much use in logging the large tropical trees whereas a 300 hp tractor would be out of place in a same range. In tropical forests some loggers maintain that a 140 hp tractor will do the job while another claims he needs a 180 to 200 hp machine. Different soil and terrain conditions plus the length of log, plus the philosophy of logging, high speed or low speed, are generally the critical factors.

In the case of cable systems the analysis is based on cycle time or turn time, related to productivity the same as for ground skidding methods. In cable logging, non-productive time such as changing roads and settings is a major productivity (non) factor which must of course be included in productivity/unit cost calculations.

In your operation, however, you will be in one forest, therefore, you can make direct comparisons between machines manufactured by the same company, since the forest condition inputs will be the same. Productivity is not enough - this must be merged with machine operating cost to give a unit cost. When estimating, the lowest unit cost machine should be the winner, but if we overwork the smaller machines their down time might be higher than we put into the estimates or it might wear out faster than we allowed for, therefore, marginal unit cost differences can be misleading at times.

Comparison of two machines of the same approximate size and power brings a different input into a calculation, "reliability", and this generally can only be found out by experience and comparison with other operators.

Comparisons of two different machines designed to do the same job is also a problem when we have no operating experience behind us. We can only take the word or advice of the dealer or we can try to search out research and study papers, (especially on new units), but getting around and talking to other operators and owners is one of the better methods. If an operator continues to use a certain type of machine and is still in business he must be satisfied with his equipment. A word of caution, some people buy on price alone because of their particular financial circumstances and do not always buy the most suitable equipment. Similarly operating philosophy may be different than yours i.e. high speed-low speed, longer write off periods and the like.

A similar process can be carried out to determine the ratio of skidders to crawlers, once the basic size selection has been made.

For this sytem it can be said that crawlers are slower than skidders, therefore, the crawler should log the closer areas and the skidders the furthest. Productivity calculations can give you the distance at which the productivity of each machine is approximately equal.

When it comes to size and configuration of trucks and extraction equipment, the size or length of log becomes very important in the selection process, over and above terrain and road conditions and other restrictions. For instance a peeler log is usually of much higher value than a saw log and usually rarer in the forest. Logs for plywood, and for sawing for that matter, require to be cut to a specific length, with trim, to meet mill specifications. We know that it is difficult to train the feller/bucker to buck (crosscut) his logs to the correct length and still get the most value out of a high quality tree. Sometimes the lie of the tree prevents bucking for quality. In order to overcome this, some operators extract tree length and even haul tree length to the mill, so that the tree can becrosscut under very close supervision. You can see what effect this factor has on your choice of size and configuration. Perhaps you n ed the 300 hp tractor a l perhaps you nee a pole type trailer truck with extendible reach (pole).

Nothing beats actual productivity and cost figures. Each and every new operator should, if his operation is large enough, hire both a cost accountant and a mechanical superintendent. These two should set up a cost accounting system, complete with individual machine costing. The foremen should be trained to understand costs and be able to pinpoint what is raising costs. With a set up such as this you should be able to come up with a better picture before your old equipment wears out, and before it is time to replace it, possibly with something else. A problem in many cases is the ability to keep the key men, too often the incentive is not there and they leave for other work. Salaries from a key part of any economic machine calculation, and if a man is doing his job and worth it, pay him. Similarly, younger men should be in the training pipeline so that the enterprise has continuity.

Simi ar estimates can be mad for the other sy: ems. Productivity and operating costs.

Just imagine the job you have as you work your way through each machine. You find you need a lot of data, to name a few we have not mentioned: fuel, lubricants, tires, spare parts (the amount to be used of each and the cost), labour rates and fringe benefits, depreciation periods, insurance, interest, re-sale value and on and on.

A new venture in a developing country should not try untested, undeveloped systems or equipment unless it has no other choice. And it should also be pointed out that what works in a developed country, probably in temperate forests with different criteria than those mentioned in Section 2, may not work in your case. Too many factors are involved to pick more or less blindly from a large assortment and risk having your venture fail.

Mechanized logging has been going on in the tropical forests for a long time and there are many proven systems and pieces of equipment readily available. In your particular case you should be sure that good service and spare parts are available. A case in point is which manufacturer or dealer has the most machines out working in the forest. I have seen an area where almost every skidder that is manufactured was in use and many were lying idle. When a dealer sells only one machine he cannot afford to have much service and a big stock of spare parts. In another area one machine dominated all the others and the dealers service was excellent.

It does not take very long of having a machine sitting around idle for lack of spare parts before you wish you had chosen the other machine. The mechanical capability of your personnel or the people in your area may influence your choice of high, medium or low mechanization. Similarly, your expertise in all the preparatory phases such as road layout and construction, to name one, must be considered when selecting systems or equipment.

Fixed costs have a direct relationship to the amount of time worked and thus productivity. Some machines are very susceptible to poor soil conditions and therefore, may sit idle, eating away the fixed dollars. When you have such a situation you either have to find another type of machine which may extend your working period or modify what you have (chains, low ground pressure tracks). If all else fails and you still want to operate you can resort to double shifting in order to bring your operational hours up to your first expectations. From this latter comes the alternative of double shifting anyway. Many operations now load and truck on two shifts, thus cutting original capital layout and lowering fixed costs. As a matter of fact in some temperate areas they even log under floodlights just to keep those high priced machines producing.

Wear and tear is a factor to be thoughtof when ordering equipment. This can come about through misuse and/or through the soil and other weather conditions prevalent in area. For instance, crawler tracks normally need turning at about 2,500 hours and a complete rebuild is needed at some 4,000 hours. This could change drastically for the worse if you are working in sandy soils. Similarly truck tires will wear out a lot faster on laterite and crushed hard rock than on sand or clay and overloading of trucks can seriously shorten their useful life.

In concluding this section let it be recognized that "service" is one of the most important factors to be considered when selecting equipment.

We have now taken a quick tour through the basic principles or factors which any prudent operator must take into account when selecting his logging equipment. We have by no means covered everything, but we have gone over the basics.

You may have noted that "know-how" and "training" were mentioned throughout the paper. In the event that these points were not stressed sufficiently or correctly, they are again being emphasized as follows.

A system implies a planned method of logging. Therefore, planning an operation is the key to its success or failure. In order to have the best chances of success you must have trained, qualified people doing your planning from the first, not half way through the exercise when corrective action will come too late. People become "qualified" through training, whether it be from experience or on-the-job training, or formal training supplemented by experience.

If training is not available an effort must be made to get a training programme started as soon as possible for there is a lag between the start and completion of training and making the training of some use through experience. Training covers the whole range from the simplest to have the upper levels of academia and should be recognized as being a must or even a part of your overall operation as well as a must for individual phases or machine operation and operating techniques (i.e. felling).

An operation which starts off from poor or improper planning through to selection of equipment, followed by the use of untrained operational personnel, will have less chances of becoming profitable than a well planned one, and often it cannot be turned around, due to built in problems that cannot be eradicated, without closing the operation.

Above all one must remember that logging is only one phase of the forest industry which covers the field from seedling to market. Do not do as some have done: build a mill, then ask if there are any trees and what will they cost at the mill gate.

Many countries do not have the necessary logging expertise nor do they have facilities to train people in the requisite skills. This is one area where FAO have a considerable amount of expertise to draw upon, its primary task being to help Member Nations to the maximum. If you qualify for such assistance, contact may be made with the appropriate Division in the Forestry Department of FAO in Rome, especially the Forest Industries Division.

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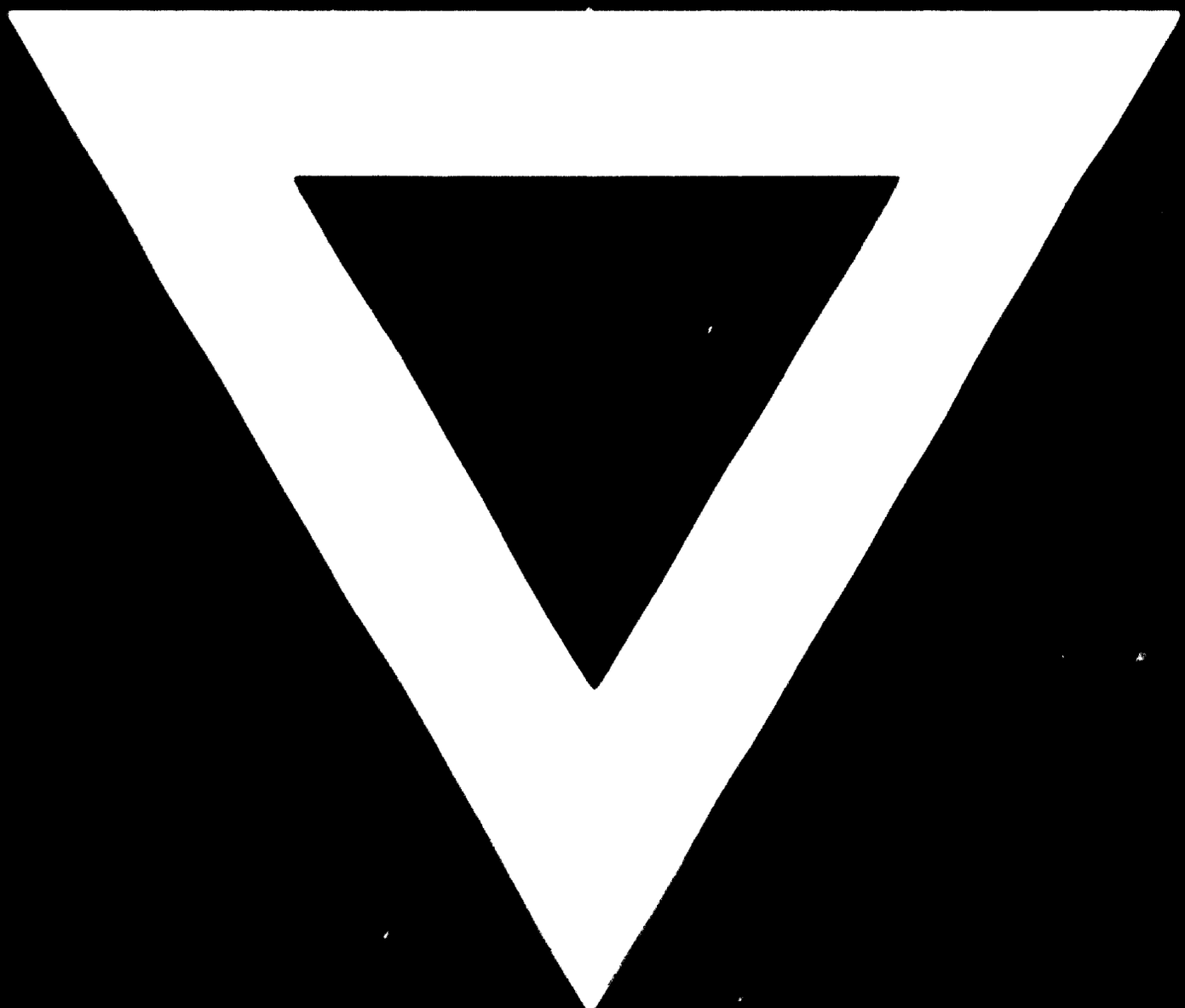

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