AN ECONOMIC STUDY OF THE TECHNOLOGY OF HARVESTING AND TRANSPORT SYSTEMS USED IN CLEARFELLING *ACACIA MEARNSII*, *EUCALYPTUS GRANDIS* AND *PINUS PATULA*

by

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I hereby certify that, unless specifically indicated to the contrary in the text, this thesis is the result of my own investigations, that it has not already been accepted in substance for any degree, and is not being concurrently submitted in candidature for any other degree.

Signed ______________________

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TERMINOLOGY

Modern operations in preparing and removing timber from the plantation to the point of sale are varied. Clear-cut divisions, and thus definitions, of operations are frequently impossible. In this thesis the South African usage of technical terms was adopted. Harvesting refers to all operations from felling to presenting timber for loading onto transport vehicles. Transport includes all operations from loading transport vehicles to offloading them at the point of sale.

Harvesting is subdivided further into primary conversion of timber and extraction. The former includes all activities of felling, marking, crosscutting, debranching, stacking brush and debarking. With wattle primary conversion also includes bundling and stacking the bark if it is to be sold. Extraction includes all movement of timber from the stump to where transport operations commence. Where transport commences at the stump, there is no extraction.

Normal work study expressions are used. Work is referred to as undefined human effort or machine utilization. An activity is a definable portion of work such as felling a tree or loading a lorry. Elements are small or minute sub-sections of an activity as with a crane grabbing logs while loading. An operation is a group of all activities comprising a complete section of the work for example timber extraction.

During the final stages of completing this thesis, the name of the writer's place of employment was changed from the Wattle Research Institute to the Institute for Commercial Forestry Research.

ABSTRACT

Objectives of this thesis are to project the description and supply of Black labour in the forestry industry of southern Africa, survey harvesting and transport systems used overseas and locally, select and adapt a method to analyse and quantify local systems and present the results of this research.

The next objective is to write a computer programme which uses these results to estimate labour and machine requirements with their respective production rates and give standard cost analyses. This supplies the detail for system selection, daily management of harvesting and transport operations and the basis for control by comparing projected production rates and costs with historical data.

Although labour intensive systems are still being comployed, it was found that costs and unavailability of Black labour has forced a conversion to capital intensive systems. This trend is expected to continue at an increasing rate.

Many European machines appear to have developed from forwarders with various heads fitted to their cranes to perform different operations. American equipment has tended to develop around the articulated front-end loader. In South Africa, the locally invented three-wheel loader has been adapted to fill a similar role. However, it is premature to forecast the direction southern African forestry will follow.

Of the possible work measurement techniques, the so-called stop watch methods were selected as they proved to be the most accurate,

penetrating and rapid. Results were reproducible and highly significant when regressed on the appropriate tree, terrain or work site dimensions.

A survey of available computer simulation programmes revealed that in their present form they were unsuited to southern African harvesting and transport operations investigated. Consequently, the writer wrote a programme in FORTRAN 77 which contains all results in this thesis and analyses timber harvesting and transport. The programme, named Techno-Economic Analysis of Logging (TEAL), supplies its results in a form suitable for both field staff and senior management. TEAL analyses have been found to compare closely with efficient operations.

Many of this thesis' data have been compiled into tables giving piece work rates in simplified form. These are presented in appendices.

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CHAPTER 1

INTRODUCTION

Despite the current Black population explosion in southern Africa, a recent survey (de Laborde, 1982b) revealed a reluctance among Black workers to undertake heavy manual labour. Female labourers are used almost exclusively in manual timber and *Acacia mearnsii* (wattle) bark preparation which was formerly essentially a male occupation.

As the average educational standard rises and numbers of totally unschooled workers declines, aspirations of the people rise. This transition reduces the labour intensiveness of all forest work and, thereby, numbers employed by the industry. The effect is unfortunate at a time when creation of job opportunities is vital. However, more capital intensive systems do provide occupations which increase the satisfaction of rising aspirations.

Although no comparative national census data are available, constant contact by the writer with the industry has shown clearly that labour costs have risen steeply since 1972. Further, larger-scale timber growers have had to provide fringe benefits including, *inter alia*, free medical care, food and high quality housing for workers and usually their families.

To remain competitive on both a macro and international level, growers are increasingly being compelled to mechanise forest operations. With the exception of a few of the largest-scale growers, forest owners and managers have had no quantitative information on which to base decisions and have been reliant on hearsay and the integrity, and often limited knowledge, of salesmen.

In 1972, the Wattle Research Institute took steps to rectify the situation and the writer was instructed to commence formal analyses of systems. As shown in Table 1.1, harvesting and transport of forest products constitute approximately two thirds of the total direct cost of such produce at its final destination. Consequently, the writer was directed to concentrate research on these topics.

Although work could be undertaken on wattle and *Eucalyptus grandis* regulations disallowed the Institute from research on pine species until July 1982. Thus only *Pinus patula* has been studied. This thesis collates all work undertaken to date on the above operations and tree species.

There are two major objectives of the thesis. Firstly, to give guidelines to provide the following :

Projection of the structure and supply of Black labour,

systems for harvesting and transport forest produce which are suitable for southern African afforested areas and accommodate the various trasitional stages of Black labour.

a means to accurately and quantifiably establish work content of these systems, and

a computerised analysis programme that will forecast labour and machine requirements, their production rates and detailed cost structures which also will establish a means

TABLE 1.1

Distribution and relative proportion of total direct forestry costs[1]

Allocation	Distribution and relative proportion of costs							
	Pine		Eucalypts		Wattle		Average	
	(R/ha p a)	%	(R/ha p a)	%	(R/ha p a)	%	(R/ha p a)	%
Planting	16,70	7	26,91	12	21,34	12	21,65	10
Maintenance	61,55	24	56,84	25	44,93	26	54,44	25
Harvesting	87,39	35	88,98	38	68,32	39	81,56	37
Transport	85,16	34	58,74	25	38,87	23	60,92	28
TOTAL	250,80	100	231,47	100	173,46	100	218,57	100

Note: [1] Information in this table is drawn from Table X of Document No 21/1982 of the Economics Division, S A Timber Growers' Association of management control.

The second objective is to provide the timber industry with all of the above for the current situation realising that the information will be superceded and that this research and updating of data banks must be continuous.

CHAPTER 2

LABOUR SUPPLY AND TRENDS TOWARDS MECHANISATION

Prediction of trends in the southern African Black labour supply and the movement towards mechanisation are difficult because of a lack of comparable, historical data. Such predictions are required to provide direction to research into harvesting and transport systems and to supply guidance to the industry in selecting systems that will not be forced into early redundancy through changes in the labour market.

To attempt the prediction, the relative location of forestry areas and Black homelands is discussed followed by a description of changes in structure of the Black labour market.

2.1 LOCATION OF FORESTRY AREAS

South African forestry may be divided into seven major and separated areas, *viz*, north-eastern Transvaal, central-eastern Transvaal, south-eastern Transvaal and northern Natal, Zululand, Natal Midlands, southern Natal and southern Cape. Figure 2.1 shows these areas. Greater detail is provided in Table 2.1 (Lourens, 1983, p. 17).

Other important southern African forestry areas include central-eastern Zimbabwe, northern and western Swaziland, north-western Transkei and central Transkei.

2.2 LOCATION OF POTENTIAL BLACK LABOUR

Concentrations of the rural population are shown in Figure 2.2

FIGURE 2.1

Distribution of forestry areas in the
Republic of South Africa

(Shaded sections are forestry areas)

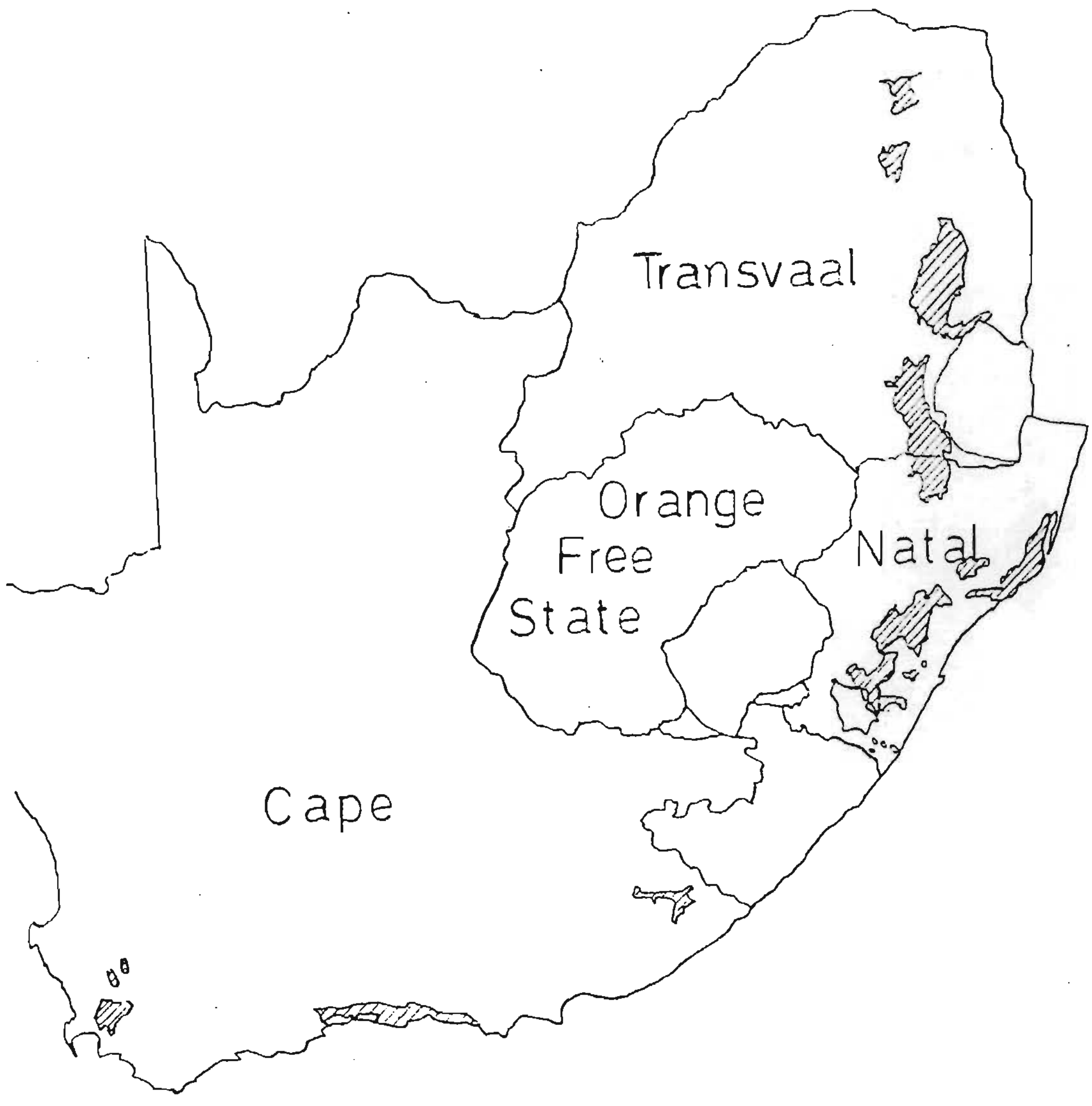


TABLE 2.1

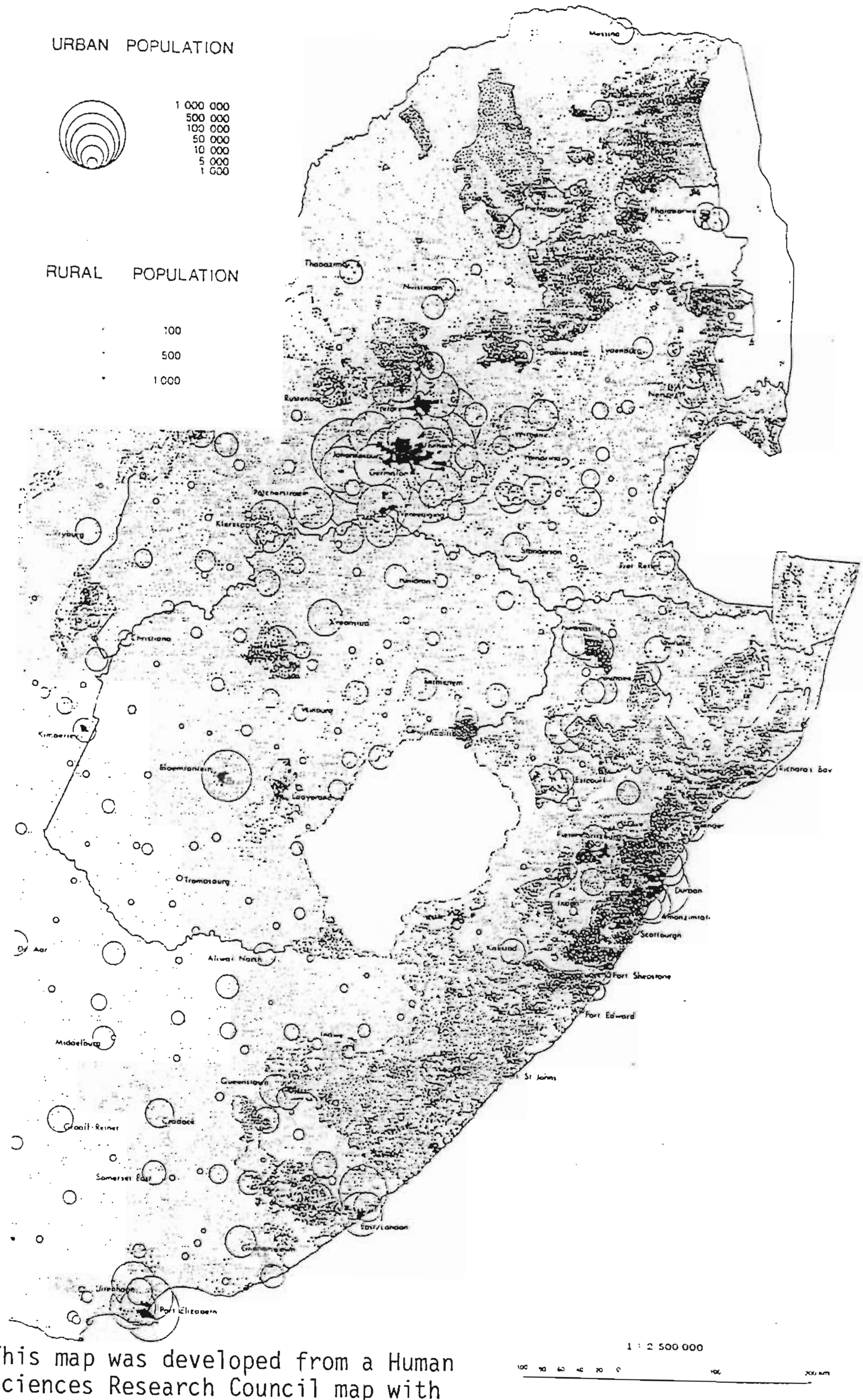
Distribution of timber species by Zones and States [1]

No	Zone/State	Total all species		Pines and other softwoods		Eucalypt species		Wattle		Other hardwood species	
		ha	%	ha	%	ha	%	ha	%	ha	%
1	Northern Transvaal	61 460	5,3	25 967	2,2	33 836	2,9	846	0,1	811	0,1
2	Eastern Transvaal	250 676	21,7	166 712	14,4	83 126	7,1	122	0,1	716	0,1
3	Central Transvaal & O F S	23 611	2,1	16 139	1,4	6 429	0,5	777	0,1	266	0,1
4	Southeastern Transvaal	223 640	19,3	99 894	8,6	84 695	7,3	37 599	3,3	1 452	0,1
Total Transvaal & O F S		559 387	48,4	308 712	26,6	208 086	17,8	39 344	3,6	3 245	0,4
5	Maputaland	15 837	1,4	14 645	1,2	1 185	0,1	-	-	7	0,1
6	Zululand	97 598	8,4	32 696	2,8	41 435	3,5	23 458	2,0	9	0,1
7	Natal Midlands	151 520	13,1	59 524	5,2	41 434	3,5	48 125	4,2	2 437	0,2
8	Northern Natal	45 119	3,9	9 523	0,8	13 659	1,2	21 860	1,8	77	0,1
9	Southern Natal	88 878	7,7	38 988	3,4	39 335	3,4	9 747	0,8	808	0,1
Total Natal		398 952	34,5	155 376	13,4	137 048	11,7	103 190	8,8	3 338	0,6
11	Eastern Cape	29 855	2,6	26 973	2,3	1 601	0,1	1 166	0,1	115	0,1
12	Southern Cape	76 724	6,6	70 846	6,0	4 682	0,4	449	0,1	747	0,1
13	Western Cape	30 239	2,6	28 576	2,3	1 377	0,1	125	0,1	161	0,1
Total Cape		136 818	11,8	126 395	10,6	7 660	0,6	1 740	0,3	1 023	0,3
	South Africa	1095 157	94,7	590 483	50,6	352 794	30,1	144 274	12,7	7 606	1,3
	Transkei	56 646	4,9	43 048	3,7	11 425	1,0	1 702	0,1	471	0,1
	Venda	5 109	0,4	4 206	0,2	890	0,1	-	-	13	0,1
	GRAND TOTAL	1156 912	100,0	637 737	54,5	365 109	31,2	145 976	12,8	8 090	1.5

Note [1] Details provided in the table were given by the Department of Environment Affairs (1981)

FIGURE 2.2

Population distribution in the Republic of South Africa, Transkei, Bophuthatswana, Venda and Ciskei[1]



[1] This map was developed from a Human Sciences Research Council map with their kind permission.

for South Africa and the various independent homelands. The proportion of Blacks of this population is so high that this aspect of the figure may be regarded essentially as showing the distribution of rural Blacks.

Comparison of Figures 2.1 and 2.2 shows that most forestry areas occur adjacent to or within areas of high Black population. Exceptions are the south-eastern Transvaal, northern Natal and the southern Cape. In the former case the situation is mitigated by the employment of Swazis and in the latter case essentially Coloured labour is used.

Despite the apparent convenient location of Black labour to most forestry areas, Beggs (1979) found that workers' actual homes were beyond a reasonble day's travelling distance on foot or by bicycle. This necessitated them having to hire accommodation closer to their work or live in employer-provided villages.

Due to the attraction of the cities, within a 40 kilometre radius of Pietermaritzburg and Durban Black labour is often recruited from as far away as the Thukela (Tugela) river basin over 100 kilometres away. Special fringe benefits including free transport home for weekends are common with the accompanying increased fixed costs.

2.3 STRUCTURE OF LABOUR FORCE FROM BLACK SOUTH AFRICANS

The 1970 Population Census Register 02-05-11 (p.244) gives the number of forestry Black workers as 29 853 men and 11 495 women totalling 41 348 persons. The most common age 25 - 34 years with the

35 to 44 year old group being only slightly fewer.

In direct telephonic discussion, it was stated that results of the 1980 census will not be published until early to mid 1984. However, currently available information was kindly supplied by the Department of Constitutional Development and Planning. This shows a total of 36 340 Blacks were employed in forestry in 1980. The following educational levels were stated:

Educational level	Number of Blacks employed in forestry
Nil	22 380
Grade 1 to Standard 1	3 400
Standard 2	3 260
Standard 3	2 260
Standard 4	1 860
Standard 5	1 500
Standard 6	840
Standards 7 to 10	760
Post school	0
Unspecified	80
	36 340

If it is assumed that those with above a Standard 2 education are employed in semi-skilled or clerical positions, this means that there were only 29 040 male and female labourers. This is a drop of 30 per cent over 10 years with a drop of 12 per cent total of Black forestry workers.

Terblanche (1981 p.7) reporting for the Human Sciences Research Council predicts that the Black economically active population will grow by 33 and 35 per cent for males and females, respectively, between 1977 and 1987. Further, that in 1977 the greatest population was in the 20 to 24 year old group and in 1987 it will be the 25 to 29 year old group. This is taken as indicating that the rate of Black population growth is declining marginally. The most important conclusion is that between the 1970 and 1980 period there was probably over 34 per cent growth, but the population entering forestry dropped 12 per cent. Thus forestry is becoming an increasingly unpopular form of occupation for Blacks.

There appear to be several reasons for the decline. Terblanche (1981, p.74) shows a fluctuating but generally declining overall proportion in Black labourers between 1965 and 1979 and predicts a continuation of the trend for 1987.

However, as shown above, economically active Black females will increase 2 per cent faster than males. Terblanche (1980, p. 35) shows a steady rise in the total proportion of Black female labourers which is predicted to continue through in 1987. Combined with the population growth, industries must look to Black females to fill labourer and semi-skilled positions.

As a greater proportion of Blacks receive education, the numbers shown above for nil or low education will drop. This should support Terblanche's prediction of declining numbers of labourers. Those with possibly a standard two education will tend to refuse to undertake the strenuous labourer work their uneducated parents did.

Terblanche (1981, p.67) states that the lack of employment opportunities is a more serious problem than manpower shortages and recommends combating the situation by "Research aimed at the development of labour intensive techniques as well as management, is necessary". (Terblanche, 1981, p. 68)

From the above, it is concluded that the forestry industry should employ labour intensive harvesting and transport systems for as long as labout is available which will vary for different areas and/or until the employment costs rise to the extent that mechanisation is compelled.

The writer has noted (de Laborde, 1982b) that certain work such as pole loading onto lorries is becoming increasingly unpopular among labourers. However, loading logs onto, and from, a debarking machine is acceptable. Employment in a more mechanized operation appears to have greater appeal. For example, seldom is difficulty experienced in obtaining machine operators or drivers.

Terblanche (1981, p.62) calls for increased job opportunities for Blacks and stresses that their aspirations and expectations are rising. He also warns that "work and companies which offer little opportunity for advancement, are becoming more unpopular". This supports the above conclusions that the forestry industry is becoming increasingly unpopular to Black workers.

2.4 PRIVATE GROWERS' CONVERSION RATE TO MECHANIZATION

In discussion with the Economics Division, South African Timber Growers' Association, it was concluded that the relationship between man-days and total fuel usage would supply a reasonable index of mechanization as this was independent of inflation and gave the ratio of human effort to mechanical power. The following equation was applied to obtain a mechanisation index as a percentage, (MI).

$$MI = \frac{\text{Total litres of liquid fuel used}}{\text{Total man-days for all Black labour}} \times 100 \quad \ldots\ldots\ldots \quad 2.1$$

As the above Economics Division started recording historical data in 1976, the following information from that date was extracted:

Period	Mechanization index
1976/77	111
1977/78	131
1978/79	124
1979/80	123
1980/81	126
1981/82	137

Fluctuation in the above MI values are probably due essentially to price hikes and uncertainty of supply of liquid fuels. It is clear from the positive slope of the above date that there is a distinct trend towards increasing labour efficiency and mechanization.

2.5 TOTAL NON-WHITE WORK FORCE IN SOUTH AFRICA

Data for the total numbers of Non-White workers employed in South African forestry are only available for the period 1978/79 to 1982/83 (Department of Environment Affairs, 1979 to 1983). The numbers differ from those in Section 2.3 as they also include workers from neighbouring States working in South Africa.

Table 2.2 gives these totals and a division into categories of unskilled, lower semi-skilled, higher semi-skilled and skilled workers. Numbers of employees in these categories for the 1978/79 period were incompatable with subsequent years and, therefore, were omitted.

Two major trends are apparent from the data. Total employment peaked in the 1979/80 period, fell steeply in 1981/82 and continued to fall in 1982/83. This drop was principally due to a reduction in the numbers of unskilled workers.

These data thus show a similar behaviour to that described above in this Chapter and support the predictions. Findings here are similar to those of the International Labour Office (1960, p 208) where it is stated that "The main push factor causing workers to leave agriculture is the low level of income. --- The difference in wages --- influences hired workers and members of their families in their decision to find other employment." Further, it was found that "The main factor determining the rate of outward movement is the expansion of employment in other occupations."

TABLE 2.2

Total numbers of Non-White workers employed by plantation owners in South Africa, Venda and Ciskei, after their independence, and their classification into four levels of skill.

Year	Unskilled labour	Lower semi-skilled workers	Higher semi-skilled Workers	Skilled employees	Total
1978/79					94 477
1979/80	89 011	8 603	968	333	98 915
1980/81	82 308	11 552	1 838	400	96 098
1981/82	61 414	10 249	2 627	268	74 558
1982/83	58 054	9 773	1 707	276	69 810

Notes: Data and table headings as published by the Department of Environment Affairs (1979 to 1983).

Division of workers into categories of skill for this year are incompatable with subsequent years and, therefore, have been omitted.

CHAPTER 3

SURVEY OF OVERSEAS HARVESTING AND TRANSPORT

Due to the labour situation prevailing in southern Africa, it is both economically and socially expedient to resort to more labour intensive harvesting and transport systems for reasons discussed in Chapter 2. However, that chapter demonstrated that there currently is a distinct transfer to more capital intensive systems. It is valuable to investigate systems developed by countries which have passed through this transfer to provide a guide for the local timber industry. As winching from a fixed position (cable extraction) stands rather in isolation from the remainder of harvesting, it is discussed initially.

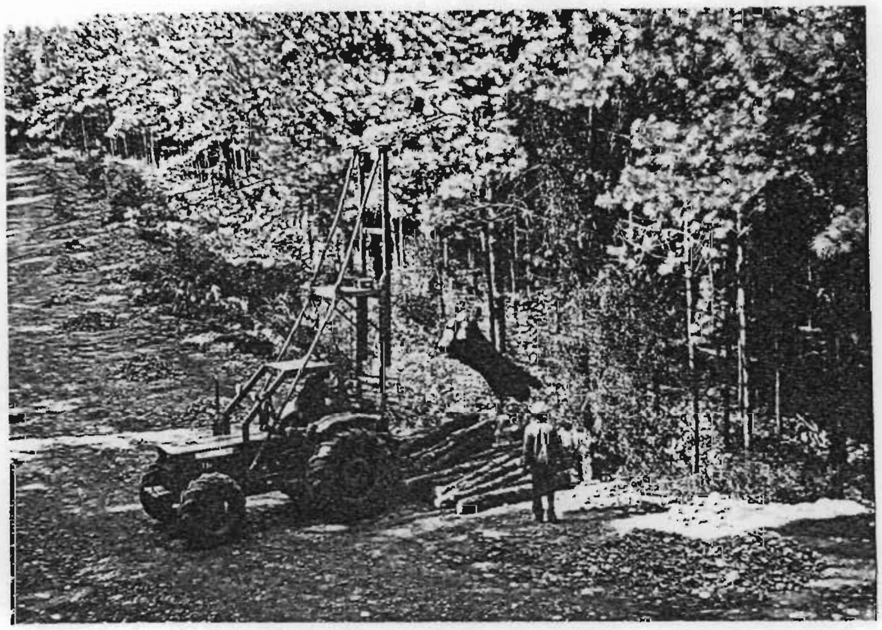
3.1 CABLE EXTRACTION

Cable extraction (cable yarding) is comprised of three types of operation: simple winching, highleads (Figures 3.1 to 3.4) and skylines, a more sophisticated form of highlead where the carriage is suspended from an overhead cable.

Although tractor mounted or independently powered winches of all sizes are common, the development of radio controlled winches are reported to be of value to the small-scale, one-man harvesting operations (Nilsson, 1978, p. 162; de Simiane, *et al*, 1977). The winch described weighs approximately 100 kilograms, has a 4,4 kilowatt engine and can accommodate 150 metres of 6 millimetre cable. It can apply an 800 kilogram maximum force with a cable speed of 30 metres per minute.

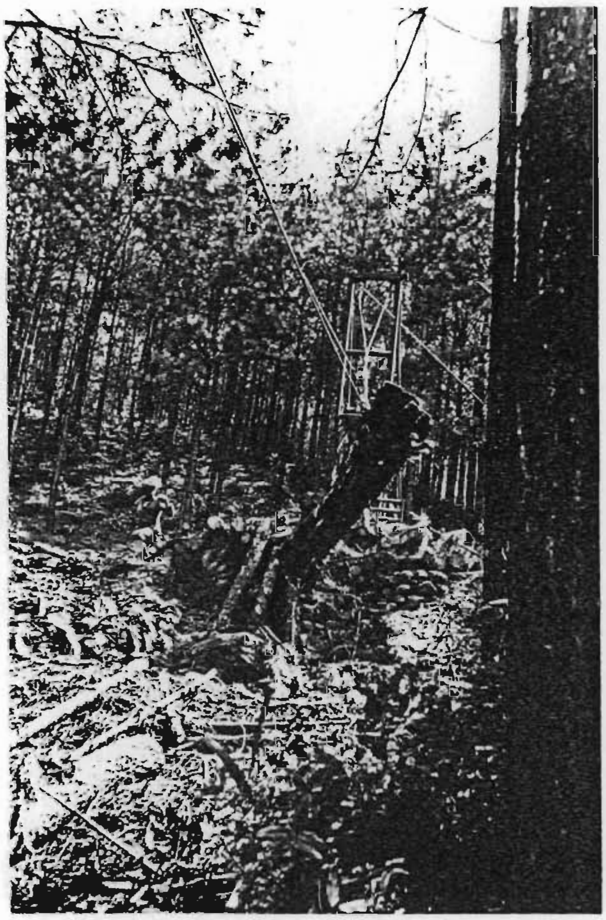
Application of such winches are for small diameter timber. The ability to be able to set chokers (Figures 3.5 and 3.6) and walk with

FIGURE 3.1



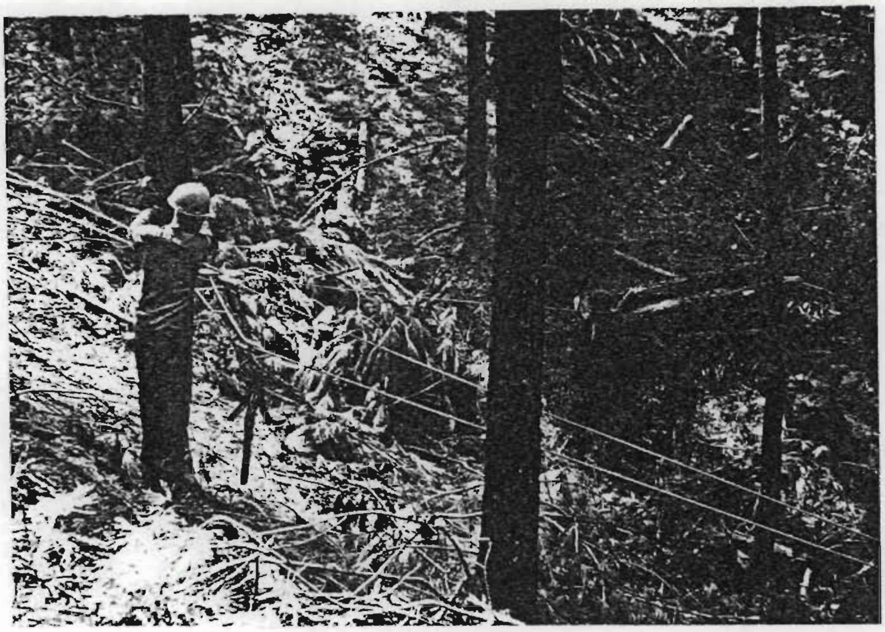
A locally popular form of highlead with a parallel-frame tower winching shortwood poles to roadside

FIGURE 3.2



Poles are lifted clear of the ground to negotiate a very steep section during the highleading operation

FIGURE 3.3



A snatch block is used to winch poles from an awkward location during a highleading operation

FIGURE 3.4

The tailhold of a highlead is attached to a spar tree. Where the spar tree is too weak to support the forces demonstrated in Figure 3.2, a further wire rope is connected from the spar tree to a tree directly behind which is referred to as an anchor tree.

FIGURE 3.5

A labourer sets a choker chain to an *E. grandis* log

FIGURE 3.6

A choker chain on a tag-line set ready for winching the timber to avoid, or release, snagging while working alone is clear. Versatility of such winches is enhanced with the use of snatch blocks (Figure 3.3) to permit circumventing obstacles or modifying the direction of pull, as required, in the manner of most winching operations.

Highleading has been described in detail (Crowther & Forester, 1964) for the type of parallel-framed tower bolted onto the rear of a tractor. This type of tower required precise orientation and levelling of the tractor which frequently is approximately perpendicular to the road.

Although the basic technique of highleading described by Crowther and Forester remains, some more modern towers have a single-pole which is usually telescopic. This permits the tailhold to be moved through 310 degrees without repositioning the tower. With winch-drum capacities of approximately 250 metres of 10 millimetre cable, theoretically heavy timbers over 16,9 hectares can be cleared without moving the highlead. However, timber congestion is reported to occur (Corey, 1981) and requires planning of systems for its continuous removal.

On account of damage to the environment by infield vehicles (Section 4.5.1.2), studies into the relative economics of using highleads or skylines in place of skidders have been investigated (Fisher, Gibson & Biller, 1980; Murphy, 1978, p. 16; Corey, 1981; Lysons & Twito, 1973, p. 580). Fisher *et al* conceded that costs compared with ground skidding could be higher while Corey suggests these costs could be 35 per cent higher. However, all researchers draw attention to the need to establish the long-term costs of damaging the environment which will ultimately reduce timber yields per hectare and of devastating the countryside.

Murphy and Corey demonstrate that highlead productivity is directly proportional to the individual log size extracted. They conducted studies using three different log preparations the one of which included crosscutting. In extracting the crosscut lengths, four to eight lengths per haul were tested. Although mean cycle times were in direct proportion to the number of lengths per haul, output was considerably lower when compared with extracting uncross-cut timber.

Skylines are described by Lysons and Twito (1973, p. 580) in four different applications from a simple layout to complex layouts having a number of spans or intermediatory supports. Set-up times for the rigs vary but are quoted to range between one and four hours. It is obvious that variables such as terrain conditions and the expertise of the workers result in it being impossible to state a general set-up time.

At the extreme of cable extraction is the use of balloons to provide an intermediary support (Silversides, 1981, p. 34). Peters (1973 p. 577) describes three techniques of applying a 15 000 cubic metre helium-filled balloon in skyline systems used by three different timber harvesting concerns. Difficulties encountered included, *inter alia*, gas losses through deterioration of the balloon fibre by ultra-violet rays, wind and snow.

3.2 HARVESTING

3.2.1 *Available Machinery*

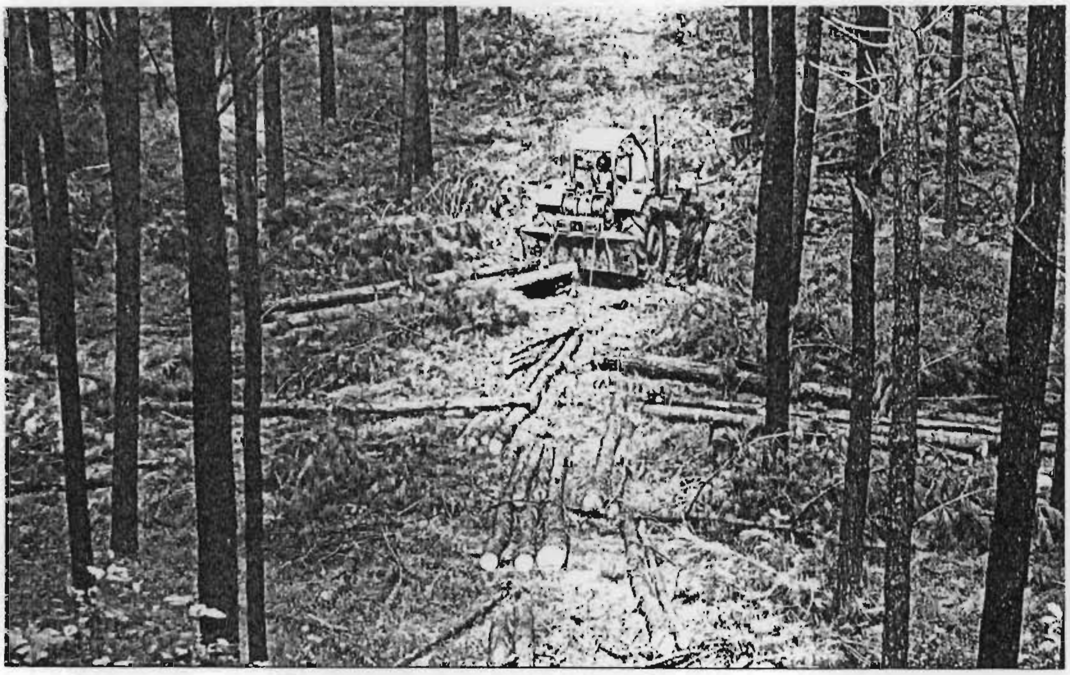
Although attempts to mechanise harvesting commenced in earnest around 1960 with the development of the specialised skidder (Figures 3.7 & 3.8), Sondell (1978) states that it was in the early 1970's that Sweden commenced using harvesters in significant numbers and that in Finland "mechanization came later". He reports that approximately 100 harvesters were operating in Scandinavia at the start of 1978.

During the interim period various machines for felling, limbing (debranching) and bucking (crosscutting) were developed. According to Hallonborg (1977,1978, 1979) there were about sixty different types and sizes of harvesting machines operating in Sweden. He divides these machines into seven major categories which are regarded as being representative of what is used elsewhere in Europe, the Americas and wherever labour intensive systems have had to be mechanized through labour scarcity.

These categories include forwarders (Figures 3.9 and 3.10) and skidders as timber extraction machines and the felling and processing machines which include feller-skidders, feller-bunchers, limbers, limber-buckers, and harvesters which fell, debranch and crosscut. Most harvesters carry the crosscut logs on the side of the machine. Once a full load is reached, they travel to a landing and deposit the load for further processing or handling. (Bjerkelund, 1980).

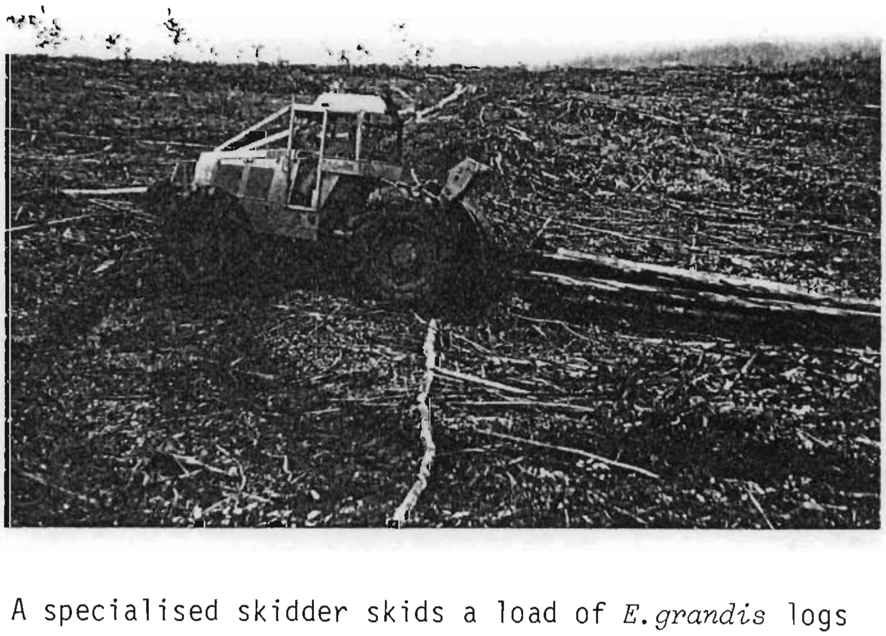
Of the 60 machine types Hallonborg cites, there are 25 forwarders divided into four categories, five plain and clam-bunk skidders, one feller-skidder of the clam bunk design, four feller-bunchers, one limber, 12 limber-buckers and eight harvesters. Clam-

FIGURE 3.7



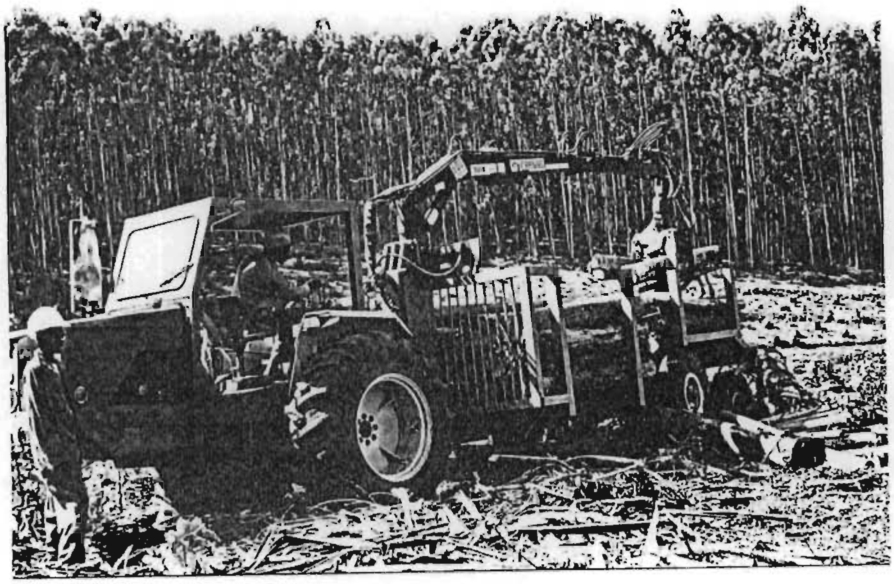
A small four-wheel-drive tractor fitted with a double-drum four-ton winch being used as a skidder. The double drum permits winching from two directions as is shown above. This can be of distinct use to obtain a full load where logs are more sparsely distributed

FIGURE 3.8



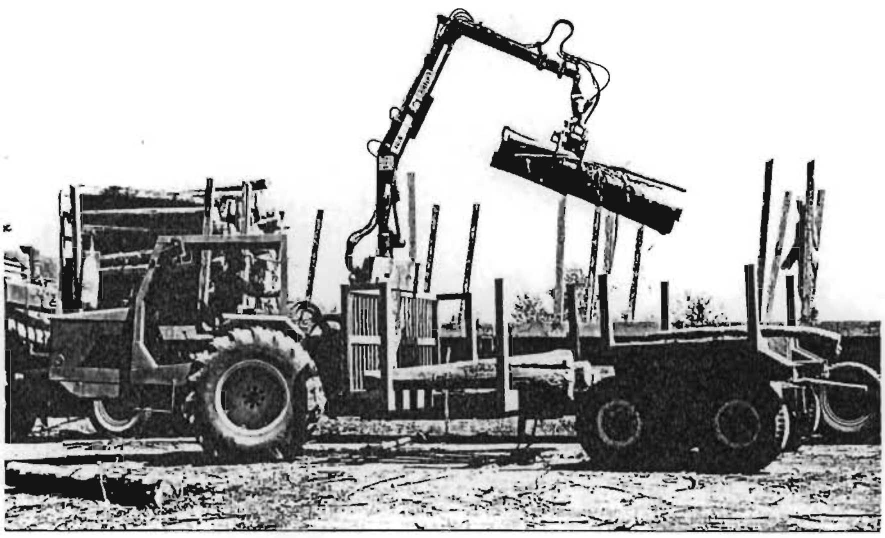
A specialised skidder skids a load of *E.grandis* logs

FIGURE 3.9



A locally-made forwarder loading *E.grandis* logs infield

FIGURE 3.10



The forwarder transships its load directly onto an awaiting 30 ton lorry bunk skidders hold the log-butts by a large grapple on a short truck-like back. The majority of machines cited have a knuckle-boom crane base of up to 12,5 metre reach to which the grapple, limber, bucker or feller head is attached. This is in contrast to many of the American-designed machines which are essentially articulated front end loaders (Figures 3.11 and 3.12) modified to accommodate the various feller heads.

Myhrman (1970) describes limbing devices and concludes that the most popular is the 'wrap-around or knife belt'. Rotary knives are used to a limited extent and their use is expected to decline further. Although most limbers at that time operated stepwise it was predicted that the then limited use of feed rollers would increase.

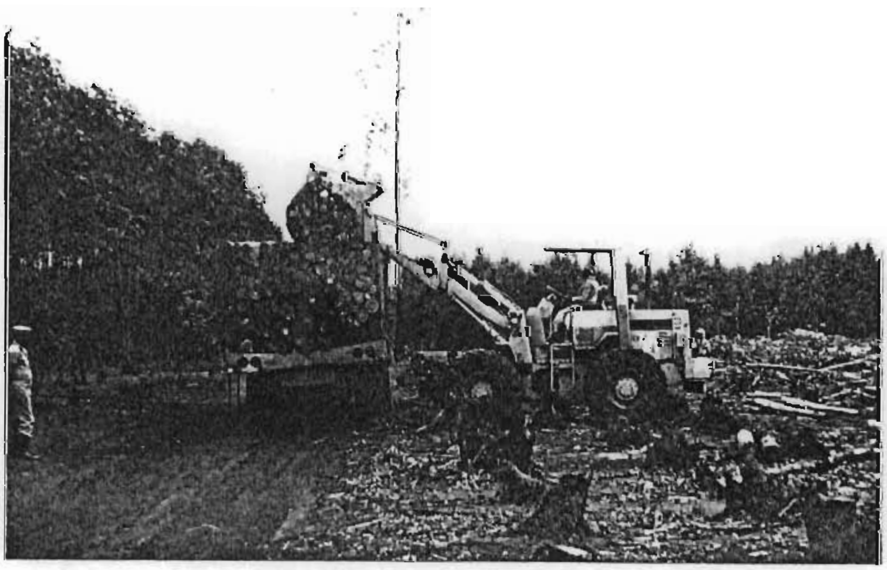
Many limbers have the difficulty of slash disposal. Myhrman describes several machines where slash even incurs internal congestion. To avoid these problems, many machines were designed which limbed at various locations in or out of the forest. Techniques included limbing and topping trees (removing the tree's top) before felling, limbing and crosscutting after felling and while travelling, felling then carrying the tree to a small timber stack where it was limbed and dropped onto the stack as it was crosscut in a stepwise action and finally, felling then limbing as the machine fed the tree into itself where it crosscut and stacked the logs internally to be deposited later.

Many of these machines are still in current production, but as predicted, the stepwise action has been replaced by rollers where feeding is interrupted momentarily to allow crosscutting. An interesting point is that, in most cases, the machines could only

FIGURE 3.11

An articulated front-end loader gathers a load of *E. grandis* short-wood poles infield. (Articulation is steering by pivotting between the front and back wheels)

FIGURE 3.12



Poles are transported and loaded by the front-end loader onto an awaiting 25 ton lorry. Both the articulation and high vehicle mass can cause serious compaction and damage particularly to sandy soils accommodate maximum branch diameters of five to ten centimetres.

Recently Morbark Industries have mounted their feller-buncher head to the South African made three-wheel Bell loader (Section 4.4.5). From personal discussions with the local manufacturers the machine, called a Mor-Bell, is proving most versatile and with exceptional manoeuvrability achieves superior productivity compared with conventional machines. As it is available with walking beam axles or tracks, it can operate in a wide variety of terrain and, being relatively light, incurs less soil compaction than other feller-bunchers. Its popularity is understood to be rising.

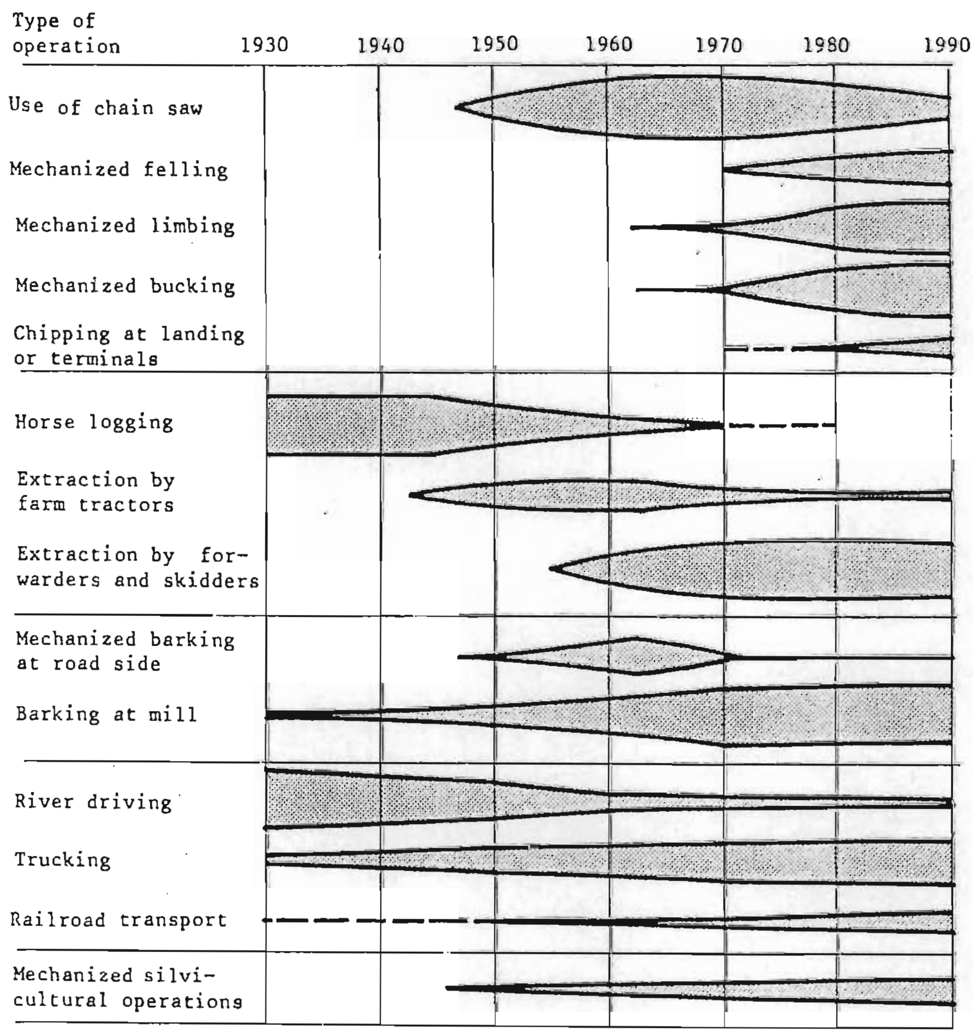
Stokes and Landford (1981) reported on the study of three felling saws mounted on large rubber-tyred vehicles. The machines were purely for felling. They found satisfactory correlation between machine time to move between various densities of merchantable stems per hectare and slope. Positioning the feller head and felling correlated with the tree diameter at breast height. Comparison of their results with felling times given in Chapter 5 indicate that the machine would have difficulty competing against a chainsawyer and, therefore, would decrease yields per man-day. The vast cost difference is obvious.

3.2.2 *Trends in Harvesting*

The Swedish Logging Research Foundation, Skogsarbeten, (1980, p. 5) provides an informative graphical presentation of the types of harvesting and transport systems used and projected for the year 1930 to 1990 which is reproduced with kind permission in Figure 3.13. The figure demonstrates clearly that to a major extent all forms of animal

FIGURE 3.13

Trends in forestry mechanization in Sweden between 1930 and 1990



and manual harvesting and transport are expected to be phased out if not by 1990 then before the turn of the millenium. It is interesting to note that chipping, which is discussed below, is expected to develop as well as rail transport. The trend in the use of chainsaws and farm tractors is interpreted as indicating the move towards large forestry companies or harvesting contractors, but that the small-scale operations will continue in limited numbers.

Skogsarbeten (1980, p. 6) also shows that in 1955 to fell, limb and crosscut 100 cubic metre of timber 35 man-days were required and that its extraction required 14 man-days. This fell sharply for the former series of operations until 1973 when approximately six man-days were needed. SInce then it has risen slightly. Extraction operations dropped to about two man-days by 1970 and have continued to decline marginally.

These changes demonstrate that mechanisation has risen in large-scale forestry which accounts for two thirds of the total Swedish harvesting and transport. Before 1970, Skogsarbeten (1980, p. 6) show that there was about five per cent mechanization but it rose steeply reaching 40 per cent in the mid-1970's following which the second order derivative of growth shows a progressive but slight decline with an overall continued increase. The 1980 level of mechanication was approximately 63 per cent and it is projected to reach 76 per cent by 1987.

Obviously the type of timber being harvested influences the system employed. Burke (1973) and Silversides (1981, p. 35) discussed the use of helicopters for extraction of high-value timbers, a system recently employed in the George-Knysna area in South Africa.

The principal advantage is that the tree can be extracted from the natural forest with a minimum of damage to its surroundings. A further advantage of the techniques is that these trees are often in areas inaccessible to ground or cable extraction.

Vyplel (1980, p. 105) compared various changes in harvesting system in Austria between 1975 and 1979. Manual labour dropped by 15 per cent; timber extraction with animals by 57 per cent, but this was already low; tractor usage increased five per cent; cable extraction (yarding) increased 100 per cent, and total mechanization increased from 65 tp 76 per cent. The increase in cable extraction was accompanied by a conversion to mobile cable cranes.

3.2.3 *Harvesting Systems*

With a large number of harvesting machines available, there are an even greater number of possible combinations of these machines and, therefore, systems. Consequently, only a few generally applied systems will be discussed.

Four Nordic systems are described by Skogsarbeten (1980, p. 7). These are common through Europe and, with small modifications due to differently designed machines, are used in North and South America.

In the first system a chainsawyer fells, limbs and crosscuts. Assuming that the terrain permits it, a forwarder loads from infield roads (strip roads), travels to an awaiting lorry with a trailer and transships the load. To facilitate the forwarder's work, accurate directional felling is important.

System two is similar to the integrated system described in Sections 4.3.4.1 and 5.5.3. A chainsawyer fells and limbs at stump, stems are skidded to roadside or a landing and another chainsawyer marks and crosscuts. Logs are then loaded on to a lorry and trailer. The loading system is not described.

System three is sub-divided into four parts. In sub-division one, two and three, the trees are felled by a chainsawyer in the direction that a mechanical limber will pass. In sub-division one, another chainsawyer crosscuts infield, a forwarder extracts the timber to roadside and transships it to a waiting lorry and trailer. In sub-division two, the forwarder is equipped with a grapple-bucker head on its crane. It cuts and extracts sawlogs and transships to the haulage vehicle whereupon it returns and repeats the operation for the pulpwood.

In sub-division three, a clam-bunk skidder extracts stems to the roadside whereupon they are mechanically crosscut and loaded on a transport vehicle. With sub-division four, the chainsawyer is replaced by a feller-buncher which extracts to roadside where trees are mechanically limbed, topped and loaded on to the transport vehicle. Bucking takes place at the mill.

System four is sub-divided into three parts. The latter three stages of each sub-division incorporates limber-buckers preparing, sorting and bunching the timber after which forwarders extract it and load the transport vehicles. In sub-division one, a chainsawyer fells with accurate directing placing the trees parallel to each other for the limber-bucker.

In sub-division two, a feller-buncher substitutes the chainsawyer and undertakes an extent of extraction to facilitate the limber-bucker's operations. The technique used in sub-division three is to accommodate difficult terrain and this includes the employment of a chainsawyer with a clam-bunk skidder or a feller-skidder to extract the timber to a point accessible to efficient operating of the limber-bucker.

System five provides for the use of harvesters which, as previously described, deposit a load of timber along a strip, or plantation road for extraction by a forwarder which loads the transport vehicle.

Whole tree utilisation has become topical following the energy crisis of the mid-to-late 1970's and numerous studies have been conducted to establish the biomass of many commercially harvested tree species. As this topic is not under consideration, no works are cited. However, there are systems which permit utilisation of a greater proportion of the tree. Stump utilisation is being investigated. Chipping could not normally take place in the forest due to lodged soil, gravel and stones. (Andersson, *et al*, 1978) These can be removed effectively by a drum debarker. (Koch, 1981, p. 178)

In considering whole-tree harvesting, several factors require attention. It was found (Garlicki & Calvert, 1969, p. 83) that skidding whole trees uses double the power required for stems only. Thus, unless there is a very short lead distance, skidder fuel consumption could exceed the extracted biomass energy. Bjerkelund (1980) proposes a compromise of topping trees prior to extraction.

A prime consideration in the proposal is the reduction of congestion at the landing with a maximisation of tree utilisation. Analyses showed that the skidding costs of the small Canadian trees over distances of 200 yards was significantly lower than forwarding costs unless additional forest roads were required to affect short skidder lead distances, *viz* load haulage distance. Bjerkelund does not state how trees are felled and topped, but it is assumed that the topping only could be accommodated by a chainsawyer. He also regards tops as being of low economic value. This infers that the biomasses energy potential is only marginally greater than the requirements to extract and process it.

Whole-tree harvesting is a popular concept. However, in supporting the system Horncastle (1980), does not regard congestion as problematic and advocates maximising of mechanization. His principal concerns are to exclude heavy machinery such as fell-limbers from infield use and thereby simplify and lighten their structure. This would result in greater accessibility for maintenance, easier illumination for night-shift work and improved operator comfort. Similar benefits would prevail for limber-slashers or chippers and facilitate maximum tree utilisation. Presumably light feller-bunchers and, perhaps, skidders are used for the initial timber movement. When using this sytem, Horncastle advocates establishing well-organised landings, *viz* temporarily established worksites usually adjacent to a road.

Bjerkelund expresses concern, though, for systems that increase soil compaction and disturbance by concentrating vehicular traffic with the accompanying necessity to bulldoze such landings. His compromise suggestion for topping at stump is also to reduce the removal of organic material so as to minimise changes in the soil's microbiological ecology and he states further that harvesting operations must be conducted in a manner that minimises adverse interference with the water table.

3.2.4 *Factors Influencing Infield Machine Productivity*

Skidder productivity was found to differ substantially and with low predictability. Sampson and Donnelly (1977) discovered that productivity losses were incurred during "hook time per piece", general delays and low volume per cycle which agree with the findings detailed in Section 5.5.3.1

Operator productivity has been found to vary between 30 and 40 per cent about the mean in Canada (Bennett & Winer, 1964). This was affected by physical, physiological and psychological circumstances (Cottrell, Winer & Bartholomew, 1971). Sampson and Donnelly identified these circumstances as skidder type, including power, gear speeds and wheel slippage; timber characteristics including tree and log volumes, 'pieces per acre' and stand density of unharvested trees; and terrain factors including lead distances, slope and surface condition. They express concern about the lack of information regarding physical constants for log resistance to drag.

Undergrowth density has been found to be a further factor reducing productivity of infield operations. Granskog and Andersson (1981) defined two undergrowth conditions in Louisiana, *viz* 'dense and light', and found that there was an approximate two thirds drop in feller-buncher productivity between the two conditions.

3.3 MOBILE WOOD CHIPPERS

3.3.1 *Advantages and Disadvantages*

Mobile wood chippers operating at landings and strip and forest roads are employed in North America, northern Europe down to Holland and Germany, Hungary and Poland (Hakkila, 1978, p. 198).

To date these chippers have not gained international popularity. This is principally due to the machines' inability to separate adequately the wood chips from residues comprised of bark, leaves and soil. Further, there is no uniformity of quality control (Nilsson, 1978, p. 165; Hakkila, 1978, p. 201). However, they have greater popularity in the United States (Tufts, 1976, P. 60). In 1975 they had 350 chippers in operation (Keays, 1975).

A noteworthy disadvantage of the use of chippers is the accompanying whole tree harvesting which may result in the adverse environmental effects discussed in the last paragraph of Section 3.2.3

Advantages cited by Tufts (1980, p. 62) include the reduction of unsightly debris and greater mechanization, despite its accompanying relatively high capital investment, results in reduced harvesting costs compared with conventional systems and greater productivity per man-day. Further, mechanization reduces human physical effort and increases safety. Obviously, there is a greater timber utilisation per tree and there remains the possibility of gathering the debris for energy production (Horncastle, 1980). Tufts (1976, p. 60) also notes that chips average 1,056 higher bulk density than logs which will reduce transport marginally, and the chips may result in a more uniform and full loading of vehicles.

3.3.2 *Systems Incorporating Chippers*

Chippers are manufactured in a wide range of sizes from small units that attach to an agricultural tractor suitable for a one or two man operation up to machines intended for large-scale harvesting operations of up to 600 tons per eight-hour shift (Morbark Industries 1982 product manual).

Application of the various chipper sizes has been described (Koch, 1981, p. 153). These smallest chippers have a bin trailer mounted in tandem behind the chipper on the tractor. Small trees are felled by power saw (chainsaw or brushcutter) and bunched by one operator. The second operator manually feeds the chipper and drives the tractor. Another form of crawler chipper has a felling bar which pushes trees over and draws them in by means of a roller. The chipper works in tandem with a vehicle equipped with a bin. These units have a maximum speed of 5 kilometres per hour. The third, and apparently most common category, are self-loading mobile chippers which operate at a given point and have trees extracted to them by various techniques. Transport of the chips is by any desired vehicle with a suitably sized bin.

Koch (1981, p. 167) describes how a chipper can be integrated with a conventional sawlog operation with it feeding all residues into itself. The economics of such log sorting have been investigated (Graves, Bowyer and Bradley, 1977, p. 94). The cost per cord (a 1,2 metre high by 1,2 metre wide stack of 2,44 metre long poles) was calculated when, firstly, a chainsawyer selects sawlogs and crosscuts and, secondly, these operations are undertaken by mechanized means. The costs were $7 and $18 per hour respectively.

Hakkila (1978, p. 98) advocates the deployment of chippers and accompanying equipment at a landing in preference to strip roads, but concedes that there are certain situations chiefly in thinnings where the latter may be preferable. A major advantage in clearfell operations is that it prevents accumulation of residues if these are not collected for energy.

Various techniques to extract the timber to the chipper are discussed by Hakkila, but these are similar to the cable and other harvesting operations described in Section 3.1 and 3.2.

An economic study of extraction to a chipper was undertaken (Arola & Miyata, 1981) for thinning and clearfelling operations. Their study demonstrates the necessity of having a careful balance of machine numbers from felling to the haulage of the chips. Delays caused critical variations in chipper productivity.

3.4 HARVESTING ROADS

Guidelines for harvesting roads were described by Skogsarbeten (1967) and various mathematical models have been developed to optimise these roads and estimate their cost (Matthews, 1941; Peters, 1978, p. 209; Ashley, Concoran & Whittaker, 1973). These works are intended primarily for application in natural forest harvesting.

However, certain information may be gleaned from the suggestions Skogsarbeten make in the above reference. Strip-road lengths for forwarders should be in inverse proportion to timber volume per hectare. Converted to metric units, their recommendations are as follows:

Timber volume per hectare	Recommended lead distance for forwarders
(m^3)	(m)
50	100
30	120
10	350

These data could be of local value in thinnings operations for which they are intended, but are difficult to extrapolate to plantation clearfelling which normally commences at 150 cubic metre per hectare.

They advocate 14,6 metres between strip roads for final felling. The average in southern African eucalypt plantations is currently 13,7 metres. Their suggested layout for strip roads and timber stacking is to have 3,2 to 4,2 metres for the road, an approximately 0,5 metre clear zone then a two metre zone in which the timber is stacked thus giving 8,2 to 9,1 metres total width. The remaining strip on either side is cleared of timber. This layout is similar to that used in most southern African eucalypt plantations where brush rows are usually made every fifth tree row with a 2,74 metre espacement. The reaches of locally available cranes' are now such that the slightly wider roads bring this layout into close relation to Skogsarbeten's recommendations.

Skogsarbeten warn that in light terrain, road routing should be studied carefully for each section of forest, but that even greater care must be taken in difficult terrain.

CHAPTER 4

DESCRIPTION OF HARVESTING AND TRANSPORT AND SELECTION OF WORK ANALYSIS METHOD

4.1 CIRCUMSTANCE OF HARVESTING AND TRANSPORT

Each tree species may yield a variety of produce. The nature and dimensions of categories of products, terrain description, scales of operation and lead distances (the distance the load is moved) influence the harvesting and transport system selected.

Certain products command considerably higher market prices than other products, but need specialised and, therefore, more expensive, handling techniques. The more sophisticated the systems, the greater must be the sensitivity of the control system to attain high efficiency.

4.2 CLASSIFICATION OF FOREST PRODUCE

Categories of forest products harvested in South Africa and certain neighbouring states during 1979/80 are detailed in Table 4.1. Uses of South African timber according to management objectives are given in Table 4.2 in terms of hectares of forest.

4.2.1 *Acacia mearnsii (wattle)*

Wattle harvesting is complicated by the harvesting of its bark which is approximately of equal value per hectare to the timber. As shown in Table 4.2, 51 per cent of wattle timber is allocated to pulpwood and 30 per cent to mining timber for the mining and pulpwood markets for which it is cut into shortwood lengths usually of 2,27 or 2,44 metre. The only exceptions in length are with timber intended

TABLE 4.1

Endstock of sawn timber, poles, mining and other timbers[1] for the Republic of South Africa for 1982

Timber Class	Softwood (m^3)	Hardwood (m^3)	Total (m^3)	Hardwood (t)
Sawn and planed timber				
Structural timber	63 159	3 676	66 835	
Industrial shelving	49 680	32 508	82 188	
Shelving	526	0	526	
Furniture stock	1 240	498	1 738	
Strip and board flooring				
Floor blocks and ceiling	1 059	0	1 059	
Shooks for wooden containers				
Agricultural	1 969	1 080	3 049	
Industrial	1 021	47	1 068	
Laminated beams	854	0	854	
Other sawn timber products	1 394	190	1 584	
Sub Total	120 902	37 999	158 901	
Sleepers	0	117	117	
Treated wooden poles				
Transmission poles			14 173	
Telephone poles			2 954	
Other poles, laths				
Droppers and round cross-arms			43 604	
Sub Total			60 731	
Mining timber for supports				
Poles and laggings				12 701
Manufactured items				4 878
Sub Total				17 579
Charcoal				1 597
Wood chips				96 328
Mill residues				1 525
Firewood				3 936
Roundwood in transit [2]	0	5 102	5 102	
TOTAL	120 902	43 218	224 734	120 965

Notes : [1] Information supplied by the Department of Environment Affairs (1982, p 148).

[2] Roundwood not processed by mill, but which was handled and sold.

for charcoal production where poles are crosscut to shorter lengths and firewood. The latter consists mainly of too thin or distorted top sections of the stem and dead, but not rotted, stems.

Wattle also is very popular in the African homelands for the structural timbers of their huts and is grown especially for this purpose and to provide fuel.

4.2.2 *Eucalyptus grandis*

Table 4.1 shows that most hardwoods are used industrially. Table 4.2 projects that 80 per cent of *E.grandis* timber is intended to be divided almost equally between the mining and pulpwood markets. The remainder is cut into various lengths ranging from 0,9 to 13,4 metres. Certain growers cut up to 31 categories of pole sizes. Tasking of workers, planning of timber sorting, extraction from stump and transport systems of these categories is complex and can result in the net revenue from minor low return categories being insufficient to warrant their inclusion.

4.2.3 *Pinus patula*

For the purpose of planning harvesting operations, *P.patula* is divided into sawlogs and pulpwood. Apart from the mean lengths of logs influencing the crosscutting activities, crane loading and transport equipment types are not normally affected.

Table 4.1 shows most softwoods, *viz* almost exclusively pine, were used for structural timbers with a large proportion being used for industrial purposes. Table 4.2 shows 77 per cent of softwoods

TABLE 4.2

Uses of South African timbers according to management objectives for the period 1979 to 1980[1]

Timber species and uses	Plantation areas			Proportion of total (%)
	Private ownership (ha)	Public ownership (ha)	Total (ha)	
Softwood				
sawlogs	196 558	266 969	463 527	77
poles & droppers	2 971	3 643	6 614	1
pulpwood	91 622	39 119	130 741	21
firewood	135	90	225	0
other	2 095	1 341	3 436	1
Total	293 381	311 162	604 543	100
E. grandis				
sawlogs	24 270	10 556	34 826	11
poles & droppers	13 968	10 934	24 902	8
mining timber	127 956	2 257	130 213	41
pulpwood	117 960	3 257	121 237	39
firewood	717	151	868	0
other	2 015	45	2 060	1
Total	286 906	27 200	314 106	100
Wattle				
sawlogs	1 783	0	1 783	1
poles & droppers	2 362	1 178	3 540	3
mining timber	42 286	835	43 121	30
pulpwood	71 104	1 249	72 353	51
firewood	5 946	3 125	9 071	6
other	9 062	3 979	13 041	9
Total	132 543	10 366	142 909	100

Note: [1] Data in this table are derived from information supplied by the Department of Environment Affairs (1981, pp 20 and 21) being allocated to sawlogs and 21 per cent to shortwood lenghts for pulping.

4.3 CATEGORIES OF SYSTEMS FOR PRIMARY CONVERSION

Systems for primary conversion can be divided into the three broad categories of the type of equipment used. THese categories and related systems are described below.

4.3.1 *Hand Tools Only*

4.3.1.1 *Axe*

Until the advent of the chainsaw in South Africa in the mid-1960's, the axe was used almost exclusively in wattle and *E.grandis* harvesting. Shifts in the supply and cost of labour discussed in Section 2.3, compelled a reduction in labour intensiveness in operations. Further, the high stump and kerf results in approximately 45 centimetres of the base of the tree being lost which Schönau (1971 & 1972) has shown amounts to a five to nine per cent wastage of timber. Finally, it should not be used on crops intended to coppice, or rattoon. As the axe is withdrawn from the tree it lifts the bark from the xylem thus damaging the cambium and the quality of the subsequent coppice. Consequently, the axe is not considered further.

4.3.1.2 *Bowsaw*

Two methods of applying bowsaw felling have been identified (de Laborde, 1980, p. 3.2). In the first method, each labourer is issued with a 0,9 kilogram hatchet and pairs of labourers are provided with a 914 millimetre bowsaw.

Labourers come together in pairs to fell one another's trees thus they work effectively as one person. After this they separate again to debranch by hatchet, stack the brush, debark by hatchet and, if wattle, bundle and stack the bark. Crosscutting of the stems to poles is undertaken by a separate team working in pairs with the same size bowsaw and following several days behind the former team.

In the second method the labourers are relieved of the felling activity by a sawyer team using the 914 millimetre bowsaw and working in pairs.

4.3.1.3 *Two-man saws*

Zaremba (1976) cites the use of the two-man saw which was popular before the advent of the chainsaw for felling large diameter pine. This system is now completely obsolete in private and State forests in Africa south of the Limpopo river.

4.3.2 *Hand Tools and Chainsaws*

Due to high log mass, *P.patula* is usually harvested by the integrated system described in Section 4.3.4 below.

4.3.2.1 *Types of Chainsaws and Hand Tools used with Chainsaws*

With wattle and *E.grandis*, 0,9 kilogram hatchets are used by labourers to debranch, if not undertaken by chainsaw, and to debark.

Prior to 1973, nearly all chainsaws used in

South Africa had a mass in the order of 15 kilograms with engine capacities in excess of 100 cubic centimetres. During 1973, chainsaws of a mass of approximately eight kilograms and 53 to 72 cubic centimetre capacity were introduced. This was concomitant with the Wattle Research Institute introducing chainsawyer training courses and protective clothing for the first time in southern Africa.

Subsequent to these changes, the chainsaw has been used almost exclusively for felling and crosscutting of all tree species.

4.3.3 *Systems used with Hand Tools and Chainsaws*

4.3.3.1 *Conventional System*

There are a number of variations in the application of the conventional chainsaw system. In essence, the chainsawyer fells and crosscuts the trees and labourers debranch with hatchets, usually stacking the brush, and debark by hatchet.

Poles may be left scattered on the ground (left rough), swung and placed neatly, bunched or sorted into pole categories or stacked. In isolated instances poles are carried to roadside, sorted and stacked. With wattle, the bark is bundled and stacked preparatory to it being loaded and transported to the mill.

4.3.3.2 *Bench System*

The system derives its name because originally a bench was formed by felling a tree across where other trees were to be felled. This was to facilitate debranching the underside of the stem and crosscutting. However, the bench is no longer employed due to it incurring considerable work and because it frequently caused stems to break under the impact of the falling tree, although a particular application of the bench is suggested in Appendix C.

When using the bench system, the chainsawyer fells a tree, possibly trims the butt (butt cuts), attaches a steel tape and marks for crosscutting and debranches. He then stops the chainsaw, stacks the brush in a line, restarts the chainsaw and crosscuts the stem and he may remove any poles in the brushline.

Labourers follow at a safe distance behind the chainsawyer, debarking the poles which are usually bunched or sorted into pole categories and stacked.

4.3.3.3 *Semi-bench System*

Variations of the bench system have developed with a chainsawyer's assistant stacking the brush or by having various chainsawyer activities transferred to the labourers.

Any system incorporating the distribution of activities of labourers and chainsawyer between the descriptions of conventional chainsaw and bench systems is referred to as a semi-bench system.

4.3.4 *Hand Tools, Chainsaws and Heavy Machinery*

Chainsaws are usually used to fell and crosscut *P.patula* and frequently they debranch and top the trees. Often, though, debranching is undertaken manually using a 1,13 or 1,36 kilogram limbing axe. Debarking, if undertaken at all, is done mechanically, often at a sawmill, or manually using a spade or spadelike tool.

Two categories of feller bunchers have been observed by the writer. These include large imported machines capable of shearing the stem of a 30-year-old *P.patula* and carrying it to roadside and a small three-wheeled, locally made machine were described in Chapter 3. Two cutting techniques are used, hydraulically powered chainsaws and shears. Various descriptions of circular saws fitted in the feller head are being introduced.

Various other types of heavy machinery which have never been imported to southern Africa, or have been imported but have proved to be a failure in this region, will not be described and discussed.

4.3.4.1 *Integrated System in Pinus patula*

Skidding of tree stems takes place after chainsaw felling and chainsaw or limbing axe debranching and topping, but before marking and crosscutting. As extraction is incorporated in the primary conversion, the system is named the "integrated system".

Due to high mass, manual sorting on roadside into categories and stacking of 6,6 metre long logs of cut 28 year-old *P.patula* requires about seven labourers with 1,5 to 2 metre long crowbars. Alternatively, small agricultural tractors with either "A frame" choker bars on their three-point linkage or light grapples are used (de Laborde, 1982). Recent observations revealed that a locally made three-wheel loader with a 0,25 square metres grapple is the most popular machine for sorting and stacking.

Where slopes exceed 22 degrees or rock outcrops prevent access by infield vehicles, stems are extracted by highlead either to a point accessible to a skidder or to the roadside.

4.3.4.2 *Integrated System in Eucalyptus grandis*

During the past two years, several forestry companies have reported verbally to the writer that they were using the integrated system to harvest *E.grandis* in steep terrain. During 1983 the writer assisted in introducing this system in Zimbabwe, where it is understood to be operating successfully.

4.4 CATEGORIES OF TIMBER EXTRACTION AND TRANSPORT SYSTEMS

All information in this section is drawn from a report by the Forest Owners' Association (1981), a report by the writer (1982b) and personal observations subsequent to the writer's report.

Descriptions of timber extraction and transport systems chosen by growers depend on a variety of circumstances. If farming is mixed with forestry as a secondary interest, agricultural equipment is normally adapted to forestry operations.

Increasingly sophisticated systems are encountered and warranted at increasingly high scales of operation. Terrain conditions clearly also influence the infield extraction and transport system selected.

4.4.1 *Manual Timber Extraction*

Labour supply was discussed in Sections 2.2 and 2.3. In areas where labour is available and the terrain inhibits or excludes vehicle entrance to the field, labourers are employed to extract timber to the roadside.

Although it is anticipated that this method will become obsolete it is still used sufficiently to warrant it being studied. Further, there are occasional small gullies in many areas where pole masses permit carrying and manual extraction is a viable solution.

4.4.2 *Plastic Chutes*

In steep terrain where labour to extract timber is still available plastic chutes are used to reduce human effort and increase productivity. Shortwood lengths are preferred unless the chutes can be kept straight as longer lengths gauge curves or dips.

4.4.3 *Mules*

Mules have retained popularity in the southern Cape, southern Natal, Swaziland and the eastern Transvaal, principally for slipping (extracting by animal) pine thinnings. In all these areas they are reported to be able to compete both on a cost and a daily production basis with mechanical systems.

4.4.4 *Skidders*

Skidders of two broad categories are employed. Depending on pole or log mass, terrain and climatic conditions, either a two-, or four-wheel-drive tractor is used usually with a four-ton, double-drum winch attached for the prime extraction of lighter timbers.

Large specialised cable skidders are used almost exclusively in southern Africa where extraction of heavier timbers is by skidding. With the decreased labour availability, grapple skidders are being introduced in a few large-scale operations.

4.4.5 *Highleads and Skylines*

Although growers have been apprehensive in employing highleads in terrain where slopes exceeded 22 degrees or rock outcrops, cliffs or gullies occur, an eastern Transvaal company succeeded in applying highleads successfully on steep slopes. This system is being used increasingly, being the subject of study by other companies (Howe, 1982).

Skylines are being introduced in southern Africa and are under investigation by several companies and the writer.

4.4.6 *Forwarders, Tractor-Trailers and Lorries*

Imported forwarders were tested principally by one large company, but their use has been virtually discontinued. A locally made forwarder became available in 1982 and it has been reported verbally by a grower who has tested it, to be efficient and robust. It usually extracts from infield to roadside, but in smaller-scale operations it may be necessary to transport timber to a rail point or mill. Lead distances, the distance a load is transported, with forwarders are kept minimal for most situations.

Tractors and trailers are used most frequently for timber transport from infield to roadside and/or along roads for lead distances of up to 10 kilometres and occasionally for distances of up to 20 kilometres.

However, lorries and rail trucks are the most popular forms of timber transport although no statistical data exists to support the observation.

Timber loading methods vary according to labour availability (de Laborde, 1983) and scales of operation. Manual loading is still the most popular technique in terms of numbers of growers employing the method, especially in the flat areas of the south-eastern Transvaal and Zululand where timber is loaded infield and transported directly to its final destination or rail point. It is, however, more popular in small-scale operations and most timber is probably handled mechanically because large-scale growers account for the greater proportion of timber production.

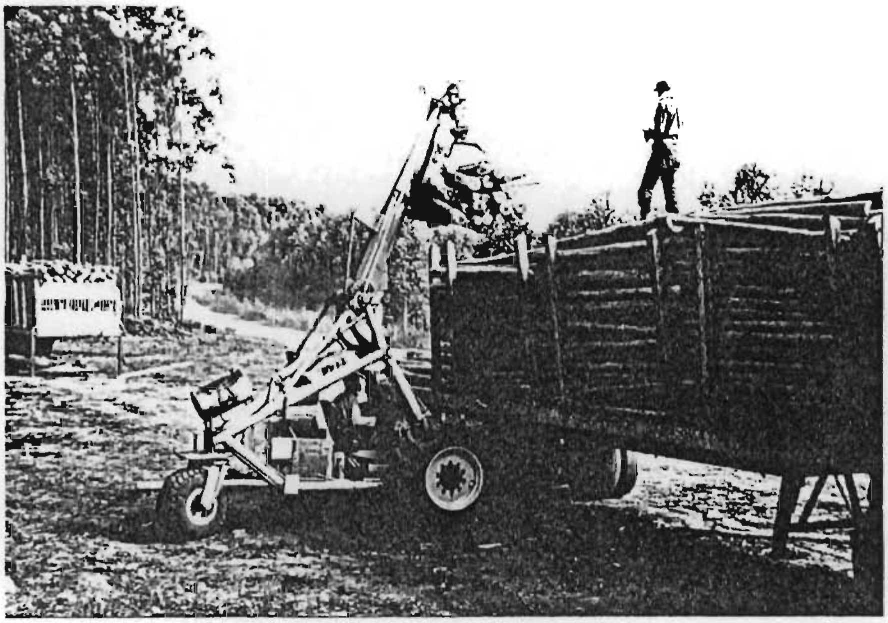
4.4.7 *Mechanical Loaders*

Mechanical loaders used in forestry are of two major categories. Large, front-end loaders are employed only occasionally. The only purposes noted for which they are being used in southern Africa are to load 25-ton lorries and rail trucks and to offload lorries at mills.

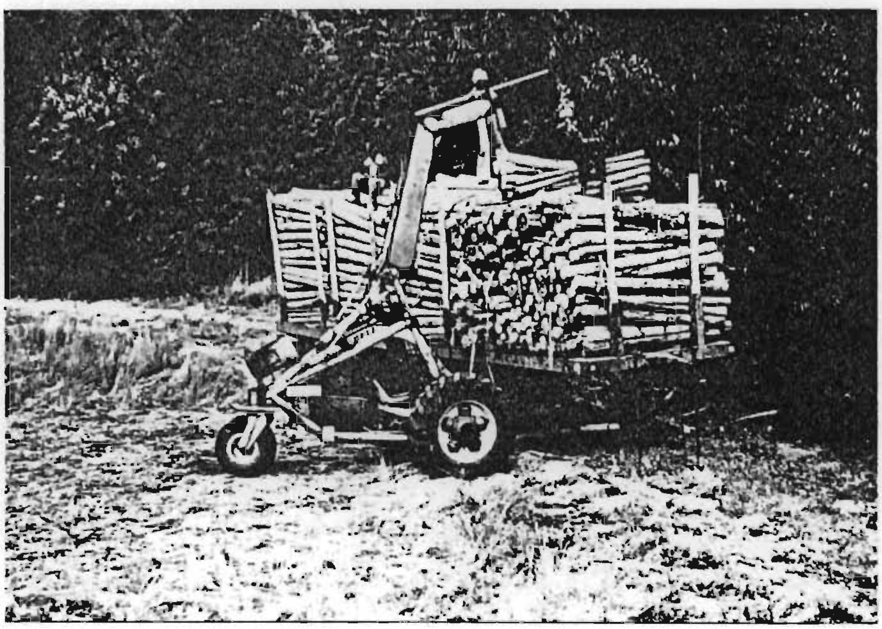
Locally-made, three-wheeled loaders are attaining considerable popularity. These are manufactured in three sizes quoted as being a half ton, a one ton and a two ton which was recently developed. Various attachments are available. These include, *inter alia,* three grapple sizes of 0,25, 0,33 and 0,60 square metres for the three machine sizes, respectively.

The one ton loader is available with four types of booms, *viz* a low boom, a high boom, a new crank boom and a telescopic boom called a teleboom. The first of the three is suited for moving and stacking timber at roadside. High booms can load satisfactorily to a height of 3,5 metre while the teleboom loads to 4,0 metre (Figure 4.1).

FIGURE 4.1



A three-wheel loader with a 'high' boom loading to the maximum 3,5 metre height



A three-wheel loader with a telescopic boom loading to the maximum 4.0 metre height

Tip lorries and 25 to 30 ton lorry and trailer combinations have a bed height of 1,5 metres. In most cases full vehicle capacity can be attained only by loading to 2,5 metre above the bed when loading lighter timbers such as *E.grandis* shortwood poles after six-weeks air-drying.

4.4.8 *Cranes*

Cranes are mounted on the rear of a tractor drawing a trailer, or on the trailer thus forming forwarders which are becoming increasingly popular (de Laborde, 1984c).

Lorries were found to have mounted cranes with 64 per cent of all growers. Mobile cranes constructed by mounting a crane on the rear of a tractor or lorry or by building a crane onto a tractor are common. The last type of crane was developed originally for sugar cane loading. Currently, only one large-scale company is known to be using this type of crane in an efficient system where shortwood poles are handled in bundled form (de Laborde, 1983a).

4.5 FACTORS AFFECTING HARVESTING AND METHODS OF WORK MEASUREMENT

All analysis of work has to be related to the characteristics of the plantation product mix, climatic conditions and terrain. These will be described initially to facilitate discussions on the various work measurement techniques.

4.5.1 *Forest Mensuration, Terrain Characteristics and Climatic Conditions*

Procedures in assessing the mean tree size of a compartment, *viz* sub-section of a plantation, have been specified by the British Forestry Commission (1975). These data and the terrain characteristics are required for two purposes in work measurement, the first of which is to permit investigation into whether these factors influence the harvesting activities. Where significant influence is encountered, correlation is sought between ranges of dimension and activity times.

Secondly, tree dimensions and plantation stocking are required to estimate the daily output of the various categories of line workers , the time duration to harvest a compartment, man-days per hectare and standard cost projections.

4.5.1.1 *Tree Dimensions, Bark Mass and Timber Volume*

Where plantations are assessed for harvesting, usually means and standard deviations of tree diameter at breast height, *viz* at 1,3 metres, total height, pruning height for *P.patula* and bark thickness for wattle and *E.grandis* are calculated for each compartment thus establishing a representative mean tree. The greater the standard deviation, the greater the variation and possible inaccuracies of projections.

Pole or log lengths influence the descriptions of harvesting and transport equipment or vehicle selected. Pole lengths may vary from 0,9 to 13,4 metres and a mean length could be valueless for this selection. Thus pole or log lengths to be cut require specification. However, the mean length is required to estimate daily production rates for chainsawyers crosscutting stems.

Market fluctuations cause changes in product mix and specifications for pole or log lengths and/or acceptable end diameters. The fluctuations can complicate seriously daily tasking of chainsawyers and equipment and vehicle selection.

Equations have been developed by Schönau (1971, 1972, 1973) to assess per tree bark mass for wattle and timber volume for wattle and *E. grandis* with allowance for stump and kerf (width of the cut) wastage.

Wattle bark mass :

$$\log BM = 1{,}87253(\log D) + 0{,}72118(\log H) + 1{,}152919(BT) - 0{,}11767(BT \times \log D) + 0{,}037728(BT \times \log H) - 2{,}04586 \quad 4.1$$

Wattle timber volume :

$$\log V = 2{,}23286(\log D) + 1{,}2969(\log H) + 1{,}56726(BT) - 0{,}50129(BT \times \log D) - 0{,}90612(BT \times \log H) - 3{,}27782 \quad 4.2$$

Allowance for stump and kerf wastage :

$$\% STKV = 0{,}026041 - 0{,}13587(STKHT) + 0{,}0032014(STKHT \times TOTHT) + 3{,}82282(STKHT/TOTHT) \quad 4.3$$

E. grandis timber volume :

$$\log V = 2{,}3350(\log D) + 1{,}46222(\log H) + 0{,}063331(BT) - 0{,}024106(BT \times \log D) - 0{,}034757(BT \times \log H) - 2{,}44352 \quad 4.4$$

Allowance for stump and kerf wastage :

$$\% STKV = 0{,}025288 - 0{,}347059(STKHT) + 0{,}0086631(STKHT \times TOTHT) + 6{,}12514(STKHT/TOTHT) \quad 4.5$$

where :

BM = total undried bark mass per tree in kilograms up to an underbark tip diameter of five centimetres

D = diameter at breast height in centimetres

H = total tree height in metres

BT = bark thickness at breast height in millimetres

V = total timber volume per tree in cubic decimetres up to a five centimetre underbark tip diameter

% STKV = stump and kerf volume as a percentage of the total tree volume up to a five centimetre underbark tip diameter

STKHT = stump height and kerf wastage in centimetres

TOTHT = total tree height in metres

Bredenkamp (1983) gives the following equation for *P.patula* timber volume. Symbols are as for the volume equations above.

P.patula timber volume :

$$\log V = 2{,}43963 \log(D + 8) + 1{,}32537 \log H - 5{,}84966 \quad \ldots\ldots\ldots \quad 4.6$$

A general bark thickness is incorporated in the coefficients.

4.5.1.2 *Terrain Characteristics*

The following terrain characteristics could have varying influences on harvesting.

Obstacles such as rock outcrops and small cliffs influence the type of harvesting system chosen, particularly timber extraction.

Slope is a factor which can have an influence on most harvesting activities.

Undergrowth normally dies shortly after the closure of the forest canopy. However, the writer has noted that in the Port Durnford area in Zululand, dense fern grows to a two-metre height and distinctly impedes work. Towards the bottom of gorges in the Natal Midlands and on some of the slopes of the eastern Transvaal Drakensberg indigenous plants form an undergrowth. Occasionally, this undergrowth may inhibit harvesting, particularly primary conversion activities.

Bramble is a serious problem in the Natal Midlands. Where tree espacement is wide, as in pine plantations, the forest canopy is insufficiently dense to inhibit bramble growth and could inflict work restrictions, but no influence was experienced in any studies.

Presence of undergrowth that is likely to cause work restrictions should be recorded in quantifiable units giving density, height, presence of thorns and frequency of occurrence.

Soil compaction caused by infield vehicles has resulted in serious growth inhibition in *P. radiata* in the southern Cape (Beekman & Grey, 1982). Personal observations in this region revealed that tree growth was stunted from an average plantation height of 13 metres to two metres in trees in and near the skidder roads. Mortality in these areas was very high.

Schönau (1984) reported the effects of soil compaction in the Fernwood soil in KwaMbonambi caused by a large tractor-trailer extracting infield. Differences in tree size and stocking after 3 years 11 months and 4 years 9 months in compacted and non-affected areas are shown below.

	Compacted areas		Non-affected areas	
Stand parameter	3 years 11 months	4 years 9 months	3 years 11 months	4 years 9 months
Mean diameter at breast height (cm)	5,61	7,60	11,12	12,61
SD	2,81	3,17	2,02	2,23
CV (%)	50,0	41,7	18,2	17,6
Mean height (m)	-	10,75	-	15,0
Basal area (m^2/ha)	3,58	4,96	15,17	17,85
Stocking (trees/ha)	1 177	1 093	1 514	1 430

Compacted areas compared with non-affected areas have under half the diameter, over double the coefficient of variation are shorter and have a lower stocking. It is expected that these losses will never be regained.

Finally, many verbal reports of similar damage in *P.patula* have been received from Swaziland.

In response to these reports meetings have been held with various research, private and public organisations and the writer to initiate research into the phenomomen. Final results of this research will not be available in time for inclusion in the thesis. Major factors to be investigated, will be, *inter alia*, to assess the ultimate economic significance of this stunting, establishing the extent of compaction sensitivity of our different soils, harvesting layout and systems that will reduce compaction and soil restoration treatments.

4.5.1.3 *Climatic Conditions*

High rainfall influences the type of timber extraction and transport systems used. Equipment, vehicles and tyre types should be selected to accommodate these conditions.

Severe winds have been reported verbally to overturn feller-bunchers of the type that carry the tree in a vertical position from the forest after severing its stem. Such equipment should be disallowed in high winds.

Where a prevailing strong wind is experienced, it may only be possible to fell trees in the direction of the wind and this occurs in the flat coastal areas of Zululand. Here plantations need to be laid out with consideration to prevailing wind direction.

4.5.2 *Use of Historical Data and Work Study*

In an attempt to estimate performance of labour and capital equipment, plantation mensuration data and terrain characteristics are recorded for a compartment to be harvested.

During harvesting, a record is kept of labour and machinery employed on a daily basis for the compartment. Where this procedure is repeated for a succession of compartments, correlation between components of the above data can be analysed in order to produce mathematical relationships. Thereby, future projections for labour and capital requirements and standard cost projections may be made.

The alternative is to use formal work study methods discussed below.

4.5.2.1 *Using Historical Data for Planning*

The use of historical data which may be linked to accounting systems, has a degree of merit. Data are simple to extract and will give useful guidance. However, with planning the historical approach has serious shortcomings which have been cited (de Laborde, 1980).

Historical data do not measure the precise time of each worker, but only the amount of time spent at the work site. Field studies showed that workers performed at extremes of either half or double an estimated normal daily output.

As human output is being measured, it is important that the amount of effort exerted be assessed. Studies have found effort to vary by 40 per cent and wider fluctuation is anticipated by the International Labour Office (1979, p. 248). Apart from effort, people work at varying levels of efficiency and worker efficiency may affect output drastically.

Where a new system is introduced, historical data will provide limited information and growers may continue to use inefficient systems because they gave superior results to previous systems.

Expensive machinery such as skidders are frequently employed inefficiently. As the output levels compare favourably with industry averages, based on accounting-type data, these are being accepted as the normal by many growers and contractors.

Where transport systems are analysed using historical data, the above shortcomings are mitigated due to the greater simplicity of the operations. When these data are used in conjunction with tachographs the results are considerably enhanced. However, it still may not provide suitably detailed analyses of loading and off-loading operations.

4.5.2.2 *Using Historical Data for Control*

Historical data are invaluable for control. Where correct work measurement techniques have been used to establish systems and, thereby, standard performance and costs, it is important for management to ensure that these are being achieved by monitoring historical data. Further, where difficulties or inefficiencies are being encountered, these will reflect in differences between projected and actual performance and corrective action may be applied.

4.5.2.3 *Work Study*

For forestry operations there are currently two possible methods of measuring work. Firstly, predetermined motion-time standards have been established by resolving body movements and the extent of concentration into basic categories. Work-times, incorporating the necessary rest allowance, have been established for each of these categories, and are recorded in tables. To establish work content of an activity or operation, distance moved and type of actions are listed for each work element. Using this list, the respective times are taken from the tables and, thereby, work content established.

Method-Time Measurement is the most popular and internationally accepted of the predetermined motion-time standards. It has been established in three levels, *viz*, for high precision and intricate operations, for less complex operations where movements are expressed in broader categories and for simple operations where movements are given in a few general categories (International Labour Office, 1979, p. 314).

The second method of work measurement employs the use of a stop watch. There are essentially two applications of the stop watch, *viz*, time studies where each element of work is timed and recorded, and activity sampling where at selected time intervals a note is made of what each worker, or machine, being studied is doing. Time studies only can be used for studying a single person or machine while activity sampling can include any number of people and/or machines. Greater description is given in Section 4.6 of the stop watch techniques.

While it is possible to use Method-Time Measurement and obtain the distances and determine work division into the various types of actions, forestry is particularly variable making such data very difficult to obtain. For example, when debranching a tree by hatchet and stacking the brush, branch diameters and distances to brushlines may vary considerably.

On account of the above complications, Method-Time Measurement was rejected for general use in analysing forest operations although specific instances for its use may be found. Stop watch techniques as discussed below are simpler to apply and may provide adequate accuracy. Therefore, these techniques were accepted.

4.6 STOP WATCH TECHNIQUES IN APPLYING WORK STUDY

Stop watch techniques of work study have been shown to be reliable and to provide a penetrating analysis into work (British Forestry Commission, 1973).

4.6.1 *Time Studies*

Time studies are conducted in the following way which is recommended by the International Labour Office (1957). Continuous timing is preferred to separate element timing, *viz*, fly-back timing, as it removes much of the tension and allows more concentration on the work.

Studies usually run for many hours through the heat, wind, rain or cold of the day with time intervals frequently as short as three centiminutes. When using fly-back timing on a lengthy study and a few readings are missed in various ways, the entire study may have to be rejected. The timing error obtained when comparing the total of all fly-back times against the total elapsed time cannot be checked or it may be in excess of the prescribed two per cent (Whitmore, 1980, p. 240), alternatively compensating errors could occur. Continuous timing negates these difficulties. Further, continuous timing permits the type of studies described in Section 4.6.4.

An example of the time study forms used is given in Figure 4.2. To reduce eye strain, green paper is used for all in-field work to great advantage.

4.6.2 *Time Summing*

During a time study it may be necessary to gather the total time for a certain work element. To achieve this, two work study stop watches are employed. The one stop watch runs continuously for the time study while the second stop watch is used to accumulate the time of the required element.

An example is crosscutting *E.grandis* shortwood poles. To obtain the actual crosscutting time which may be very brief with equally short intervals between cuts, the above technique has been used. This has provided an insight into the relative efficiencies of different site layouts which otherwise would not have been possible (Section 5.4.4.3).

4.6.3 *Activity Sampling*

The are several variations of activity sampling, *viz* random or fixed time and rated or non-rated studies (Whitmore, 1980, Ch. 10). Of these variations fixed time, rated activity sampling was chosen.

FIGURE 4.2

Time study recording sheet

REF ____________

SHEET ____________

STUDY ____________

DATE ____________

STARTED ________ ENDED ________

Element	Rate	W.R.[1]	O.T.[2]	N.T.[3]	Remarks	Element	Rate	W.R.	O.T.	N.T.	Remarks

RMdL:ltd 9/7/82

Notes:
1 Watch readind
2 Observed time
3 Normalised time

The principal advantage of random timing is that it avoids inadvertently engaging a sympathetic sequence with the work resulting in biases. In forestry, the activities where activity sampling is applied are of long duration, that is, in excess of 10 minutes and are not usually integrated with other activities. The 0,5 to 2 minute time intervals used will not form a sympathetic sequence.

To increase the accuracy of the studies further, four to six labourers are studied using a one-minute cycle. Where two or three workers are studied, a 0,5 minute cycle is used. Random times would probably include times from 0,5 to 1 minute up to 5 to 10 minutes. This will result in an average cycle time considerably greater than the fixed time's cycle which reduces the total number of readings and accuracy of the study for a given study period.

Most activity sampling studies are of 6 to 10,5 hours duration. Continuously consulting a set of random tables increases the complexity of running studies and, thereby, the likelihood of error.

Fixed time, rated activity sampling is recommended by Whitmore (1980, p. 248). Acceptance of this technique was stated in correspondence with the British Institute of Management Services and with the British Standards Institute (1983).

An example of the forms used for field studies is given in Figure 4.3. The ten numbered columns are an aid in cross-checking time durations while running and analysing studies.

FIGURE 4.3

Rated activity sample recording sheet

REF ______________

SHEET ______________

STUDY ______________

DATE ______________

STARTED __________ ENDED __________

	1	2	3	4	5	6	7	8	9	10
RMdL:ltd	9/7/82									

4.6.4 *Combined Activity Sampling and Time Study*

When studying skidder operations considerable difficulty was experienced in obtaining a total analysis when recording alone.

A skidding operation usually has two to four labourers setting choker chains on logs while another labourer releases the chokers at the landing. These workers should be studied using activity sampling. However, a time study should be used for the skidder. Consequently, the form shown in Figure 4.4 was developed.

Results from using the combined analysis have been most satisfactory. However, it was found that a maximum of three people could be studied using activity sampling with a one minute cycle. Times for the labourer releasing the chokers are obtainable from the time study.

4.6.5 *Duration and Layout of Studies*

Each study provides a complete and detailed analysis of the work. Where certain fixed activities occur seldom in a study, appropriate studies are combined, where possible, to increase the number of observations. When activity sampling is used for pole preparation by labourers, some studies were subdivided so that a third of the day's quota of trees was completed before the next third was felled. Thus 12 to 18 analyses were obtained. However, great caution was exercised to avoid introducing atypical factors into the studies.

With studies on the conventional and integrated systems, plantations mensuration was completed and all trees numbered prior to running the study. Where trees were to be debarked during the study, a small square of bark was removed and the number written on the wood to permit identification later.

Studies on loading and transporting shortwood poles required no previous preparation where the load passed over a weigh bridge. Only the total number of poles per load was recorded. However, where load mass was unavoidable, prior to the study a 10 per cent sample of mid-point diameters and lengths of poles were measured and their mass obtained by spring scale. From these measurements the mean pole density was estimated. To estimate individual load masses, the mid-point diameters were recorded of a 25 per cent sample distributed evenly over all poles to be loaded during the studies.

4.7 STANDARD MINUTE

4.7.1 *Rating Scales and Calculation of Basic Time*

During all studied, worker speed is rated during each element. The International Labour Office (1979, p. 247) have described the 60 - 80, 75 - 100 and 100 - 133 rating scales and the newer 0 - 100 rating scale now used as the British Standard. In all cases the higher value is equivalent to a man walking at 6,4 kilometres per hour (4 miles per hour) unimpeded on level ground.

Selection of the rating scale was made a number of years prior to the development of the 0 - 100 scale. Calculation of normalised time was given by the International Labour Office in their original manual (1957, p. 240) as

$$\text{normal time} = \text{observed time} \times \frac{\text{rating}}{\text{normal rating}} \qquad \ldots\ldots\ldots\ldots\ldots \quad 4.7$$

In the 75 - 100 rating scale, rating is normalised (reduced) to 75 per cent. The 0 - 100 scale does not include this overall allowance. By taking 75 per cent of the hours worked per day instead of

FIGURE 4.4

Combined study recording sheet

REF ____________________

SHEET ____________________

STUDY ____________________

DATE ____________________

STARTED __________ ENDED __________

	1	2	3	4	5	6	7	8	9	10

Element	Rate	W.R.	O.T.	N.T.	Remarks	Element	Rate	W.R.	O.T.	N.T.	Remarks

increasing the normalised time, and using 100 as the normal rating, greater flexibility was left to select or modify the hours worked per day.

This approach gave a similar effect to what was obtained later by the British Standard (0 - 100) scale as given by the International Labour Office (1979, p. 249) where normalised time is replaced by basic time as

$$\text{basic time} = \text{observed time} \times \frac{\text{rating}}{\text{standard rating}} \quad \ldots\ldots\ldots\ldots\ldots \quad 4.8$$

where the standard rating is 100. However, it incorporates the shortened working day which is preferred for reasons discussed in Section 4.9. Where the minute is the unit of time, basic time becomes the basic minute.

4.7.2 *Relaxation Allowance and Rest Factor*

Relaxation, or rest, allowance commence at 10 per cent and increase according to the amount of mental and/or physical stress. The International Labour Office (1979, p. 425) provide tables to assess the allowance. Although these tables were not developed for use in forestry, adaptation is easy.

To simplify the inclusion of the percentage relaxation allowance (RA) in an equation, use is made of the rest factor (RF) which is one plus the allowance in decimal for, thus

$$RF = 1 + (RA/100) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 4.9$$

Analyses and a list of all relaxations allowances employed is provided in Appendix A.

4.7.3 *Calculation of the Standard Minute*

The International Labour Office (1979, p. 271) shows the standard time to be comprised of 'observed time', 'rating factor', 'relaxation allowance' and a contingency allowance for 'work' and 'unavoidable delays'. The last two items are included in fixed activities discussed below. Thus the standard minute is calculated as follows :

standard minute = observed time x observed rating x rest factor .. 4.10

4.8 CATEGORIES OF ACTIVITIES AND WORK EFFICIENCY

Activities have been divided into three categories, *viz*, variable, semi-variable and fixed. The British Forestry Commission (1973, p. 29) identify the first and last activities. To simplify description, the example of a chainsawyer's work is taken.

Variable activities are those which are influenced by the dimensions and/or characteristics of the object being worked. Felling and crosscutting are variable activities influenced by tree dimensions and pole specifications.

Semi-variable activities include activities which are influenced by the amount of work processed and not the article's dimensions or characteristics, but are directly related to the number of piece of work processed. Walking to the next tree during felling is a semi-variable activity.

Fixed activities are those that occur at regular or random intervals but are independent of the former two activities. Refuelling, tending to the chainsaw and certain unavoidable delays exemplify this category.

Where an activity's time may be influenced by independent variables such as tree or terrain characteristics, time is regressed on this variable. Where no such relationships can be established, the mean of the activity's time is calculated. This is discussed in detail in Chapter 5.

Once assessed independently for a given situation, the standard minutes for variable and semi-variable activities are added. Fixed activities are subtracted from the length of the working day specified. All times are expressed in standard minutes unless basic minutes are specified. Reasons for manipulating activities in this manner are demonstrated in the following example.

As has been shown (de Laborde, 1979a, 1979b, 1982a) daily task rates vary considerably for a given operation. Appendix B, Table 7 shows how a chainsawyer's normal daily task to fell and crosscut first rotation *E.grandis* can vary from 430 to 125 trees depending on tree size. Fixed activities comprise 20,8 per cent of the days work or 75 standard minutes (Equation Total 5,49).

If times for fixed activities are added to the number of pieces of work produced per day then the correct amount of such activities will only occur at the mean output level of the total range of dimensions of the studies included in the regression analysis. As daily output is extended to smaller dimensions, the results will require increasingly less effort from the worker and *vice versa* for larger tree dimensions.

If the mid-point of the above daily output range is 278 trees, this means that 75/278 = 0,270 standard minutes per tree of the total standard minutes are fixed activities. In Section 4.9 it is shown that a 360 minute day is taken to calculate the normal daily output. With 75 standard minutes of fixed activities, the time into which variable and semi-variable activities must be divided is 360 ÷ 75 = 285 standard minutes. Thus the standard minutes of variable and semi-variable activities for the smallest trees must be 285/430 = 0,663 standard minutes per tree and for the largest trees 285/125 = 2,28 standard minutes per tree.

If the fixed activity is now added, the daily task rate for the smallest trees becomes 360/(0,663 + 0,27) = 386 trees and for the largest trees 360/(2,28 + 0,27) = 141 trees. This gives a 100 - 386/430 x 100 = 10,2 per cent decrease of the daily task rate for the smallest tree and a 100 - 141/125 x 100 = 12,8 per cent increase for the largest tree when the fixed activity is added.

To summarise the above, the daily task is calculated by dividing the sum of variable and semi-variable activities into the intended length of the working day from which fixed activities have been subtracted.

4.8.1 *Selection of Workers to Study*

Standard daily tasks are produced to provide foresters with a guide to what workers daily production should be. Consequently, such data must reflect the output of a competent worker.

As was discussed above, although it is possible to rate the speed with which a person is working, it is impossible to estimate inefficiency. An inefficient worker may be working fast, but includes superfluous activities or delays in his work. When comparison of analyses show that an inefficient worker was studied its data was discarded.

When requested to undertake studies of systems that had obvious inefficiencies, these were eliminated prior to the study where they were likely to interfere with individual performance.

4.8.2 *Efficiency Factor*

An efficiency factor was developed to make allowance for reduced performance, *inter alia,* due to sickness, weather or machine failure and maintenance. However, the efficiency factor is not applied to setting worker, or machine, daily output, but to projections of production levels and costs for overall planning purposes.

The efficiency factor is the product of the average proportion of the target achieved and the average proportion of machine availability (where applicable) and is calculated as follows :

$$\text{Efficiency factor} = p_1/p_2 \times h_1/h_2 \qquad 4.11$$

Where p_1 = production achieved over a given period

p_2 = projected production for the same period

h_1 = actual hours a machine or vehicle operated over a given period

h_2 = total hours the machine or vehicle could have operated over the period omitting all stoppages that are not an integral part of the job

Either p_1 and p_2 or h_1 and h_2 may be absent from the equation.

4.9 NORMAL AND MAXIMUM DAILY OUTPUT

4.9.1 *Length of the Normal Working Day*

Traditionally, the Black African commences work around sunrise. The tribal two-meal-a-day system is followed with a 30 minute breakfast being taken between 08h30 and 10h30. The second meal was a dinner taken shortly after dark. After about 14h00 people rested and performed daily household duties. Thus work covered six to seven hours per day which is similar to using a 75 per cent normalisation of an eight-hour working day. Therefore, it was decided to adopt a basic or normal working day containing 360 standard minutes of work for heavy manual work.

A 480 standard minutes working day is regarded as correct for lorry drivers, tractor drivers on roads and operators of cranes, front end loaders working on even terrain and any machinery that does not incur high physical stress.

4.9.2 *Normal Daily Task Rate*

In the preceeding sections, length of the working day, the standard minute and treatment of the three categories of activities were discussed. From these the normal daily task rate can be calculated as follows :

$$\text{normal daily task rate} = \frac{\text{length of working day in minutes} - \Sigma FA}{VA + SVA} \quad .. \ 4.12$$

Where VA = variable activity

SVA = semi-variable activity

FA = fixed activity

All components are expressed in standard minutes. The length of the working day is either 360 or 480 minutes (Sections 4.9.1 and 4.9.3).

In strenuous labourer work where the 360 standard minute working day applied, it has been found repeatedly over the past decade that it will take workers about 7,5 hours to complete their tasks and that it provides a most satisfactory daily task rate.

Chainsawyers frequently develop high skills and often complete their tasks in below six hours by working over a 100 per cent rating and taking little or no rest. This, however, is not encouraged as it may be injurious to the chainsawyer, decrease safety to all workers and disrupt the labourers' work (Sections 5.3.6.3 and 5.4.6.2).

4.9.3 *Extended Working Hours*

There is no precise stipulation in the Factory's, Machinery and Building Work Act 22/1941 (as amended) on the maximum number of hours per day that may be worked. It merely states (Section 19, p. 16) that 'no employer shall require or permit an employee ... to work more than forty-six hours, ... in any week ... or to work overtime more than ten hours; or ... a number of hours (which may exceed ten) fixed by an inspector.' Any person in South Africa using a machine, including a chainsaw, falls under this Act.

Despite research into the subject, there appears to be no medical evidence indicating the maximum number of hours per day an average person can work without injuring his health. Obviously, it also depends on the nature of the work.

Welsh (1971, p. 215) and Davis (1978, p. 153) have described how chainsaw usage leads to health damage including the development of Reynaud's Phenomenon, an incurable disease of the nervous system caused through excessive exposure to vibration. Further, chainsaw operating is tiring and reduced attention through fatigue will increase the danger of accidents (Appendix D, Section 3).

In lieu of specific information it was decided to regard a third extra work, over the normal hours per day as the upper expected limit. Application of this maximum has shown that it provides a reliable guide to the maximum daily work that can be reasonably expected. Although it is achievable by experienced and capable workers it is seldom that daily tasks above this level are exceeded constantly.

However, workers should only exceed the normal daily task rate under their free volition and should be renumerated accordingly (de Laborde, 1984a).

CHAPTER 5

ANALYSES OF HARVESTING AND TRANSPORT OPERATIONS

The objectives of this chapter are to describe techniques of data analysis and present the writer's research findings.

All data of harvesting and transport operations must be analysed in such a way that the results can readily be applied by foresters. The British Forestry Commission (1973, 1978, p. 245) uses tree volume as an independent variable, where applicable, in regression analyses. Volume is principally a function of tree diameter and height (Section 4.5.1.1). This requires the forester to measure the trees then include an additional step to estimate the volume of the mean tree before applying work data. Of greater importance, though, it is shown below that tree diameter and height can operate independently in affecting work content.

5.1 PRIMARY ANALYSIS OF FIELD DATA

5.1.1 *Analysis of Continuous Timing Time Studies*

An objection to continuous timing in time studies is that each time must be subtracted from the one following to obtain the observed time per work element. With fly-back timing this is immediately available. This objection has been overcome with a 29 step programme, Time Study Analysis (TSA), for the Hewlett-Packard programmable calculators. The programme given in Figure 5.1 is for the Model 41C but by omitting the steps in parentheses, the programme can be applied to simpler models of programmable Hewlett-Packard calculators. TSA gives

FIGURE 5.1

Programme for the Hewlett-Packard 41 C to analyse continuous timing time studies to give observed time, basic time and standard minutes. Lines in parentheses are omitted for smaller programmable models

(01 LBL ^{T}TSA)	
02 STO 07	
03 X<>Y	
04 -	
05 100	
06 /	
(07 STO 00)	
(08 0)	
(09 STO 01)	
(10 ^{T}OT=)	
(11 ARCL Y)	Enter R/S on smaller models.
(12 PROMPT)	
(13 STO 01)	
(14 RCL 00)	
(15 RCL 01)	
(16 X=0?)	
17 RCL 08	On smaller models, include for fixed rating only.
(18 RCL 00)	
19 *	
(20 ^{T}BT=)	
(21 ARCL X)	Enter R/S on smaller models.
(22 PROMPT)	
23 *	
(24 ^{T}SM=)	
(25 ARCL X)	Enter R/S on smaller models.
(26 AVIEW)	
27 RCL 07	
28 TONE 8	
29 END	

To run the programme:

Enter the most common rating in register 08 before starting the analysis.

	Keystrokes
Initial time (only to start programme or repeat a line)	ENTER ↑
Second time	R/S
Enter rating if different from that stored in register 08	R/S
Enter rest factor	R/S

observed time, basic time (normalised time) and standard minutes. Approximately 225 lines per hour of time study can be analysed. Another programme, also named Time Study Analysis, TSAN, was written in FORTRAN, (de Laborde, 1980, p. 4.6) for analysing continuous timing time studies on a main-frame computer. A flow diagram of TSAN is given in Figure 5.2. The programme provides various statistical analyses of each activity, but only means of the entire study are calculated for each activity which is unsuitable for regression analyses.

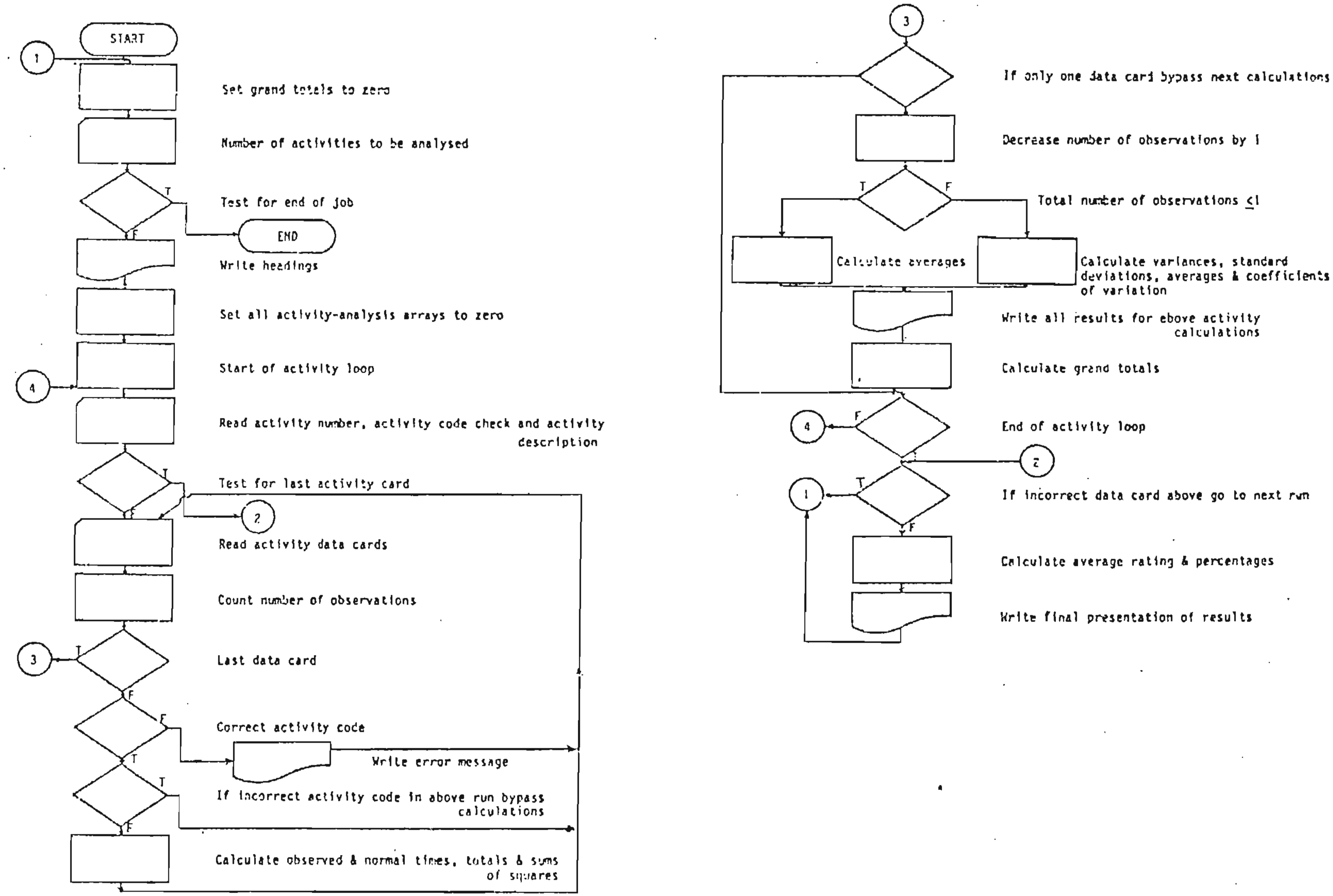
Subsequent to writing TSAN, the International Labour Office (1979, p. 360) published results of a programme to analyse fly-back time studies. A copy of the programme was obtained from its author (Steele, 1979), but it was found to be written in a version of BASIC that contained statements unacceptable for the University of Natal's computer. As fly-back timing is not used and the programme TSA produced the data in the form required for regression and other statistical analyses, no attempt has been made to translate the International Labour Office's programme.

5.1.2 *Analysis of Activity Sampling Studies*

Normally, activity sampling studies are analysed in the manner described by the International Labour Office (1979, p. 257) where the number of occurances of each level of rating of each activity are counted and recorded on a tableau. On completion of all counting, tallies are multiplied by their respective rating and the sum of all products are divided by a hundred to give the total basic minutes. This total value divided by the number of units of output, gives the basic minutes for an activity.

FIGURE 5.2

Flow diagram of TSAN computer programme



However, it was found that the analysis could be completed much quicker by using an ordinary adding machine preferably providing results on a paper tape for subsequent checking and keeping of records.

Ratings are read in decimal form and are added, irrespective of their value, for every reading of a given activity and divided by the total number of pieces of work produced during the study to obtain the basic time for the activity. Thus, for j observations of an activity,

$$BT = \left(\sum_{y=1}^{j} x_y \right) / n \quad \ldots\ldots \quad 5.1$$

Where BT = basic time of an activity in minutes

x = individual activity rating expressed as a decimal

n = total number of pieces of work produced during the study

Total elapsed time per activity is obtained if the adding machine gives a printout of the total number of entries. Thus the analysis can be checked for omissions by subtraction of the sum of all entries divided by the number of entries per minute from the total elapsed time of the study. Therefore,

$$e = T - \left(\sum_{m=1}^{i} j_m \right) / b \quad \ldots\ldots \quad 5.2$$

Where e = integer value giving the number of entries omitted

T = total elapsed time of the study

i = number of different kinds of elements and/or activities

b = number of readings per minute

It e does not equal zero, the paper tape is compared with the original field-study sheet(s) until the omission is located. Following the extraction and calculation of basic times for all activities, these are multiplied by the appropriate rest factors to give standard minutes.

5.2 SECONDARY ANALYSIS OF DATA

Analysis of the three categories of activities described in Section 4.8 are discussed below.

5.2.1 *Variable Activities*

Times for variable activities are dependent on variables such as tree diameter and height, terrain conditions and/or machine power (Section 4.7).

Several functional relationships were considered. The following is a linear regression model :

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon_i \quad \text{.............. 5.3}$$

Where X_1 .... X_4 = independent variables

β_0 = constant term

β_1 .... β_4 = partial regression coefficients

ε_i = random variable with a zero mean and assumed to have constant variance σ^2 and to be mutually uncorrelated

Y_i = dependent variable expressed in standard or basic minutes as indicated

Possible non-linear relationship of the variables was tested in every regression analysis by using natural logarithmic, square root abd reciprocal transformations of the variables.

Due to there being a maximum of four independent variables in the models, stepwise regression was unwarranted. Variables with t values of the partial regression coefficients greater than that for the 10 per cent significance level were retained in the models. If a second variable was dropped following a further analysis, the first variable was re-introduced and analysed before its final rejection. At each stage of the analysis, outliers were screened from the plotting of error residuals and examined to assess the necessity for their rejection.

In most multiple regression equations presented below, there is the possibility of some extent of 'multi-collinearity', for example, between tree diameter at breast height and total height. However, significance levels of partial regression coefficients quoted for each model show that 'multi-collinearity' was not serious.

Models were selected by ensuring that error residuals were uncorrelated with estimated dependent and independent variables. In addition to this, comparison was made between t values of partial regression coefficients and coefficients of determination. Examples of the distribution of error residuals and their interpretation are given in Appendix F. Natural logarithmic transformations of dependent variables was selected by residual analysis procedures as coefficients of determination are not comparable (Gujarati, 1978, p. 110).

5.2.2 *Semi-variable Activities*

Times of some semi-variable activities are dependent on independent variables and were regressed on these. Alternatively the times are random, but occur often within a sub-cycle of the work, for example clearing undergrowth before felling and sundry delays during felling. In this latter case means and standard deviations of times were calculated. High standard deviations indicate that activity times varied considerably and not that there was worker inefficiency.

5.2.3 *Fixed Activities*

Times for fixed activities are usually random and analyses are undertaken similarly to those for random semi-variable activities. The exceptions are that they have a low frequency of occurance and their times vary considerably due to work-site layout and worker efficiency. To overcome these difficulties, times were drawn from many studies even including different tree species, where this was possible, but excluding atypical conditions and inefficiency.

5.2.4 *Range of Quoted Data*

Daily outputs are given for a range of plus and minus one standard deviation from the mean of independent variables as recommended by the British Forestry Commission (1973, p. 44). Where there are a number of studies, range over which data are given is calculated separately. Thus, the total range may be greater than two standard deviations when groups of studies are analysed collectively.

5.3 PRIMARY CONVERSION OF *ACACIA MEARNSII* (WATTLE)

5.3.1 *Description of Field Studies*

Studies on primary conversion of wattle have been undertaken mainly in the Natal Midlands. Axe felling has been studied and regression equations estimated. Nevertheless, these are not quoted for the reasons given in Section 4.3.1.1. Table 5.1 provides a list

TABLE 5.1

Circumstance of wattle field studies, their type and duration for primary conversion

Study No.	Subject	No. of workers in RAS[1]	Area	Pole diameter range[2] (cm)	Tree dbh range (cm)	Tree height range (m)	Slope (degrees)	Ambient day temperatures	Type of study	Duration of study (min)	No. of readings RAS[1] only
1	Bowsaw felling		Eston		9,3 to 20,7		≤7	Cool to warm	T.S.[4]	153	
2	Bowsaw crosscutting		Eston	6,5 to 18,0			≤7	Warm	T.S.	83	
3	Bowsaw crosscut & stack poles	4	Inadi	5,2 to 16,4			≤7	Cold	R.A.S.	82	280
4	Bowsaw crosscut & stack poles		Inadi	5,2 to 16,4			≤7	Cold	T.S.	320	
5	Bowsaw fell & prepare bark and poles	6	PMBurg		7,7 to 26,3	10,3 to 25,4	≤7	Warm	R.A.S.	406	2225
6	Bowsaw fell & prepare bark and poles	6	PMBurg		9,7 to 22,2	16,2 to 20,7	≤7	Warm to hot	R.A.S.	524	2507
7	Labourers preparing bark & poles	8	Iswepe				≤5	Warm to hot	R.A.S.	635	2540
8	"		Melmoth				≤7	Warm	T.S.		
9	"	6	Karkloof		11,5 to 27,0	10,3 to 25,3	≤7	Warm to hot	R.A.S.	576	3272
10	"		PmBurg		6,2 to 24,0	12,0 to 19,0	≤7	Warm to hot	T.S.	631	
11	"	4	Wartburg		8,6 to 15,4	12,3 to 16,3	≤7	Cool to warm	R.A.S.	310	1081
12	"		Inadi		16,5 to 29,3	18,4 to 24,4	≤7	Cold	T.S.	683	
13	"	2	Eston		12,3 to 21,7	17,7 to 21,4	12	Warm to hot	R.A.S.	513	2177
14	"	8	Eston		9,2 to 19,4	14,0 to 22,9	13	Cold	R.A.S.	508	1972
15	"	6	Otto's Bluff		13,7 to 24,0	18,5 to 27,0	0 to 15	Warm to hot	R.A.S.	354	1993
16	"	4	Upper Umvoti		9,3 to 21,9	12,6 to 29,8	≤10	Warm to hot	R.A.S.	419	1656
17	"	6	Upper Umvoti		11,1 to 29,8	14,5 to 19,0	≤7	Warm to hot	R.A.S.	298	1652
18	Chainsaw felling & crosscutting		Karkloof		14,0 to 23,7	19,9 to 27,3	≤7	Warm to hot	T.S.	467	
19	"		Wartburg		7,4 to 20,3	11,0 to 18,0	≤5	Warm to hot	T.S.	112	
20	"		Upper Umvoti		8,8 to 23,0	17,4 to 22,3	≤7	Warm to hot	T.S.	592	
21	Chainsaw following bench system		New Hanover		5,7 to 26,9	8,1 to 20,4	≤5	Warm to hot	T.S.	612	
22	"		Sevenoaks		12,8 to 25,5	19,0 to 25,6	5 to 17	Warm to hot	T.S.	147	
23	"		Dalton		8,3 to 19,0	11,0 to 17,8	13 to 18	Warm to hot	T.S.	368	
24	"		Kranskop		8,4 to 24,6	13,5 to 22,5	≤5	Cool	T.S.	347	
25	Chainsaw using semi-bench system		Wartburg		7,2 to 29,9	11,2 to 23,3	≤9	Warm to hot	T.S.	318	

Notes: [1] R.A.S. is an abbreviation of rated activity sampling
[2] Pole diameter range is the mid-point pole diameter
[3] Ambient day temperatures are expressed arbitrarily and relate to degrees celsius as follows:

very cold => -2 to < 5°C
cold => 5 to <10°C
cool => 10 to <20°C
warm => 20 to <30°C
hot => 30 to <35°C
very hot => ≥35°C

[4] T.S. is an abbreviation of time study

of circumstances of all major wattle studies undertaken and their type and duration. Climatic conditions, altitude and soil types are the principal factors determining tree height, breast height diameters to height ratios and bark thickness (Sherry, 1971). As the Institute for Commercial Forestry Research (Wattle Research Institute) is in Pietermaritzburg, studies have been undertaken principally within a 100 kilometre radius of the city in order to reduce high costs and maximum work output. To compensate for this, areas for studies have been selected to obtain a wide distribution of environmental conditions, tree sizes and characteristics. By employing study layouts and types described in Chapter 4 and applying appropriate analyses, daily tasks and systems developed are applicable throughout the southern African wattle belt.

Column 8 of Table 5.1 shows the terrain slope in degrees in the study plots which indicate that currently most wattle is grown on moderate slopes of up to seven degrees. Influences of slopes on chainsaw felling are discussed in Sections 5.4.4.2 and 5.5.1.

Indication of ambient day temperatures are shown in Column 9 of the table in broad terms as wind-chill has not been measured (Lanthorp, 1968). These are simply to indicate the temperature ranges over which studies have been undertaken. Results have shown no evidence that day temperature influence the work rate.

Maximum time duration of a study is determined by the amount of work the person or persons being studied can produce in one day and, with activity sampling, the number of workers the writer could record per minute.

5.3.2 *Analysis of Bowsaw Felling and Crosscutting*

Two-man bowsaw felling and crosscutting data from the studies listed in Table 5.1 were analysed. Means and standard deviations and sample size of dependent and relevant independent variables are given in Table 5.2.

Standard minutes for two labourers working as one for the felling activity (Section 4.3.1.2) were regressed on tree diameter at breast height and total tree height. t Values of partial regression coefficients were highly significant for diameter, but not significant for height.

Standard minutes for crosscutting stems to shortwood poles with two labourers working as one were regressed on underbark mid-point diameter only. Highly significant t values were obtained.

However, in both analyses when untransformed values of variables were used in regression equations, distributions of error residuals as a probit plotted against variables were 'U' shaped and expanded to the right as shown in Figure 2, Appendix F. These patterns indicate that transformation of dependent variables was required (Draper & Smith, 1981, p. 147). Natural logarithmic transformations gave a satisfactory random (homoscedastic) distribution (Draper & Smith, 1981, p. 145; Gujarati, 1978, p. 201).

An increase in t values and obviously, coefficients of determination was also obtained with a natural logarithmic transformation of independent variables. Details of the regression models for felling and crosscutting are given in Table 5.3.

TABLE 5.2

Means and standard deviations of standard minutes for bowsaw operations and bark and timber preparation from studies in wattle and the relevant dimensions of trees or poles processed during these studies

Activity	Standard minutes		Breast height diameter		Height		Underbark mid-point pole diameter		Sample size
	Mean	SD	Mean (cm)	SD (cm)	Mean (m)	SD (m)	Mean (cm)	SD (cm)	
Bowsaw fell	2,055	0,124	15,09	2,80					45
Bowsaw crosscut	0,488	0,204					10,90	3,46	60
Debranch and stack brush	9,459	2,862	16,41	2,87					34
Debark	11,394	3,247	16,57	3,03	18,69	3,53			29
Bundle bark	8,881	3,135	16,35	2,98	18,32	3,49			30

Table 5.3

Regression models relating standard minutes for bowsaw felling and crosscutting of wattle to tree and pole diameter, respectively, for two labourers working as one, and a model relating the number of shortwood poles per tree to tree height

Dependent variable	df	r^2	Constant term	Regression coefficient			Equation number
				Dbh (cm)	d (cm)	Height (m)	
Fell	43	0,6076	- 2,555771 (6,392)	1,207043 (8,160)			5,4
Crosscut	58	0.5103	- 3,479569 (10,346)		1,109722 (7,775)		5.5
Poles per tree	201	0,8826	- 2,142300 (8,075)			0,414428 (26,609)	5.6

Notes: Dbh : tree diameter at breast height
d : mid-point pole diameter
Height : total tree height
Equation 5,14 applies to a tree crosscut to a five centimetre tip and poles 2,27 metres long.

Figures in brackets are t values of regression constants and coefficients.

Equation models :

Equation numbers 5.4 and 5.5: $\ln Y = \beta_o + \beta_1 \ln X_1 + \varepsilon$

5.6: $Y = \beta_o + \beta_1 + \varepsilon$

Mean standard minutes for semi-variable activities for felling and crosscutting with two labourers working as one vary considerably as shown below by the relative size of standard deviations. This is intrinsic to the nature of work and not worker inefficiency. 'Sundry delays' listed relate to the number of trees felled and, with this operation, is not a fixed activity. Standard minutes for semi-variable activities that occurred while felling are as follows :

Semi-variable activity	No. of observations	Standard minutes
Prepare to fell	40	0,24 (SD 0,21)
Walk between fellings	43	0,19 (SD 0,70)
Sundry delays	11	0,03 (SD 0,14)
Total		0,47 .... 5.7

The only fixed activity encountered is setting the teeth of the bowsaw blade which is in common to felling and crosscutting and should be undertaken daily (de Laborde, 1980, p. 2.5). This activity takes 2.5 standard minutes, but is usually undertaken by the supervisor and does not affect the labourer, so it is ignored.

Standard minutes for semi-variable activities that occur while crosscutting are as follows :

Semi-variable activity	No. of observations	Standard minutes
Measure and reposition	60	0,31 (SD 0,09)
Move log	27	0,06 (SD 0,20)
Clear, delays, unjam saw	10	0,05 (SD 0,13)
Total		0,42 .... 5.8

Felling is frequently undertaken by the labourers preparing bark (Section 4.3.1.2). On account of complexities of balancing and synchronisation described in Sections 5.3.6.1 and 5.3.6.2, this job allocation is distinctly preferable to having an independent felling team.

Variable and semi-variable activities for crosscutting are quoted per pole. As all work data must refer to the mean tree, it is necessary to develop an equation that relates to mid-point diameters of poles crosscut to the range of possible tree sizes. Variables that require specification are the length of crosscut poles, tree diameter at breast height, diameter at which tree is topped and stem length and taper. The calculation is complicated further where the mean of the expected number of poles per tree is a real number, for example, 5,63 poles per tree. This was overcome by calculating standard minutes for the integer number of poles, *viz*, 5, then calculating standard minutes for a sixth thinner pole and proportioning this result by the decimal component, 0,63. The two results are then added.

Total standard minutes (TSM) to crosscut a tree stem for the integer of poles, k. are

$$TSM = (VA_{d_1} + SA) + (VA_{d_2} + SA) \; ..... \; (VA_{d_k} + SA)$$

$$TSM = \sum_{n=1}^{k} (VA_{d_n}) + k(SA)$$

If the extra pole is k + 1 and the decimal component DC, then TSM is as follows :

$$TSM = (\sum_{n=1}^{k} (VA_{d_n}) + k(SA) + DC(VA_{d_{k+1}} + SA) \; .... \; 5.9$$

where d = mid-point pole diameter underbark for the given pole length

VA_{d_n} = Standard minutes of variable activities calculated from Equation 5.5

SA = semi-variable activity given for Equation Total 5.8, *viz*, 0,42 standard minutes

The following simplified numerical example demonstrates the above equation. Assume that there is a mean of 2,75 poles per tree and mid-point diameters for the first to third poles, if the latter were made, are 10, 7 and 3 centimetres respectively. The total standard minutes are calculated from Equation 5,9 as follows :

k = 2 poles and the decimal component (DC) = 0,75 poles

$$TSM = (VA_{d_1} + VA_{d_2}) + 2SA + DC(VA_{d_3} + SA)$$

$$TSM = (0,40 + 0,27) + 2 \times 0,42 + 0,75(0,10 + 0,42)$$

TSM = 1,90 standard minutes with two labourers working as one.

Mid-point diameters (d_1 to d_k) have to be determined. Where mean values of the basal and tip diameters of the underbark stem, and stem length or taper are to hand, values of d at the various cross-cut points are readily ascertainable. If not quoted, the centimetre taper per metre, T, is calculated. The diameters are proportioned for the given pole lengths. Thus,

$$\left.\begin{aligned} d_1 &= B - (T \times PL/2) \\ d_2 &= B - (T \times PL/2) + (T \times PL) \\ \text{and} \quad d_k &= B - [(T \times PL/2) + (T \times PL(k-1))] \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ 5.10$$

for underbark basal diameter B of the stem as calculated below and pole length PL.

Unfortunately, normally only the intended pole length and overbark tree diameter at breast height (D), total tree height (H) and bark thickness (BT) are available. By using Equation 5.13, the number of poles per tree (PT) can be calculated. Tree height minus the product of poles per tree and intended pole length give the tree length discarded through topping. The centimetre taper per metre (T) may be estimated as follows :

$$T = (S - 2BT - 5)/(H - (1,3 + (H - PT \times PL))) \quad \text{.......... 5.11}$$

$$B = D - 2BT + 1,3T \quad \text{.................................... 5.12}$$

The 1,3 is the height in metres at which D is measured. Calculated in this manner, B ignores any basal flare which is correct for this situation.

Unpublished information provided by Schönau gave the number of 2,44 metre poles and mid-point pole diameters for various tree diameters at breast height classes. These data are recorded in Table 5.4.

To provide an alternative, all 2,27 metre poles crosscut during bowsaw and chainsaw studies in wattle were regressed on total tree height. The sample excluded broken and dead trees and included means where groups of stems were cut together. The untransformed values of variables gave the highest t value of the regression coefficient and highest coefficient of determination. Details of the regression model (Equation 5.6) are given in Table 5.3. The equation is modified as follows to accommodate calculating the number of poles per tree (PPT) for any pole length (P) and total tree height (H) :

$$PT = (0,414428H - 2,1423)2,27/PL \quad \text{...................... 5.13}$$

TABLE 5.4

Number of wattle shortwood poles and pole sizes for trees of various breast-height diameter classes

DBH (cm)	Mid-point diameters of poles (cm)						
	Pole 1	Pole 2	Pole 3	Pole 4	Pole 5	Pole 6	Pole 7
9	8,33	7,50	6,63				
10	9,28	8,37	7,45	6,38	5,48		
11	10,24	9,24	8,27	7,17	6,23		
12	11,20	10,11	9,10	7,97	6,99	6,06	
13	12,16	10,98	9,92	8,77	7,74	6,69	
14	13,12	11,85	10,75	9,57	8,50	7,32	6,14
15	14,08	12,72	11,57	10,36	9,25	7,94	6,53
16	15,04	13,59	12,39	11,16	10,00	8,57	6,92
17	16,00	14,46	13,22	11,96	10,76	9,20	7,31
18	16,96	15,33	14,04	12,76	11,51	9,83	7,69
19	17,91	16,20	14,86	13,56	12,27	10,45	8,08
20	18,87	17,02	15,69	14,35	13,02	11,08	8,47
21	19,83	17,94	16,51	15,15	13,77	11,71	8,86
22	20,79	18,81	17,33	15,95	14,53	12,34	9,24

5.3.3 *Analysis of Bark and Pole Preparation by Labourers*

Labourers' variable activities in preparing bark and poles includes debranching and stacking the brush in brush lines, debarking, bundling and stacking bark and possibly swinging, bunching or stacking the poles. The distances bark bundles are carried for stacking vary considerably. Determinants include whether the transport vehicle passes infield or, if not, distances to the nearest plantation road and particular route labourers may take around brush lines and obstacles to reach the road. With distances varying at this unpredictable level, the activity is omitted. Where distance is determinable, work values for manual pole extracting in Section 5.6 will apply. Details of studies, means, standard deviations and sample sizes are given in Tables 5.1 and 5.2, respectively.

Standard minutes for the 'debranch and stack brush', 'debark' and 'bundle bark' activities were regressed on tree diameter at breast height and total height. t Values of partial regression coefficients were highly significant for diameter, but were significant for height for the last two activities only.

With the first activity the distribution of error residuals plotted against the variables was 'U' shaped and expanded to the right indicating that a transformation of the dependent variable was required. The natural logarithmic transformation gave a satisfactory distribution and it was found that a natural logarithmic transformation of the independent variable increased the t value of its regression coefficient.

The untransformed values of the independent variables of the 'debark' activity gave the highest t values and coefficient of determination. However, transformations of the independent variables of the 'bundle bark' activity increased the t values and coefficients of determination.

Details of the three regression models are given in Table 5.5

No semi-variable or fixed activities have been encountered. Hatchet sharpening is normally undertaken by the supervisor. Positioning of poles after debarking is discussed in Section 5.3.7.

5.3.4 *Chainsaw Felling and Crosscutting by the Conventional System*

Means and standard deviations for dependent and relevant independent variables identified for chainsaw felling and crosscutting are given in Table 5.6 for studies listed in Table 5.1

Standard minutes for felling were regressed on tree diameter at breast height and total height. t Values of partial regression coefficients of both independent variables were highly significant. However, the distribution of error residuals plotted against the variables expanded strongly to the right indicating that a transformation of the dependent variable was required (Draper & Smith, p. 147). Natural logarithmic transformations gave satisfactory distributions. Similar analyses were conducted on diameter and height. In both cases t values of coefficients increased marginally with a corresponding increase in coefficients of determination.

Standard minutes for crosscutting were regressed on the same variables as used for felling. Satisfactory distributions of error residuals plotted against the variables were obtained. Although

Table 5.5

Regression models relating standard minutes for manual timber and bark preparation in wattle to various tree dimensions

Dependent variable	df	R^2	R_A^2	Constant term	Regression coefficients		Equation number
					Dbh (cm)	Height (m)	
Debranch and stackbrush	32	0,6477		- 1,907036 (3,514)	1,484862 (7,670)		5,14
Debark	26	0,7996	0,7842	- 4,842623 (2,990)	0,542815 (2,961)	0,387563 (2,469)	5.15
Bundle bark	27	0,7582	0,7402	-34,06385 (7,250)	9,111869 (3,173)	6,014542 (2,133)	5,16

Figures in brackets are t values of regression constants and coefficients.

Regression models are as follows:

Equation numbers : 5.14: $\ln Y = \beta_0 + \beta_1 \ln X + \varepsilon$

5.15: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$

5.16: $Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \varepsilon$

Table 5.6

Means and standard deviations of standard minutes for chainsaw work studied in operations in wattle and relevant dimensions of trees processed during these studies

Activity description and standard minutes per tree			Independent variables				Sample size
			Dbh		Height		
Description	Standard minutes Mean	Standard minutes S D	Mean (cm)	SD (cm)	Mean (m)	SD (m)	
Conventional system:							
fell	0,381	0,206	14,57	4,03	17,89	3,83	314
crosscut	0,437	0,205	12,32	2,87	15,27	2,27	126
Bench system:							
fell	0,396	0,120	15,66	3,85			52
butt cut	0,246	0,099	15,71	4,17			51
measure and debranch	1,759	0,794	12,73	2,60	15,09	1,72	114
stack brush	1,323	1,042	14,24	4,41			143
crosscut	0,711	0,232	14,24	4,41			46

transformations were tested the untransformed values gave the highest t values of partial regression coefficients of diameter and height and coefficients of determination. Details of the regression models are given in Table 5.7.

Walking between trees to fell or crosscut is the only semi-variable activity recorded. This is an area in which most growers are at fault. Because of poor worksite layout, times were unacceptably high in all studies taken. Consequently, it was necessary to compile distances and develop standard times from these.

Tree rows are most commonly spaced 2,74 metres apart. To allow for a four-tree-row safety strip every four tree rows, a 5,48 metre espacement is assumed. The chainsawyer fells by working across the face and then returns to the starting point to commence crosscutting. Thus the distance should be doubled. Allowing for a rest factor of 1,15 (Appendix A) and a walking speed of 3,2 kilometres per hour, the standard minutes for the 'walk during felling' activity per tree (WF) for slopes below 10 degrees is

$$WF = \frac{60 \times 5{,}48 \times 2 \times 1{,}15}{3\ 200} = 0{,}24 \text{ standard minutes per tree}$$

With walking during crosscutting, the distance walked from the last crosscut on a stem to the first cut of the next stem on average will be the hypotenuse of a triangle, the other two sides of which are the length of stem crosscut and the distance between rows. Calculating from a liberal six 2,44 metre-long poles per tree and allowing a metre of additional walking the length of the one side is $6 \times 2{,}44 + 1 = 15{,}6$ metres. Assuming an espacement of 2,74 metres the distance walked is $\sqrt{15{,}6^2 + 2{,}74^2} = 15{,}8$ metres. The last

Table 5.7

Regression models relating standard minutes for chainsawyer operations when using the conventional system in wattle to various tree dimensions

Dependent variable	df	R^2	R^2_A	Constant term	Regression coefficients		Equation number
					Dbh (cm)	Height (cm)	
Fell	311	0,7768	0,7754	- 6,624437 (31,157)	1,060162 (8,601)	0,946783 (5,993)	5.17
Crosscut	123	0,6472	0,6415	- 0,478944 (6,385)	0,039403 (7,289)	0,028184 (4,116)	5,18

Figures in brackets are t values of regression constants and coefficients.

Regression models are as follows :

Equation numbers: 5.17: $\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \varepsilon$

5.18: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$

column of Table 5,7 shows that of 314 trees felled, there were only 126 crosscuttings, because two stems are frequently crosscut together. To increase the leniency further, the ratio is increased by 50 per cent. Thus the distance walked per tree while crosscutting is 15,8 x 126/314 x 1,5 = 9,51 metres. Walking speed and the rest factor are the same as for felling and the standard minutes for 'walk during crosscutting' (WX) for slopes below 10 degrees is

$$WX = \frac{60(9,51 + 2,74 \times 2)}{3\ 200} \times 1,15 = 0,32 \text{ standard minutes per tree}$$

Therefore, the total standard minutes for walking during felling and crosscutting (WFX) on slopes below 10 degrees is

$$WFX = 0,24 + 0,32 = 0,54 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 5.19$$

On slopes of 10 degrees or more walking times should be increased and allowances are discussed in Section 5.4.4.2.

Times for fixed activities also have had to be developed. Most chainsaws require refuelling every 31 to 35 minutes rounding this off to 30 minutes and calculating on the 360 minute day, there are 360/30 = 12 refuellings. Each refuelling takes 2,37 (SD 0,57) standard minutes which is rounded off to 2,50 standard minutes.

The 'tend chainsaw' activity is particularly variable. By discarding studies where the chainsawyer needlessly made numerous adjustments, resharpened the cutting chain too frequently, or where there was a definite lack of attention, this activity was found to take

2,43 (SD 1,43) standard minutes per 1,5 hours. This is rounded off to 2,50 minutes per 1,5 hours which for the 360 minute day is 2,50 x 360/90 = 10 standard minutes.

Sundry delays are the remaining fixed activities. These include releasing trees which lodge in another while being felled, giving or receiving instructions and miscellaneous small and unavoidable delays. Standard minutes here vary considerably and often reflect individual efficiency. Where, as stipulated for this system, the chainsawyer is supplied with an assistant who is equipped with a steel-pronged stick to guide the direction of felling, tree lodging, the major delay, is virtually eliminated. An arbitrary five minutes, assessed from the scrutiny of all chainsaw studies, was taken. Fixed activities are as follows :

Fixed activity	Standard minutes	
Refuel	30	
Tend chainsaw	10	
Sundry delays	5	
Total	45	.... 5.20

5.3.5 *Chainsaw Activities Using the Bench System*

Table 5.6 gives means and standard deviations for dependent and relevant independent variables analysed from studies of the bench system listed in Table 5.1. The five chainsawyer activities in sequence include 'fell'; 'butt cut', *viz* square off the tree's base; 'measure and debranch'; 'stack brush' and 'crosscut'. As chainsawyers work alone in this system, felling time per tree is higher and varies more where slopes are five degrees or less or where trees are felled on the contour as directing the tree's fall is more difficult.

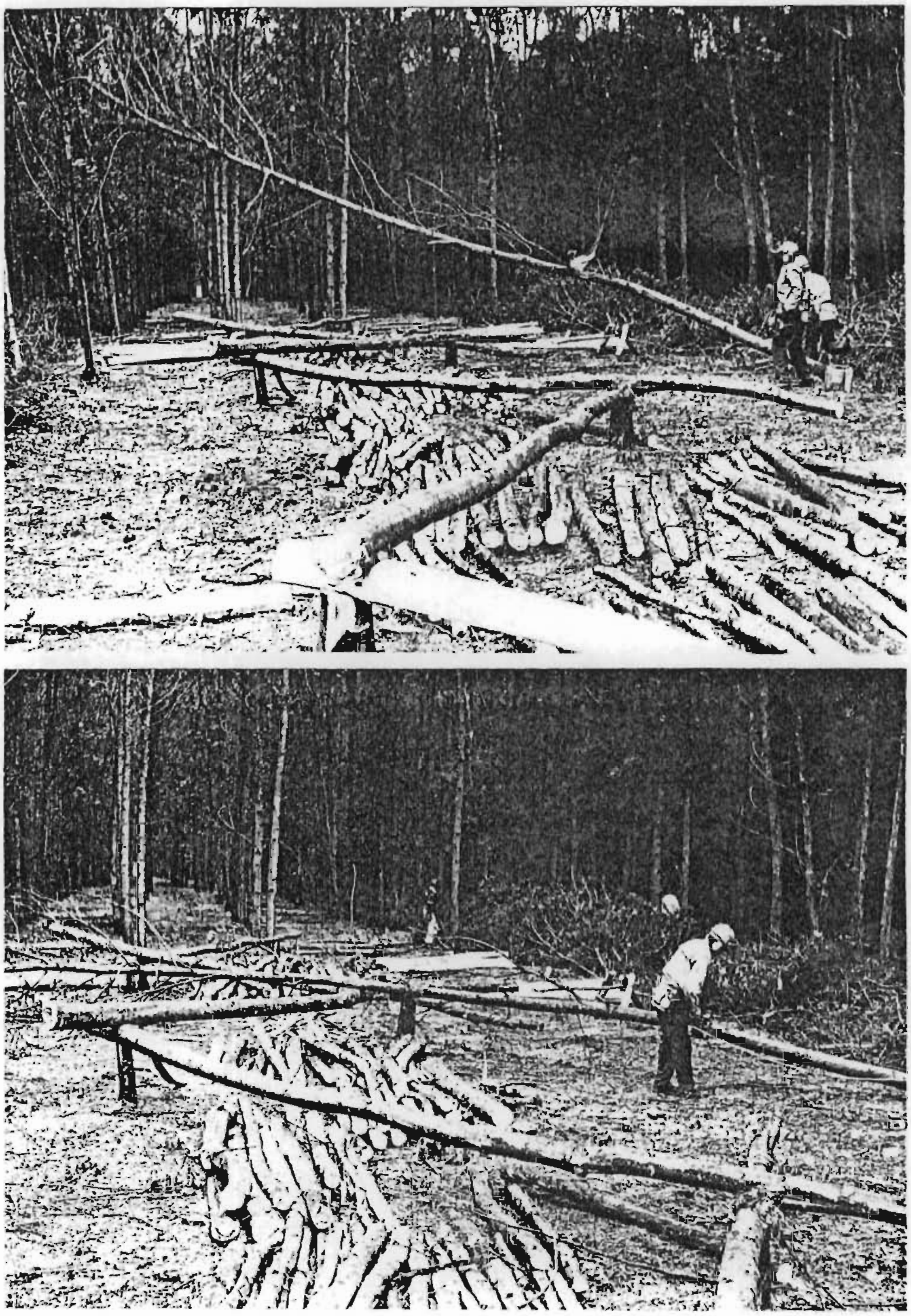
Standard minutes for each activity were regressed on tree diameter at breast height and total height. t Values of the regression coefficients of diameter were significant in all analyses, but height was significant with the 'measure and debranch' activity only. Transformations of height did not improve the model.

Error residuals plotted against the variables were satisfactory for times for the measure and debranch and crosscut activities. However, for felling on slopes greater and less than five degrees, butt cutting and stacking brush the distribution of error residuals expanded to the right. In each case a satisfactory distribution was obtained with a logarithmic transformation of the dependent variables. This model gave the highest t values of regression coefficients for felling on slopes of five degrees or less and for stacking brush. However, with felling on slopes over five degrees and butt cutting, natural logarithmic transformations of independent variables improved the t value of regression coefficients.

Details of regression equations for these activities are given in Table 5.8. The t value of the regression coefficient for stack brush has a relatively low significance. This is because with the bench system chainsawyers normally work a swathe five tree rows wide with brush lines formed on either side. When trees are felled in rows adjacent to brush lines and are positioned on the line there is little or no stacking. For inner rows there is a varying extent of stacking.

Where slopes are 10 degrees or more allowance should be made to the 'fell', 'measure and debranch', 'stack brush' and 'crosscut' activities as they include walking on a slope carrying a load. Such allowances are discussed in Section 5.4.4.2.

FIGURE 5.3



A correctly equipped chainsawyer uses the bench felling system in wattle.

Above: A tree is falling and the chainsawyer moves aside.

Below: Using the bench, the chainsawyer marks the tree's stem for cross-cutting, the measuring tape attached to his belt is visible.

The benches shown above are no longer used (Section 4.3.3.2).

Table 5.8

Regression models relating standard minutes for chain sawyer activities when using the bench system in wattle to various tree dimensions

Dependent variable	df	R^2	R_A^2	Constant term	Regression coefficient		Equation number
					Dbh (cm)	Height (m)	
Fell (slope 5°)	72	0,5551	0,5489	- 1,913075 (13,904)	0,077613 (9,478)		5.21
Fell (slope 5°)	50	0,5781		- 3,650906 (11,272)	0,985945 (8,277)		5.22
Butt cut	49	0,7235		- 5,225413 (15,842)	1,367306 (11,323)		5.23
Measure and debranch	116	0,5511	0,5433	- 2,151822 (5,063)	0,188203 (5,983)	0,100800 2,883	5.24
Stack brush	140	0,0380 (P < 0,05)		- 1,116441 (2,830) (P<0,01)	0,062304 (2,353) (P<0,02)		5.25
Crosscut	43	0,5416		- 1,211166 (4,426)	0,722006 (7,210)		5.26

Figures in brackets are t values of regression constants and coefficients.
Regression models are as follows :

Equation numbers : 5.21 and 5.25 : $\ln Y = \beta + \beta_o + \beta_1 + \varepsilon$
5.22 and 5.23 : $\ln Y = \beta_o + \beta_1 \ln X + \varepsilon$
5.24 : $Y = \beta_o + \beta_1 X_1{}^1 + \beta_2 X_2 + \varepsilon$
5.26 : $Y = \beta_o + \beta_1 \ln X_1 + \varepsilon$

Standard minutes for semi-variable and fixed activities vary considerably as shown by relatively high standard deviations. This is caused by worker techniques and not the omission of an independent variable. Slope influences some activities as indicated below. Undergrowth also is expected to have influence. However, this is normally suppressed in wattle growing areas by the closure of the forest canopy and no instance of dense undergrowth of sufficient frequency to study has been encountered.

Standard minutes for these activities are available directly from studies on this system because chainsawyers studied who follow the bench system receive concentrated training and work systematically. Further, only efficient chainsawyers were studied (Section 4.8.4). As operations with bench system differ considerably from the conventional system, their semi-variable and fixed activities bear no relationship. Semi-variable and fixed activities means are as follows :

Semi-variable activity	No. of observations	Standard minutes
Plan, prepare to fell and discuss	314	0,06 (SD 0,02)
Walk between fellings	313	0,15 (SD 0,04)
Total		0,21 ..... 5.27

The 'walk between fellings' activity should be corrected where slopes are 10 degrees or more as discussed in Section 5.4.4.2.

Fixed Activities	No. of observations	Standard minutes
Refuel and tend chainsaw	32	14,65 (SD 5,13)
Sundry delays	11	4,74 (SD 2,15)
Total		19,39
Total (rounded off)		20,0 .... 5.28

5.3.6 *Optimising the Conventional System*

There are three fundamental factors affecting production efficiency of a primary conversion system: balancing the categories of workers, work site layout and synchronisation of operations. These criteria are interrelated. Chainsawyer efficiency is maximised by compacting the worksite layout thus minimising walking distances and bringing the fuel close at all times. To minimise delays mainly to the labourers, operations require synchronisation.

5.3.6.1 *Balancing the Categories of Workers*

Appendix B shows that for a common tree size of 15 centimetres in diameter at breast height and 19 metres high, a labourer's and chainswyer's normal daily tasks are 13 and 200 trees, respectively. Therefore, 200/13 = 15 labourers will accompany each chainsawyer whose actual daily task and team daily output will be 15 x 13 = 195 trees.

It has been a frequent practice to attempt specialisation of labourers' work. Here one group of labourers de-branch trees and stack the brush, a second group debarks and possibly bunches poles and a third group bundles and stacks bark. The impracticabilities of this grouping have been discussed in detail (de Laborde, 1980, p. 7.6).

There are two basic objections. Firstly, balancing the system is virtually impossible as a ratio of each group to the others with all labourers producing a normal daily output will only occur by exceptional coincidence. Consequently, workers will be compelled to work above or below their normal daily level and lack incentive. Secondly, should one worker be absent or below standard, all those following are affected.

Beach (1970) described how over specialisation in the 1950's reduced productivity through worker boredom. Job enlargement, the opposite of specialisation, counteracted the problem. Infield observations by the writer show that a specialised system creates this boredom for labourers and distinct frustration if prevented from exceeding the prescribed output and earning higher wages.

5.3.6.2 *Worksite Layout*

Should all labourers work in a single tree row with an average tree espacement of 2,44 metres with the example quoted in the preceding section, the worksite will be 195 x 2,44 = 476 metres long.

It is necessary for the chainsawyer to fell and crosscut these trees in a number of cycles (Section 5.3.6.3). Thus, he will have to walk 476 x 2 = 952 metres, a possible 12 cycles of felling then returning to crosscut giving 952 x 12/1000 = 11,5 kilometres per day with additional walking to refuel.

Worksite area is reduced by having labourers work abreast. By each labourer working two tree rows, presentation of felled trees is more dispersed which facilitates debranching and debarking. Tree rows are normally 2,74 metres apart, thus the worksite will be 2,74 x 2 x 15 = 82,2 metres wide and 2,44 x 7 = 17,1 metres deep. Here the straight distance walked with six cycles of felling and crosscutting will be 82,2 x 12 = 986 metres which is 0,986/11,5 = 0,085 the distance of the former layout.

Using the above layout, safety rows are usually established every four tree rows, *viz* after each pair of labourers, and are four tree rows wide. While safety is a major consideration, it is often possible to dispense with the safety rows if the chain-sawyer has an assistant supplied with a steel-pronged pushing stick to direct the fall of the tree and where trees are not particularly tall and do not have an excessive adverse lean. Should there be any concern, safety rows should be included, thereby doubling the above distance.

With the compact layout, supervision is considerably easier. Where a worker exceeds the normal daily task regularly, he should change positions with slower workers every few days to retain a straight front to the layout.

5.3.6.3 *Synchronisation of Operations*

Chainsawyers prefer to complete all felling then return and crosscut. While this reduces the chainsawyer' work, labourers are presented with a dense network of branches which impedes debranching.

Debarking is also complicated. Where stems are heavy to move, only accessible portions can be debarked. Returning to debark after crosscutting results in virtual duplicating of work. Normally, and acceptably, labourers do not debark until after cross-cutting which often results in several hours delay per day, as is demonstrated below.

Synchronisation has been discussed in detail (de Laborde, 1980, p. 7.9). In that discussion, the first example of operating sychronisation analysis was of trees with a diameter at breast height of 15 centimetres. The normal daily task was 12 trees for each of 12 labourers in the team. The chainsawyer felled three trees for each labourer then returned to commence crosscutting.

In this case, on each cycle, the first labourer finishes debranching as the chainsawyer returns to crosscut. No delays are incurred throughout the day. However, the twelfth labourer incurs a 22,51 standard minute delay on the first cycle of crosscutting while waiting for the chainsawyer's return and then incurs a 9,06 standard minute delay on each of the three subsequent cycles. The total delay is 49,69 standard minutes.

When the chainsawyer is reduced to two trees worked per labourer per cycle, the first labourer again neither experiences nor causes any delays. The twelfth labourer experiences a 2,08 standard minute delay on the first cycle and a 6,04 standard minute delay on the following five cycles. The total delay is 32,38 standard minutes. Similar results are obtained for larger tree sizes.

At the extreme level of felling all trees before returning to crosscut, the situation is calculated from data provided in Tables 7.2 and 7.3 of the last reference above. The last labourer in the chainsawyer's work cycle would work initially for 38,78 standard minutes, but her trees would only be felled after 117,00 standard minutes resulting in a 117,00 - 38,78 = 78,22 standard minute delay plus a 9,72 standard minute delay while her trees are being felled. It takes a further 234,44 standard minutes before the chainsawyer return for crosscutting during which time the labourer has 104,20 standard minutes work debranching and stacking brush. A further

232,44 - 104,20 = 128,16 standard minute delay is enforced. Summing the delays, the total is 216,10 standard minutes.

Examples given above demonstrate that delays caused by the chainsawyer, particularly to the last labourer, are minimised by felling fewer trees. As it usually would be unacceptable to chainsawyers to fell one tree per labourer per felling and cross-cutting cycle, it is advisable for them to work two trees.

5.3.7 *Optimising the Bench System*

Primary conversion using the bench system reduces job allocation for labourers. Chainsawyer activities are detailed in Section 5.3.5. The remaining activities include debarking the poles, bundling and stacking the bark and positioning the poles for removal. The latter activity may require that poles be cleared from the centre of the swathe to permit the passage of a primary timber mover. Poles are bunched with or without being sorted into categories, or stacked with or without sorting. For the reasons given in Section 5.4.6.1 five tree rows between brush lines is normally preferred and is the most popular in practice.

Clearing the centre of the swathe requires a negligible effort as the poles are merely dropped or pushed aside after debarking. Bunching and stacking are a distinct activity and mean times and regression equations to calculate standard minutes are provided in Section 5.6

Balancing of the number of labourers and avoiding specialisation is undertaken similarly to the description in Section 5.3.6.1 only that the calculation is taken to the nearest half labourer. A frequent ratio is five labourers between two chainsawyers.

Chainsawyers using the bench system often exceed the normal daily task rate on account of being carefully selected and trained. Labourers may not be so highly motivated and only work at the normal rate. In balancing teams cognizance must be taken of this.

5.3.8 *Optimising the Semi-bench Systems*

Two variations of the possible semi-bench systems have been noted. Only from cost analysis can the marginal benefits or costs of alternatives be assessed. With the first variation of the system, the chainsawyer has an assistant who may assist with directional felling and stacks brush as the chainsawyer debranches, otherwise the system is similar to the bench system. Secondly, the labourer whose trees are being cut assists the chainsawyer. The chainsawyer fells a number of trees for each labourer, returns, debranches then returns again and crosscuts. Between debranching and crosscutting, the labourers stack brush then measure for the chainsawyer during cross-cutting. After crosscutting labourers have the same activities as described for the bench system.

In semi-bench systems, categories of workers should be balanced in the manner described in Section 5.3.6.1. With the second semi-bench system, note also must be taken of the worksite layout and the synchronisation of operations as described in Sections 5.3.6.2 and 5.3.6.3.

5.4 PRIMARY CONVERSION OF *EUCALYPTUS GRANDIS*

5.4.1 *Description of Field Studies*

Table 5.9 supplies details of the circumstance of all major *E.grandis* studies undertaken with their type and duration.

TABLE 5.9

Circumstance of *E. grandis* field studies, their type and duration for primary conversion.

Study No.	Subject	No. of workers in RAS[1]	Area	Pole diameter range[2] (cm)	Tree dbh range (cm)	Tree height range (m)	Slope (degrees)	Ambient day temperatures[3]	Type of study	Duration of study (min)	No. of readings RAS[1] only
1	Bowsaw felling		Wartburg		10,2 to 32,6		0	Cool	T.S.[4]	245	
2	"				6,8 to 24,4		5 to 7	Cool	T.S.	131	
3	"				22,2 to 35,7	25,6 to 36,1	26	Cool	T.S.	209	
4	"				22,2 to 35,7	26,0 to 34,6	25 to 26	Cool	T.S.	149	
5	Bowsaw crosscutting		Richmond	6,1 to 30,7			0 to 7	Cool to warm	T.S.	181	
6	Labourers preparing poles	4	Richmond		6,3 to 29,3	11,0 to 31,0	7	Cool	R.A.S.	421	1563
7	"	11[5]	Highflats		7,2 to 22,0	12,5 to 22,0	0 to 5	Cool	R.A.S.	142	1323
8	"	1	KwaMbo-nambi		11,7 to 24,1	13,0 to 26,5	0	Cool	R.A.S.	312	1498
9	"	4	KwaMbo-nambi		13,2 to 24,3	16,0 to 25,0	0	Cool	R.A.S.	473	2154
10		6[6]	kwaMbo-nambi		12,0 to 31,3	16,5 to 26,5	0	Cool	R.A.S.	476	1175
11	"	6[6]	Wartburg		11,9 to 27,1	19,5 to 30,0	0 to 51	Cool	R.A.S.	416	2094
12	Chainsaw felling & crosscutting		Richmond		7,3 to 30,2		7 to 10	Cool	T.S.	341	
13	"		Hella Hella		7,3 to 37,7	13,0 to 38,0	0 to 5	Cool	T.S.	317	
14	"		Mid Illovo		6,3 to 22,5	12,0 to 29,0	8 to 29	Warm to v.hot	T.S.	375	
15	"		Wartburg		10,1 to 32,2	17,0 to 32,0	7 to 33	Cool	T.S.	225	
16	"		Highflats		7,2 to 22,0	12,5 to 22,0	0 to 5	Cool	T.S.	54	
17	Chainsaw following bench system		Richmond		6,6 to 23,5	11,0 to 25,6	0	Warm to hot	T.S.	386	
18	Labourer's following bench system	4	Richmond	7,0 to 21,5	6,6 to 23,5	11,0 to 25,6	0	Cool	R.A.S.	413	1466

Notes: [1] R.A.S. is an abbreviation for rated activity sample
[2] Pole diameter range is the pole diameter at the point of crosscutting
[3] Definitions of arbitrary temperatures are given in Note 3 to Table 5.1
[4] T.S. is an abbreviation for time study
[5] There were effectively 8,5 labourers performing the listed operations, 1,5 labourers as tally clerks and 1 chainsawyer
[6] There were 5 labourers and 1 chainsawyer

Analyses of later studies on bowsaw and chainsaw felling revealed that height had no significant influence on this activity. Thus early studies omitting this dimension could be included.

It was apparent from preliminary observations that the ease with which the bark could be removed, strippability, was the prime independent variable influencing labourers' daily output. Consequently, study areas and the time of year of the studies were selected to obtain the necessary data. The KwaMbonambi studies which were in mid-summer provided the maximum of the strippability scale while winter studies at Wartburg provided the minimum, or worst, strippability.

To obtain a wide variety of tree diameter and height classes and a range of ratios between diameter and height, studies were taken over an altitude range of below 100 metres to 1 220 metres which is the approximately maximum recommended altitude for *E.grandis* (Wattle Research Institute, 1972, p. 6).

For reasons stated in Section 5.3.1, the majority of *E.grandis* studies have been undertaken in the Natal Midlands. However, application of the result of the studies in the Transvaal, Swaziland and Zimbabwe have indicated that the data are reliable for other areas.

Further description of the data in Table 5.9 is similar to that for wattle (Section 5.3.1).

5.4.2 *Analysis of Bowsaw Felling and Crosscutting*

Details of studies undertaken on two-man bowsaw operations are given in Table 5.9. Means and standard deviations of dependent and relevant independent variables are given in Table 5.10.

Table 5.10

Means and standard deviations of standard minutes for bowsaw work studied in operations in *E. grandis* and relevant tree and pole dimensions processed during these studies

Activity	Standard minutes		Dbh		d		Sample size
	Mean	SD	Mean (cm)	SD (cm)	Mean (cm)	SD (cm)	
Fell	2,633	1,986	19,37	7,57			150
Crosscut	0,598	0,384			14,36	5,27	114

Note: d = pole diameter at the crosscutting points.

Standard minutes for felling with two labourers working as one (Section 4.3.1.2) were regressed on tree diameter at breast height and total height. The t value of the regression coefficient of diameter was highly significant, but that of height non-significant.

Standard minutes for crosscutting with two labourers working as one were regressed on pole diameter at the point of crosscutting. The t value of the regression coefficient was highly significant.

In both cases, the distribution of error residuals plotted against the variables were 'U' shaped and expanded to the right (Figure 3, Appendix F). Of the descriptions of transformations given in Section 5.2.1, natural logarithms of both dependent variables gave a satisfactory random distribution of the residuals.

With crosscutting, the natural logarithimic transformation of pole diameter increased the t value of its regression coefficient. Transformations of the independent variable for felling did not improve the model. Details of the regression models are given in Table 5.11.

Semi-variable activities for bowsaw felling as as follows:

Semi-variable activity	No. of observations	Standard minutes
Walk between fellings	86	0,43 (SD 0,24)
Prepare to fell	86	0,10 (SD 0,10)
Total		0,53 .... 5.29

Setting the bowsaw teeth, which takes approximately 2,5 standard minutes, is the only fixed activity. As this is normally performed by the supervisor or manager while labourers are engaged

Table 5.11

Regression models relating standard minutes for bowsaw felling and crosscutting of *E. grandis* to tree and pole diameter, respectively, for two labourers working as one, and a model relating the number of shortwood poles per tree to tree height

Dependent variables	df	r^2	Constant term	Regression coefficients			Equation number
				Dbh (cm)	d (cm)	Height (m)	
Fell	148	0,9142	- 1,183041 (23,699)	0,096892 (39,699)			5.30
Crosscut	112	0,8219	- 4,697538 (25,292)		1,570534 (22,735)		5.31
Poles per tree	111	0,8599	- 1,747162 (5,290)			0,412272 (26,100)	5.32

Figures in brackets are t values of regression constants and coefficients.

Regression models are as follows :

Equation numbers 5.30 : $\ln Y = \beta_o + \beta_1 X_1 + \varepsilon$

5.31 : $\ln Y = \beta_o + \beta_1 \ln X_1 + \varepsilon$

5.32 : $Y = \beta_o + \beta_1 X_1$

d is the pole diameter at the point of crosscutting with their other activities, this is ignored.

Semi-variable activities for bowsaw crosscutting total 0,42 standard minutes as given for the wattle Mean Total 5.8. As with felling, the fixed activity is ignored.

To relate crosscutting to dimensions of a tree, Equation 5.9 is applied. The value of d in the equation is different as the mid-point diameter has been replaced by the diameter at the point of crosscutting. Equation 5.10 is modified to :

$$d_k = B - k(T \times PL) \quad \ldots\ldots \quad 5.33$$

If stem taper (T) and basal diameter (B) are not given for one to k poles per stem, they are calculated using Equations 5.11 and 5.12. PL is the specified pole length.

Frequently the butt of *E.grandis* stems are cut straight or square. For this situation Equation 5.33 requires further modification allowing for a 15 centimetre butt to be removed.

$$\left.\begin{aligned} d_1 &= B - 0{,}015\ T \\ d_k &= B - 0{,}015\ T - kT(PL) \end{aligned}\right\} \quad \ldots\ldots \quad 5.34$$

To provide a guide to the expected number of poles per tree, 2,27 metre poles crosscut during all studies were regressed on total tree height. The sample excluded broken and dead trees and included the mean data where a number of stems were cut together. Untransformed values gave the highest t value of the regression coefficient. Details of the regression model, Equation 5.32, are given in Table 5.11.

The following modification to the equation permits estimating the expected number of poles per tree (PPT) for any pole length (PL) and standing tree height (H) :

$$PPT = (0{,}412272H - 1{,}747162)\ 2{,}27/PL \quad \ldots\ldots\ldots\ldots \quad 5.35$$

When calculating labour requirements, it must be remembered that all the above equations apply to two labourers working as one using bowsaws, thus data must be doubled for calculating labour requirements.

5.4.3 *Analysis of Pole Preparation by Labourers*

Labourers' activities in preparing poles includes 'debranch and stack brush' and 'debark'. Handling of poles by these labourers is similar to wattle as described in Section 5.3.7 with the exception that *E.grandis* is frequently cut to longer lengths than 2,27 or 2,44 metres for shortwood. In this case the labourers usually only bunch or stack the shortwood poles.

With increased rainfall, strippability improves in proportion to increased moisture content of the bark. In order to quantify this major factor affecting labourers' daily output a conductivity meter was designed. The normal moisture meter used for wood is unsuitable due to the far higher water content of the bark. The probes of the meter were five centimetres apart and inserted into the bark until the xylem was reached.

Reasonable reliable results were obtained on one given site, but the electrolytic content of bark varied considerably between districts with changes in dissolvable salts in the soil and individual tree characteristics. These changes were presumed to be responsible for seriously different sets of values being obtained in each district.

As a quick simple technique was being sought to assess strippability, the meter was unsatisfactory and further work was discontinued.

From observations and results of studies the following five strippability classes were identified (de Laborde, 1982a, p. 13) :

"Strippability class	Description
1	Bark has to be chiselled off the poles and part comes off in up to 30 cm strips.
2	Bark comes off in 1 to 2 m long strips. Occassionally poles may require chiselling while other poles strip freely.
3	Nearly all poles strip freely. There should be no chiselling.
4	Most trees are rip-stripped to half the usable height before felling. All poles strip easily.
5	All trees are rip-stripped to their usable height before felling. Only the top pole of each tree requires further stripping."

Conditions may fall between two classes in which case a half class can be quoted, for example, a strippability of 2,5 is very common.

This classification has proved practical and reliable. It can only be used after the first day's work has progressed sufficiently to reveal the conditions which is a minor disadvantage. However, fluctuations in weather such as rains after a drought or a sudden cold period can raise or lower the strippability class appreciably within a week although normally the change is seldom greater than half a class.

Analysis of the tenth study in Table 5.9 on debarking provides both a guide to maximising labourer productivity and establishing the standard minutes for class 5 strippability.

Five labourers each processed about 50 trees. The chain-sawyer's work and the positioning of the labourers were arranged so that the first labourers' trees were all felled before any debarking. The second, third, fourth and fifth labourers were allowed to rip-strip standing (debark as much as possible before felling) 10, 20, 30 and 40 trees or 20, 40, 60 and 80 per cent of their day's task, respectively. The results of the study are given in Table 5.12 and shown graphically in Figure 5.4.

Mean standard minutes to debark the mean tree size of each labourer's work were regressed on their respective position in the felling sequence. It is clear from Figure 5.4 that no transformation of variables is required. The t value of the regression coefficient and coefficient of determination are highly significant. Details of the equation (number 5.36) are given in Table 5.13.

From Equation 5.36 it is possible to extrapolate to obtain the debarking time per tree had there been a labourer in a sixth position which gives debarking time for class 5 strippability. The mean of these six times gives the standard minutes for class 4 strippability.

Standard minutes for a labourer to debark a pole was regressed on pole mid-point diameter. Equation 5.37, Table 5.13 shows that both the t value of the regression coefficient and the coefficient of determination are not significant. Thus by regressing the mean

TABLE 5.12

Comparison of labourer debarking times in *E. grandis* with various numbers of trees being rip-stripped standing and with a class five strippability.

Labourer number in felling sequence	Number of trees rip-stripped standing	Per cent of task rip-stripped standing	Mean standard minutes to debark mean tree
1	0	0	8,65
2	10	20	8,17
3	20	40	7,69
4	30	60	7,21
5	40	80	6,73
6[1]	50	100	6,25

Notes: [1] The indicated sixth labourer is an extrapolation using the linear regression Equation 5.38 derived from analysis of the five labourers' debarking times.

FIGURE 5.4

Correlation between total debarking time and a labourer's position in the team in relation to the felling sequence.

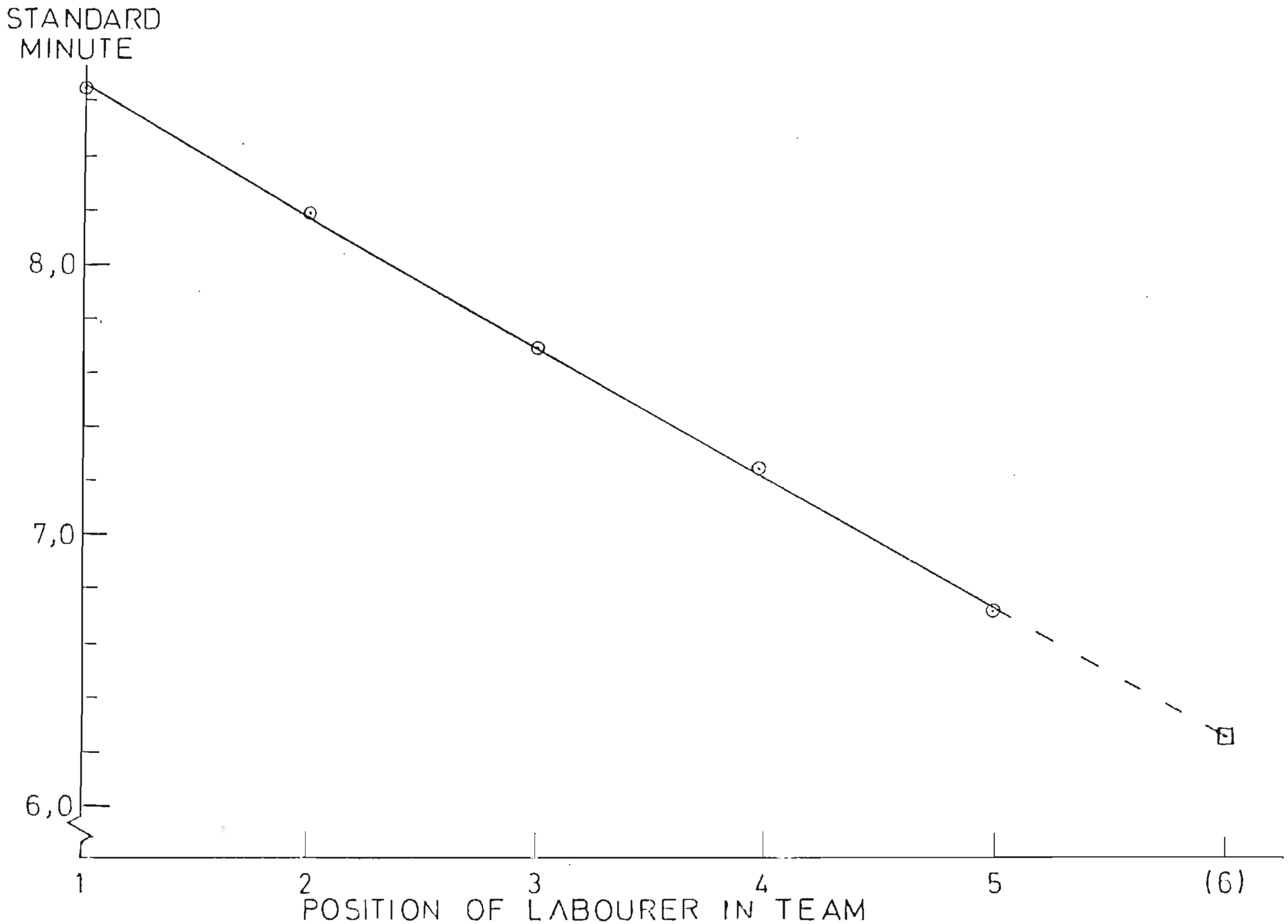


Table 5.13

Regression models relating standard minutes for manually debarking *E.grandis* to worker position in the felling sequence, pole mid-point diameter and pole strippability classes

Dependent variables	df	r^2	Constant term	Regression coefficients			Equation number
				FP	d	Strippability class	
Debark tree	3	1,0000	9,130000 (extremely high)	- 0,480000 (extremely high)			5.36
Debark pole	53	0,0122 (NS)	0,968553 (2,752)		0,015181 (0,808 NS)		5.37
Debark pole	4	0,9946	2,357227 (65,785)			- 0,968213 (27,013)	5.38

Notes: F P = position in the felling sequence.
d = mid-point diameter of 2.27 metre long pole.
N S = not significant.
Figures in brackets are t values of regression constants and coefficients.

Regression models are as follows:

Equation number 5.37 and 5.38: $Y = \beta_o + \beta_1 X_1$

5.39: $Y = \beta_o + \beta_1 \ln X_1$

debarking time per pole on the various strippability classes given in Columns 2 and 1, respectively in Table 5.14 it is possible to interpolate debarking times for any strippability class. Because pole diameter had no significant influence on debarking time per pole, it is then possible to multiply the standard minutes to debark a pole of a given strippability class by the mean number of 2,27 metre poles per tree to obtain debarking time per tree.

When debarking times per tree were regressed on strippability classes, the highest coefficient of determination and t value of the regression coefficient were obtained when the natural logarithmic transformation of the strippability class was taken. Other models tried included cubic polynomials, hyperbolic and quadratic. Due to the small sample size (Table 5.14), estimated standard minutes for debarking were compared with results derived from studies for final selection of the model. Details of the accepted model (Equation 5.38) are given in Table 5.13.

Remaining activities include 'debranch', 'stack brush' and 'position poles out of the centre of the swathe'. No significant correlation between these activities and tree dimensions could be obtained indicating that the number and size of branches are either only weakly related or not related to tree size. However, differences were found between the means of these activities and stand quality when this parameter was divided into the following three classes (de Laborde, 1982a, p.14).

Table 5.14

Standard minutes for manually debarking
E.grandis poles of various strippability classes

Strippability class	Mean debarking times per 2,27 m pole (Std mins)	Estimated debarking times per 2,27 m pole (Std min) [2]
1	2,355 (SD 0,127)	2,357
1,5	1,947 (SD 0,110)	1,965
2	1,658 (SD 0,130)	1,686
2,5	1,554 (SD 0,097)	1,470
3		1,294
4	0,981 (SD 0,010)	1,015
5	0,797[1]	0,799

Notes: [1] Derived from Equation 5.37

[2] Debarking times estimated from Equation 5.39

"Stand quality	Description
Very good	Over 1 400 stems per ha, all stems between 12 and 20 cm diameter at breast height (dbh) and no dead trees. Tree rows in both directions must be straight and espacement even. No undergrowth and slopes less than 10 degrees.
Average	Over 1 200 stems per ha, reasonable stem uniformity and only occasional dead trees, tree rows straight in two directions. No excessive undergrowth. Slopes less than 20 degrees.
Poor	1 000 stems per ha or less, a fair proportion of stems below 9 cm dbh and dead trees. Poorly aligned tree rows. Espacement irregular. Slopes over 20 degrees. (Most, but not all these factors need be present)"

As with the strippability classification, the above quality definitions are intended to divide conditions into strata that can be readily applied by a forester. They also may be divided into half classes and the tasks interpolated.

The means of the remaining labourer activities for labourers following the conventional chainsaw and bowsaw systems for the three stand qualities are as follows :

Stand quality	No. of observations	Standard minutes to debranch stack brush and position poles
Very good	10	1,02 (SD 0,10) 5.39
Average	9	2,23 (SD 0,43) 5.40
Poor	5	4,33 (SD 1,22) 5.41

By multiplying the results of Equations 5.38 and 5.32 and adding the appropriate value from Means 5.39 to 5.41, the total standard minutes for these labourer operations are obtained.

Where labourers are following the bench or semi-bench systems, as described for wattle (Section 5.3.7), Means 5.39 to 5.41 are omitted. Further, they only receive their work after the tree has been felled. Therefore, classes 4 and 5 strippability do not apply to these labourers which is a distinct disadvantage of these systems. This is illustrated by comparison of daily task levels for labourers, following the conventional chainsaw system for these two classes shown in Appendix B.

If labourers are required to bunch or stack shortwood poles, details for calculating are given in Section 5.6.1.

5.4.4 *Chainsaw Felling and Crosscutting by the Conventional System*

Means and standard deviations of standard minutes to fell and crosscut trees and of the various relevant independent variables are given in Table 5.15 for studies listed in Table 5.9.

5.4.4.1 *Felling*

To maximise timber utilization *E.grandis* established by planting or coppice should be felled as low to the ground as the chainsaw can be operated despite the stem being of greater

Table 5.15

Means and standard deviations of standard minutes for chainsaw work in studies on operations in *E.grandis* and relevant dimensions of trees processed during these studies

Activity description and standard minutes per tree			Independent variables				Sample size
			Tree diameter at breast height		Height		
Description	Standard minutes		Mean	SD	Mean	SD	
	Mean	SD	(cm)	(cm)	(m)	(m)	
Conventional system :							
fell first rotation	0,404	0,183	17,37	6,18			158
fell coppice	0,386	0,230	15,67	6,03			401
crosscut	0,832	0,423	15,59	2,41	21,38	3,31	28
Bench system:							
fell	0,645	0,344	15,08	4,61			92
butt cut	0,220	0,164	15,92	4,64			94
measure and debranch	1,408	0,707	14,95	4,50			99
stack brush	0,735	0,681	14,86	4,74	20,35	4,53	104
crosscut	0,714	0,407	14,95	4,43	20,61	4,00	100

diameter. This is also important to the quality of the subsequent coppice. If the basal section of stem is not to be sold for pulpwood, it may be necessary to square off the butt. Standard minutes for felling first rotation and coppiced trees were regressed on tree diameter at breast height and total height independently as times for the activities differ. In both cases, t values of regression coefficients of diameter were highly significant, but were not significant for height. Distributions of error residuals plotted against the variables were 'U' shaped and expanded to the right. Satisfactory random distributions were obtained with natural logarithmic transformations of the dependent variables. Natural logarithmic transformations of the independent variables increased t values of their regression coefficients. Details of the regression models are given in Table 5.16.

Walking between fellings is the only semi-variable activity and is applicable for felling irrespective of method of re-establishment at 0,14 (SD 0,05) standard minutes per tree for slopes below 10 degrees. On greater slopes walking time should be increased and allowances are discussed below.

5.4.4.2 *Allowance for Slope*

Slope principally influences chainsawyers' walking time. To measure increases in time the 'walk between felling' activity was studied. Two dependent variables were identified, *viz*, increased time to move and increased relaxation allowance as slopes become steeper.

Basic minutes, *viz* standard times excluding the rest factor, for chainsawyers to 'walk between felling' were found to vary increasingly with slopes up to 24 degrees. The following times

Table 5.16

Regression models relating standard minutes for chainsawyer operations when using the conventional system to various relevant tree dimensions in *E.grandis*

Dependent variable	df	R^2	R_A^2	Constant term	Regression coefficients			Equation number
					Dbh (cm)	Height (m)	Slope (degrees)	
Fell first rotation	156	0,6422		- 5,108282 (22,627)	1,344001 (16,731)			5.42
Fell coppice	399	0,6843		- 4,691463 (38,379)	1,328129 (29,408)			5.43
Walk between felling	55	0,2449		- 2,261262 (18,726)			0,019583 (4,067)	5.44
Crosscut (first rotation or coppice)	25	0,9212	0,9149	- 3,219765 (18,529)	0,115798 (4,637)	0,052254 (2,817)		5.45

Figures in brackets are t values of regression constants and coefficients.

Regression models are as follows :

Equation numbers 5.42 and 5.43: $\ln Y = \beta_o + \beta_1 \ln X_1 + \varepsilon$

5.44: $\ln Y = \beta_o + \beta_1 X + \varepsilon$

5.45: $\ln Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$

were recorded :

Slope (degrees)	Sample size	Mean (basic minutes)	Standard deviation (basic minutes)	Coefficient of variation (%)
7	10	0,120	0,019	16
18	8	0,164	0,030	18
24	14	0,171	0,067	39
29	12	0,183	0,076	42
33	13	0,212	0,084	40

Basic minutes of the above 57 observations were regressed on the slope indicated. The coefficient of determination and t value of the regression coefficient were significant. However, the t value increased from 3,609 to 4,067 with the natural logarithmic transformation of basic minutes. Due to the pattern given by the above data it was not possible to use the distribution of error residuals plotted against the variables as a factor in selection. Transformations of slope did not improve the model. Details of the regression model are given in Table 5.16 (Equation 5.44). Colume B, Table 5.17 gives the estimated basic minutes using this equation.

The following equation gives the increased force imposed on chainsawyers by a slope of θ degrees.

Force due to slope (kg) = total mass x SIN θ 5.46

A standard of 80 kilograms is taken for total mass comprised of mass of the chainsawyer, his clothing and the chainsaw. From the additional force the increase in effort and, thereby, the correct relaxation allowance can be calculated.

Table 5.17

Calculation of the influence of slope on a chainsawyer in the "Walk between felling" activity

Slope (degrees) A	"Walk between fellings[1] (Basic min) B	Force increase due to slope[2] (kg) C	Force points[3] D	Other points[3] E	Total points F	Allowance[3] (%) G	Rest factor H	"Walk between felling" (Std min) I	Ratio of increase[4] J
10	0,127	13,9	35	7	42	20	1,20	0,152	1,086
15	0,140	20,7	47	7	54	26	1,26	0,176	1,257
20	0,154	27,4	57	7	64	32	1,32	0,203	1,450
25	0,170	33,8	68	7	75	40	1,40	0,238	1,700
30	0,188	40,0	76	7	83	48	1,48	0,278	1,986
35	0,207	45,9	85	7	92	56	1,56	0,323	2,307

Notes:

[1] Equation 5.44

[2] Equation 5.46

[3] These are taken from the International Labour Office's relaxation allowance Tables (1979, p. 425)

[4] Standard minutes in Column I/0,14 standard minutes (viz. standard minutes to "Walk between felling" activity on slopes ≤ 10 degrees, Section 5.4.4.1).

Column C gives the results of Equation 5.46, Column H the allowance converted to the rest factor and Column I the 'walk between fellings' activity in standard minutes.

To obtain an equation that would represent the data in Column J accurately for the slope range in Column A, data from the former column were regressed on that of the latter. Equation 5.3 with and without natural logarithmic transformations of the variables, hyperbolic and cubic equations were tested. Due to there being so few data selection was made by comparing estimated values with the values in Column J. The cubic model gave the best results and had a coefficient of determination of 0,9999. Details are given below.

$$WS = 0{,}962572 + 0{,}000324\ S + 0{,}001368\ S^2 - 0{,}000008\ S^3 \quad \ldots\ldots\ 5.47$$

Where WS = increase in standard minutes to walk with a chainsaw on various slopes of 10 degrees or over.

S = terrain slope in degrees

5.4.4.3 *Crosscutting*

Standard minutes for crosscutting were regressed on tree diameter at breast height and total height. t Values of the coefficients of both independent variables were significant, but the distributions of error residuals plotted against the variables were 'U' shaped and expanded to the right. A natural logarithmic transformation gave a satisfactory distribution. Transformations of independent variables did not improve the model. Details of the regression model (Equation 5.45) are given in Table 5.16.

By using summing (Section 4.6.2) in conjunction with time studies, it was found that there is a difference in time between crosscutting a single row of trees and the same number of trees in four rows abreast. In both cases trees were felled in their rows on top of each other then debarked with the brush stacked before crosscutting commenced. Of the total standard minutes to crosscut shortwood poles with a group of stems felled in a single row, it was found that 49,36 (SD 2,80) per cent of the time was spent with the chainsaw actually cutting. The remaining time is spent moving between crosscut points.

However, when four adjacent tree rows were prepared as above, the standard minutes for the actual cutting element dropped to 39,61 (SD 2,38) per cent of the total crosscutting standard minutes. This shows a (100 x 49,36/39,61) - 100 = 24,6 per cent increase in total crosscutting time which is an appreciable amount and must be considered when developing a system.

By applying the percentage of actual crosscut element to total crosscut activity, Equation 5.45 can be modified to be applicable to any chosen pole length provided the mean poles per tree is known. The equation is,

$$XL = \exp(0{,}115798\ D + 0{,}052254\ H - 3{,}219765)0{,}4936/(0{,}412272\ H - 1{,}747162)PPT + \exp(0{,}115798\ D + 0{,}052254\ H - 3{,}219765)0{,}5064\ WS \quad \ldots\ldots\ 5.48$$

Where XL = standard minutes to crosscut pole lengths other than 2,27 metres

D = overbark tree diameter at breast height

H = tree height

PPT = mean number of poles per tree

WS = Equation 5.47 and is only included where slopes are 10 degrees or more

The component '(0,412272 H - 1,747162)' above is from Equation 5.32. The amount of time spent cutting is altered by the ratio of 2,27 metre poles cut per tree to the actual number cut. Thereby, the actual total crosscutting time per tree is obtained. Finally, the proportion of time spent moving between crosscutting per tree is added. All times are in standard minutes.

Fixed activities are common to both felling and crosscutting and are the same as given for wattle in activity Total 5.20 with the addition of an activity of walking between the labourers' work sites during felling and crosscutting cycles.

Assuming an average situation of eight labourers per chainsawyer with a daily task of 27 trees felled and crosscut in three cycles each. With an espacement of 2,44 metres in the tree rows, 2,44 x 9 x 7 = 154 metres are walked for each of the six sub-cycles giving 924 metres total. With a 2,74 metre espacement between tree rows, allowing two safety rows between workers, 24 rows are walked to return to commence each sub-cycle giving for the six sub-cycles 27,4 x 24 x 6 = 395 metres. Thus a total of 924 + 395 = 1 319 metres are walked at 60/3 200 x 1,15 = 0,0216 standard minutes per metre, assuming a walking speed of 3,2 kilometres per hour 1 319 x 0,0216 = 28,49 rounded off to 30 minutes are spent walking.

Total standard minutes for fixed activities are :

Fixed activity	Standard minutes	
Refuel	30	
Tend chainsaw	10	
Sundry delays	5	
Walk	30	
Total	75	.... 5.49

Where slopes are 10 degrees or more, the 'walk' time should be increased and allowances are discussed in Section 5.4.4.2

5.4.5 *Chainsaw Activities Using the Bench System*

Standard minutes to 'fell' and 'measure and debranch' were regressed on tree diameter at breast height and total height. In both cases the distribution of error residuals plotted against the variables gave a pattern that expanded to the right. Of the transformations listed in Section 5.2.1, the natural logarithmic transformation gave a satisfactory random distribution of residuals with both activities, t values of the regression coefficients increased with the transformation of diameters.

Regression analysis of standard minutes for the chainsawyer to stack brush resulted in a similar description of analysis to the two above, except that the t value of the regression coefficient of diameter did not improve with transformations. Therefore, untransformed values were retained.

Standard minutes for the 'butt cut' activity were regressed on tree diameter at breast height only. The distribution of error residuals was satisfactory. The t value of the regression coefficient was highly significant, but increased further with the natural logarithmic transformation of the independent variable.

Standard minutes for crosscutting were regressed on tree diameter at breast height and standing height. t Values of regression coefficients of both variables were significant, but the distribution of error residuals expanded strongly to the right. Natural logarithmic transformations gave a satisfactory distribution. t Values of regression coefficients and coefficients of determination of both diameter and height increased when their natural logarithmic transformation were introduced into the model.

Details of the regression models of the five activities above are given in Table 5.18.

Semi-variable and fixed activities are as follows :

Semi-variable activities	No. of observations	Standard minutes	
Prepare to fell	92	0,14 (SD 0,07)	
Walk between fellings	91	0,21 (SD 0,16)	
Total		0,35	.... 5.55

Fixed activities	Total standard minutes	
Refuel	12,54	
Tend chainsaw	4,56	
Sundry delays	2,28	
Total	19,38	
Total (rounded off)	20,00	.... 5.56

Where the slope is 10 degrees or more the 'walk between fellings' time should be increased and allowances are discussed in Section 5.4.4.2.

5.4.6 *Optimising the Conventional System*

In addition to setting accurate daily tasks, the same three factors apply to *E.grandis* as described for wattle in Section 5.3.6, *viz* balancing of worker categories, work site layout and synchronisation of operations. Comments in Section 5.3.6.1 on balancing of worker categories apply equally to *E.grandis* except those related to bark preparation.

Table 5.18

Regression models relating standard minutes for chainsawyer activities when using the bench system to various *E.grandis* dimensions

Dependent variables	df	R^2	R_A^2	Regression constant	Regression coefficients		Equation number
					Dbh (cm)	Height (cm)	
Fell	90	0,5972		- 3,607876 (13,279)	1,147138 (11,291)		5,50
Butt cut	92	0,5120		- 2,625125 (26,081)	0,062625 (9,825)		5,51
Measure and debranch	97	0,6336		- 2,760425 (11,920)	1,126542 (12,952)		5.52
Stack brush	102	0,1579		- 3,559883 (6,698)	0,149112 (4,371)		5.53
Crosscut	97	0,8497	0,8497	- 6,105369 (16,418)	1,065595 (7,145)	0,933593 (4,166)	5.54

Figures in brackets are t values of regression constants and coefficients.

Regression models are as follows :

Equation number : 5.50 and 5.52: $\ln Y = \beta_o + \beta_1 \ln X_1 + \varepsilon$

5.21 and 5.23: $\ln Y = \beta_o + \beta_1 X_1 + \varepsilon$

5.54: $\ln Y = \beta_o + \beta_1 \ln x_1 + \beta_2 \ln x_2 + \varepsilon$

5.4.6.1 *Worksite Layout*

As described in Section 5.3.6.2, it is important for several reasons to keep the worksite area compact. In Section 5.4.4 the advantage of felling a single line of trees per labourer to reduce crosscutting time was described. It is important for the chain-sawyer to be assisted by a labourer provided with a steel-pronged pushing stick to quide the direction of felling. Despite this, there is a greater extent of unpredictability in the felling direction of *E.grandis* compared with wattle and it is advisable to leave two tree-rows distance between labourers for safety.

Where infield timber extraction is intended, this is facilitated where brush lines are established every fifth tree row. The centre of the swathe is cleared of timber so vehicles can travel along the rows straddling the centre stump line of the five rows. The poles are in easy reach on either side of the vehicle to permit either manual or mechanical loading.

Labourers accomplishing more work than others should change sites with the others regularly after several days' work to retain the rectangular layout.

5.4.6.2 *Synchronisation of Operations*

Where there is a class 4 or 5 strippability, labourers must be permitted to rip strip the number of trees to be felled in each cycle prior to their being felled.

Because of the crosscutting technique described it is undesirable to reduce the number of trees felled per cycle to below a third of the labourers' daily task. This is not normally disadvantageous to the first third of the team, but will incur a noticeable delay particularly to the last labourer. However, delays only occur during the first felling and crosscutting cycle. During felling the last two to three labourers start some while after the others. Crosscutting incurs a further noticeable delay while waiting for crosscut poles to debark. The following example of a typical Natal Midlands and south-eastern Transvaal coppice plantation illustrates the situation. Standard minutes (std min) are derived from the respective equations :

Example

Situation :	strippability class	2,5
	tree diameter at breast height	16,0 cm
	tree height	22,0 m
	slope	7 degrees
	labourer's normal daily task	27 trees
	chainsawyer's normal daily task	215 trees
	debranch and stack brush per tree	2,23 std min
	debark per tree	12,04 std min
	fell per tree	0,505 std min
	crosscut per tree	0,805 std min
	chainsawyer fixed activity per cycle	25,0 std min

Daily task are taken from Appendix B , Sections 3.4.3 and 3.4.4.

During each chainsawyer cycle, nine trees per labourer are felled and crosscut. The eighth labourer will not start debranching until all their trees have been felled which takes 8 x 9 x 0,505 = 36,36 standard minutes. 'Debranch and stack brush' for nine trees takes 9 x 2,23 = 20,07 standard minutes. However, the chainsawyer will not return and provide the first crosscut poles for 7 x 9 x 0,805 + 25,0 x 63/72 = 72,59 standard minutes. Thus the labourer has a delay of 72,59 - 20,07 = 52,52 standard minutes.

The total cycle time for the chainsawyer is 72(0,505 + 0,805) + 25,0 = 119,32 standard minutes and for each labourer 9(2,23 + 12,04) = 128,43 standard minutes. As the labourers' work takes 128,43 - 119,21 = 9,11 standard minutes longer than that of the chainsawyer this delay will not recur.

In reality, the delay probably will be reduced considerably. The average relaxation allowance calculated into the chainsawyer's activities is approximately 24 per cent and during the first cycle of work, chainsawyers usually work at about a 105 per cent rating. Therefore, in actuality the chainsawyer's 'fell and crosscut' times per cycle will be about 30 per cent lower giving 36,36 x 0,70 = 25,45 minutes and 72,59 x 0,70 = 50,81 minutes, thereby reducing the delay to 50,81 - 20,07 = 30 minutes. Breakfast is often eaten during this delay.

This example shows that where more than a third of the daily task's trees are felled per cycle, it is to the distinct detriment of the labourers. Where there are higher classes of strippability than in the example the ratio of labourers per chainsawyer will be lower which reduces the delay.

5.4.7 *Optimising the Bench and Semi-bench Systems*

When the bench or the various forms of the seni-bench systems for primary conversion are used in *E. grandis* the work is very similar to wattle with the obvious exclusion of bark preparation.

Consequently, comments and analyses made in Section 5.3.7 apply equally here with further additions.

5.5 PRIMARY CONVERSION OF *PINUS PATULA*

As the integrated system is used by most growers in southern Africa to harvest *P.patula*, (Section 4.3.4.1) studies have been on variations of this system only. Operations include chainsaw felling and debranching or limbing axe debranching, skidding to roadside, measure and mark for crosscutting and crosscutting. The majority of data presented is taken from a paper by the writer (1983).

Table 5.19 lists the basic data of the major studies undertaken. In addition to the stated dimensions, stem diameter at the point of topping or where the top broke during felling and the length of the topped stems were recorded. However, regression analysis of the variable activities showed no significant correlation so they have been omitted.

5.5.1 *Analysis of Chainsaw Felling and Debranching*

Where *P.patula* trees are felled on a slope with extraction intended to be straight downhill, trees are either felled in the same direction or uphill at 60 ±10 degrees to the line of extraction and also the working face. The principal advantage noted of the latter techniques is that fewer stems are broken when felled.

In taking the length of topped or broken stems for trees of 18 to 27 metres height, the mean length after downhill felling was 16,22 (SD 1,74) metres and for 60 degree uphill felling, 17,56 (SD 2,27) metres, a difference of 1,34 metres. The mean tip diameter was 14,6

TABLE 5.19

Circumstance of *P. patula* studies, their type and duration for primary conversion

Study No.	Activity	No. of workers in RAS[1]	Area	Tree dbh range (cm)	Tree Height range (m)	Pruning range (m)	Slope (degrees)	Ambient day temperatures[2]	Type of study	Duration of study (min)	No. of readings (RAS only)
1	Chainsaw, fell & debranch		Natal Midlands	21,9 to 51,8	25,0 to 27,2	5,2 to 6,6	0	Warm to hot	TS[3]	236	
2	"		"	22,8 to 50,9	18,0 to 32,0	2,0 to 15,0	20° countour	Cool	TS	257	
3	"		"	21,5 to 45,6	19,5 to 29,0	2,5 to 13,5	18 to 24	Cool	TS	204	
4	Chainsaw fell		Singisi (Transkei)	23,4 to 47,8	18,0 to 27,0	5,5 to 14,5	2 to 13,5	V.cold to cold	TS	225	
5	"		Singisi	13,7 to 38,2	14,5 to 27,0	2,5 to 14,5	8 to 22	Cool to warm	TS	79	
6	"		"	21,5 to 53,4	16,5 to 34,0	4,0 to 17,5	15 to 27	Cool	TS	142	
7	Limbing axe debranch	5	"	23,4 to 47,8	18,0 to 27,0	5,5 to 14,5	2 to 13,5	Cool	RAS	121	548
8	"	5	"	13,6 to 35,0	13,4 to 26,6	2,8 to 6,0	15	Hot	RAS	62	272
					Load size range (m^3)	Lead dist. range (m)					
9	Skidder extraction to road	3	Singisi	23,4 to 47,8	6,65 to 12,31	40 to 130	2 to 13,5	Warm	RAS/TS[4]	135/139	394
10	"	3	"		3,37 to 5,17	83 to 313	0 to 5	Cool	RAS/TS	172/173	516
					logs/stem range	No. of stems in study					
11	Mark	2	"	23,4 to 47,8	3,5 to 5,8	111	0 to 7	Warm	RAS	128	256
12	Chainsaw crosscut	2	"	23,4 to 47,8	3,5 to 5,8	111	0 to 7	Warm	RAS	144	288
13	"	2	"	22,5 to 37,0	2 to 8	34	0	Cool	RAS	45	65
14	"	2	"	12,0 to 33,5	2 to 6	21	0	Cool	RAS	21	39
15	"	1	"	19,5 to 44,5	2 to 8	15	0	Cool	RAS	18	89
16	"	1	"	20,5 to 43,5	3 to 10	14	0	Cool	RAS	17	79

Notes: [1] RAS is an abbreviation for rated activity sample.
[2] Definitions of arbitrary temperatures are given in Note 3, Table 5.1.
[3] TS is an abbreviation for time study.
[4] These are combined studies (Section 4.6.4.)

(SD 5,67) centimetres. Thus a mean of in excess of $14,6^2 \times \pi/4 \times 1,34/10\,000 = 0,022$ cubic metres per tree was lost by increased breakages.

Means and standard deviations of standard minutes and relevant independent variables are given in Table 5.20 for studies listed in Table 5.19.

Standard minutes for downhill felling were regressed on tree diameter at breast height, total height and total height minus pruning height, *viz* branch distance. However, only the t value of the regression coefficient of diameter was significant. Distribution of the error residuals plotted against the variables, when diameter only was included, expanded to the right. A natural logarithmic transformation of the dependent variable gave a satisfactory random distribution.

Standard minutes for uphill felling were regressed on tree diameter at breast height, total height and branch distance. t Values of the regression coefficients of diameter and standing height were significant, but the distribution of error residuals were 'U' shaped and expanded to the right. The natural logarithmic transformation of the dependent variable resulted in a satisfactory random distribution.

As felling 28-year old *P.patula* uphill is considerably more difficult and takes a longer time to fell than wattle or *E.grandis*, data from Study 5, Table 5,19, were used to detect whether slope affected felling time. Standard minutes were regressed on tree diameter at breast height, standing height, branch distance and slope.

Table 5.20

Means and standard deviations of standard minutes chainsaw work studied in operations in *P. patula* and the various relevant dimensions of trees processed during these studies

Activity	Independent variables										Standard minutes for activities		Sample size
	Tree dimensions								Slope (degrees)				
	Breast height diameter		Height		Height - pruning ht.		Logs per stem						
	Mean (cm)	SD (cm)	Mean (m)	SD (m)	Mean (cm)	SD (m)	Mean	SD	Mean	SD	Mean	SD	
Downhill fell	34,74	6,83									0,786	0,264	120
60° uphill fell (slope excluded)	28,94	6,83	23,28	4,05							0,803	0,394	180
60° uphill fell (slope included)	33,34	6,36							17,71	5,33	1,152	0,521	77
Chainsaw debranch	1,99	0,70			15,40	3,19					1,995	0,701	116
Limbing axe branch	30,51	5,69									4,690	1,430	35
Chainsaw crosscut	31,73	3,09					4,62	0,85			1,159	0,210	18

Only the t value of the regression coefficient of diameter at breast height was significant when slope was included. The distribution of error residuals was satisfactory when plotted against the dependent variable. As shown with Equation 5.59, Table 5.21, slope is distinctly not significant.

Standard minutes for debranching and topping by chainsaw were regressed on tree diameter at breast height, total height and branch distance. t Values for regression coefficients were significant only for diameter and branch distance. The distribution of error residuals plotted against the variables expanded to the right. Of the transformations given in Section 5.2.1, only the natural logarithmic transformation of the dependent variable gave a satisfactory distribution. Transformations of the independent variables did not improve the model.

Transformations of independent variables did not improve any of the above models. Details of the four regression models are given in Table 5.21. They show that the coefficient of determination for downhill felling is a little over half the adjusted coefficient of determination for uphill felling. This shows that tree size has less influence and, therefore, less attention and skill are required for downhill felling.

Table 5.21

Regression models relating chainsaw felling and debranching times to various *P.patula* dimensions and terrain slope

Dependent variables	df	R^2	R_A^2	Regression constant	Regression coefficients				Equation number
					Dbh (cm)	Height (m)	Branch distance (m)	Slope (degrees)	
Downhill fell	118	0,4665		- 1,484802 (12,461)	0,034468 (10,157)				5,57
Uphill fell (slope excluded)	177	0,8264	0,8245	- 2,217720 (26,448)	0,054924 (16,289)	0,012790 (2,254)			5,58
Uphill fell (slope included)	74	0,7357	0,7357	- 0,972088 (5,380)	0,059834 (14,493)			0,002821 (0,549 NS)	5,59
Chainsaw debranch	113	0,2607	0,2476	- 0,292747 (1,834)	0,020686 (4,911)		0,014367 1,749		5,60

Figures in brackets are t values of regression constant and coefficients. N S means not significant.

Regression models are as follows :

Equation number : 5.57: $\ln Y = \beta_0 + \beta_1 X_1 + \varepsilon$

5.58 and 5.60: $\ln Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$

5.59: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$

Although a wide variety of terrain could be identified, for practical purposes, it was divided into two broad categories : light and difficult conditions (de Laborde, 1983b). These are defined as follows :

Terrain Condition	Description
Light	Slopes less than 15 degrees, undergrowth, rocks and brush impede neither walking nor felling. Felling faces are of a length so that the chainsawyer changes sites four or less times during the normal daily task.
Difficult	Slopes are between 15 and 30 degrees, undergrowth, rocks and/or brush clearly will impede the chainsawyer's work and/or where the felling faces of the forest are short necessitating the chainsawyer having to change sites five or more times during the normal daily task.

Semi-variable and fixed activities for light and difficult terrain for chainsawyers felling only and felling and debranching are as follows. Times for activities where conditions lie between light and difficult can be obtained by interpolation.

Semi-variable activity for felling only	No. of observations	Light conditions (std min per tree)	No. of observations	Difficult conditions (std min per tree)
Walk between fellings	130	0,14 (SD 0,05)	79	0,19 (SD 0,13)
Clear undergrowth[1]	5	0,01	7	0,01
Delays in felling[1]	12	0,04	6	0,15
Plan felling[1]			6	0,07
Total		0,19		0,42 ... 5.61

Note[1] These times are the summing of numerous minor work elements divided by 131 and 80 trees for light and difficult conditions, respectively.

Semi-variable activity for fell and debranch	No. of observations	Light conditions (std min per tree)	No. of observations	Difficult conditions (std min per tree)
Walk	48	0,60[1] (SD 0,16)	142	0,68 (SD 0,31)
Sundry delays (average)[2]		0,07		0,07
Total		0,67		0,75 ... 5.62

Note [1] Where slopes are between 15 and 30 degrees, this value should be raised proportionally to between 0,60 and 0,68.

[2] There was a total of 8,66 standard minutes of delays for 131 trees debranched.

The fixed activities 'tend chainsaw', 'refuel' and 'sundry delays' for light conditions are as given for wattle in Activity Total

5.20. Total fixed activities for light and difficult conditions are as follows :

	Standard minutes for activities		
Fixed activity	Light conditions	Difficult conditions	
Refuel	30	30	
Tend chainsaw	10	10	
Walk between sites [1]	4,73	11,83	
Total	44,73	51,80	
Total (rounded off)	45,00	52,00	..... 5.63

Note [1] 'Walk between sites' is 2,37(SD 0,87) standard minutes per change. Two and five changes of sites are calculated for light and difficult conditions, respectively.

5.5.2 *Limbing-Axe Debranching*

Means and standard deviations and sample size of the dependent and relevant independent variables are given in Table 5.20 for the studies listed in Table 5.19.

Standard minutes for limbing-axe debranching and topping were regressed on tree diameter at breast height, total height, branch distance and tree diameter at the point of topping. After testing independent variables in all possible combinations and singly, only the t value of the regression coefficient of the diameter at breast height was found to be significant. The distribution of the error residuals expanded to the right indicating that a transformation of the dependent variable was required. The natural logarithmic transformation of the standard minutes resulted in a satisfactory distribution of the residuals. By taking the natural logarithmic transformation of diameter, the t value of its regression coefficient increased. Details of the regression model are given in Table 5.22.

No semi-variable or fixed activities were recorded in the studies.

5.5.3 *Marking and Chainsaw Crosscutting*

Marking of stems for crosscutting is a precision job. Consequently, it does not correlate to the number of logs marked per stem. As a guide, the mean of the time that the pair of markers, usually women, take for the logs-per-stem range shown in Table 5.20 is 0,73 (SD 0,11) standard minutes per stem.

Standard minutes for chainsaw crosscutting were regressed on tree diameter at breast height, total height and the number of logs crosscut per stem. t Values were significant for the regression coefficients of diameter and logs per stem only. The distribution of error residuals plotted against the variables was satisfactory and transformations of the independent variables did not improve the model, details of which are given in Table 5.22.

Crosscutting is undertaken on roadside or at a landing. Walking during crosscutting and butt cutting is incorporated in Equation 5.66 as they are part of the variable activity. Therefore, there are no semi-variable activities. Fixed activities are the 45 standard minutes as developed for wattle in Activity Total 5.20.

5.6 MANUAL TIMBER HANDLING

Table 5.23 lists the major studies undertaken in manual movement of shortwood wattle and *E.grandis* poles and 5,7 and 7,5 metre *E.grandis*

Table 5.22

Regression models relating standard minutes for limbing axe debranching and chainsaw crosscutting to various *P. patula* dimensions

Dependent variable	df	R^2	R_A^2	Regression constant	Regression coefficients		Equation number
					Dbh (cm)	Logs per stem	
Limbing-axe debranch	33	0,7896		- 3,806991 (7,993)	1,552281 (11,129)		5.64
Chainsaw crosscut	15	0,4742	0,4041	- 0,694402 (1,374)	0,042637 (3,289)	0,108464 (2,290)	5.65

Figures in brackets are t values of regression constants and coefficients.

Regression models are as follows :

Equation number : 5.64 : $\ln Y = \beta_0 + \beta_1 \ln X_1 + \varepsilon$

5.65 : $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon$

TABLE 5.23

Circumstance, types and duration of manual timber extraction, loading, offloading and transshipping studies

Subject	No. of workers in RAS[1]	Area	Combined no. of studies	Pole Diameter range[2] (cm)	Pole mass mean or range (kg)	Slope (degrees)	Ambient day temperatures[3]	Type of study	Duration of study (min)	No. of readings RAS[1] only
Shortwood extraction		Wartburg	1		8,1 to 68,0	15 to 18	Cool	TS[4]	119	
"		Wartburg	2		14,4 to 50,0	18 up	Cool to warm	TS	189	
"		Wartburg	2		12,5 to 66,5	15 down	Hot	TS	138	
"	4	Wartburg	1		5,5 to 59,4	15 down	Warm	RAS	85	332
Shortwood bunching	4	Inadi	1		13,1 to 46,2	5 to 7	Cool	RAS	40	141
Shortwood sorting & stacking	4	Richmond	1	1,8 to 21,5			Cool	RAS	421	1563
Shortwood loading of lowbed trailers[5]	4 to 5	Natal Midlands	18	5,0 to 24,0	5,0 to 26,5	3 to 18	Cool to hot	RAS/TS[6]	316/326	2512
Shortwood loading, offloading & transshipping of flatbed trailers	4 to 6	PMBurg	5	6,9 to 22,3	9,5 to 60,7	6 to 10	Cool to warm	RAS/TS	159/ 99	180
Shortwood loading & offloading of plain lorries[7]	5 to 6	S.E. Transvaal	8	6,5 to 24,5	9,7 to 32,1	1 to 3	Warm	RAS	297	1544
Shortwood offloading & transshipping to SJ rail truck from plain lorry[7]	6	S.E. Transvaal	2		10,9 to 11,4	0	Cool	RAS	117	561
5,7 to 7,5 m pole loading of plain lorries	4 to 6	S.E. Transvaal	2		82,4 to 86,4	0	Cool	RAS	164	864
5,7 to 7,5 m pole transshipping from lorries to SJ rail trucks[7]	6	S.E. Transvaal	2		82,4 to 86,4	0	Cool	RAS	66	396

Notes: [1] RAS is an abbreviation for rated activity sample. The number of workers shown are for each study.
[2] Pole diameter refers to the mid-point diameter.
[3] See Note 3, Table 5.1 classifying temperature ranges.
[4] TS is an abbreviation for time studies.
[5] Lowbed trailers have a bedheight of 0,60 m.
[6] RAS/TS indicates a combined rated activity sample and time study.
[7] These studies are supported further by tachograph analyses.

poles. In most cases series of studies were taken on a given subject, but only the overall range and magnitude of these studies are quoted.

Compilation of data into systems and daily tasks given below is presented in Appendix B and discussed in Chapter 6 after the related machine and vehicle operating times have been provided. Means and standard deviations of dependent and independent variables are given in Table 5.24 for the studies listed in Table 5.23.

5.6.1 *Shortwood Extraction, Bunching and Stacking*

When using manual extraction of shortwood poles on downhill slopes, there are two possible techniques, *viz* to carry poles or tumble them end over end. A comparative study on a 15 degree slope of four labourers, a male and female carrying and a male and female tumbling yielded the following similar results under the conditions shown.

Technique	No. of poles	Mean distance (m)	Mean pole mass (kg)	Time to extract 10 poles 10 m (std min)
Carry	225	24,4(SD 12,9)	22,2(SD 13,2)	3,99(SD 0,02)
Tumble	191	22,9(SD 12,8)	20,9(SD 10,8)	4,02(SD 0,14)

Differences in worker efficiency apparent during the study disallowed detailed analysis. However, the above results indicate that 15 degrees is approximately the break-even point and that on steeper slopes tumbling should increase output compared with carrying the poles.

Poles are normally only carried uphill for the top 25 per cent or 10 metres of a site, whichever is the lesser, assuming downhill extraction is possible. Studies were conducted on 18 degree slopes as they were regarded as being an average situation. On greater slopes

Table 5.24

Means and standard deviations of standard and basic minutes for manual timber extracting and loading activities and pole masses handled during studies on these activities

Activity	Standard minutes per pole		Pole mass (kg)		No. of poles handled	Sample size
	Mean	SD	Mean	SD		
Pick up poles	0,470	0,237	34,51	14,15	110	110
Carry poles 50 m up 18° slope	2,441	0,433	29,17	9,78	55	55
Carry poles 50 m down 15° slope	1,238	0,358	38,30	16,42	58	58
	Basic minutes per ton					
	Mean	SD				
Load lowbed trailer	10,92	1,88	18,89	3,50	6227	23
Load 1,0 m high flatbed trailer	12,02	2,14	23,00	5,54	5868	13
Offload plain trailer	5,09	1,57	24,61	10,09	2395	4

where extraction will be fairly regular, mechanical means such as highleads normally should be considered.

Standard minutes to pick up poles were regressed on pole mass. The t value of the regression coefficient was highly significant. The distribution of error residuals plotted against the variables expanded to the right. A satisfactory distribution was obtained with the natural logarithmic transformation of the dependent variable. The t value of the regression coefficient increased also with the natural logarithmic transformation of the pole mass.

Standard minutes to carry poles both up an 18 degree slope and down a 15 degree slope were regressed on pole mass. The poles were carried from stacks so that there were only minor differences in the carrying distance which were negated by correcting all distances to 50 metres. t Values of the regression coefficients were both highly significant. The distribution of error residuals plotted against the variables for uphill carrying were satisfactory and transformations of the pole mass lowered the t values. However, with downhill carrying, the distribution of residuals expanded to the right and a natural logarithmic transformation of the dependent variable resulted in a satisfactory distribution.

Details of the above three regression models are given in Table 5.25.

Picking up two or more poles wastes time and should be discouraged. Stacking of poles does not correlate to any pole dimensions, but it was found that after carrying them uphill the poles are placed on the stack whereas they are thrown onto the stack after carrying downhill. Thus the following mean stacking times were obtained:

Table 5.25

Regression models relating standard minutes for manual timber extraction operations to pole mass

Dependent variable	df	r^2	Regression constant	Regression coefficient of pole mass (kg)	Equation number
Pick up poles	108	0,3762	- 3,561345 (10,713)	0,767031 (8,071)	5.68
Carry poles 50 cm uphill	53	0,7051	1,317930 (12,970)	0,037344 (11,257)	5.69
Carry poles 50 cm downhill	56	0,8128	- 0,417636 (10,172)	0,015274 (15,594)	5.70

Figures in brackets are t values of regression constants and coefficients.

Regression models are as follows :

Equation number : 5.68: $\ln Y = \beta_o + \beta_1 \ln X_1$

5.69: $Y = \beta_o + \beta_1 X_1$

5.70: $\ln Y = \beta_o + \beta_1 X_1$

Semi-variable activity	No. of observations	Standard minutes to stack one shortwood pole manually
Stack from uphill carrying	58	0,16 (SD 0,06) 5.66
Stack from downhill carrying	59	0,12 (SD 0,08) 5.67

Frequently, poles from two or three tree rows are loosely bunched in groups of 7 to 10 poles without being turned 90 degrees. To do this, after debarking , labourers drop poles into a heap which requires a negligible amount of work to neaten.

For crane loading or to facilitate counting, poles are often bunched. Numbers of poles per bunch, poles per tree, stand density and mean poles mass all alter times for this activity. A rough guide is 0,17 standard minutes per shortwood pole for wattle and *E.grandis*. If poles are sorted into four categories and stacked, the activities take 0,62 standard minutes per pole. All these times are highly variable and stated as a guide only.

5.6.2 *Relaxation Allowance During Manual Operations*

All equations and mean times in Sections 5.6.3 and 5.6.4 are given in basic minutes which exclude the relaxation allowance (Section 4.7.1). In most situations a team performing these operations is assigned to a vehicle. During its travelling time the workers rest for periods often in excess of the rest allowance required for their work.

Where this rest period is excessive, it may be necessary to formulate a compensating agreement where the length of their normal working day is extended up to 552 minutes. Although such workers may not fall under the Factories, Machinery and Building Work Act, No. 22 of 1941, as amended, it is sound policy not to expect workers to exceed the number of hours worked per week prescribed in Section 19 of the Act without mutually agreed on special compensations.

Conversely, vehicle travelling times may be less than the related relaxation allowance for the stress of the particular operation shown in Appendix A. Alternatively, work may be continuous where, for example, one team loads several vehicles or rail trucks for which poles are supplied by a series of vehicles.

In both the latter situations basic minutes must be converted to standard minutes. The appropriate relaxation allowance for the mean pole mass shown in Appendix A is expressed as a rest factor using Equation 4.9.

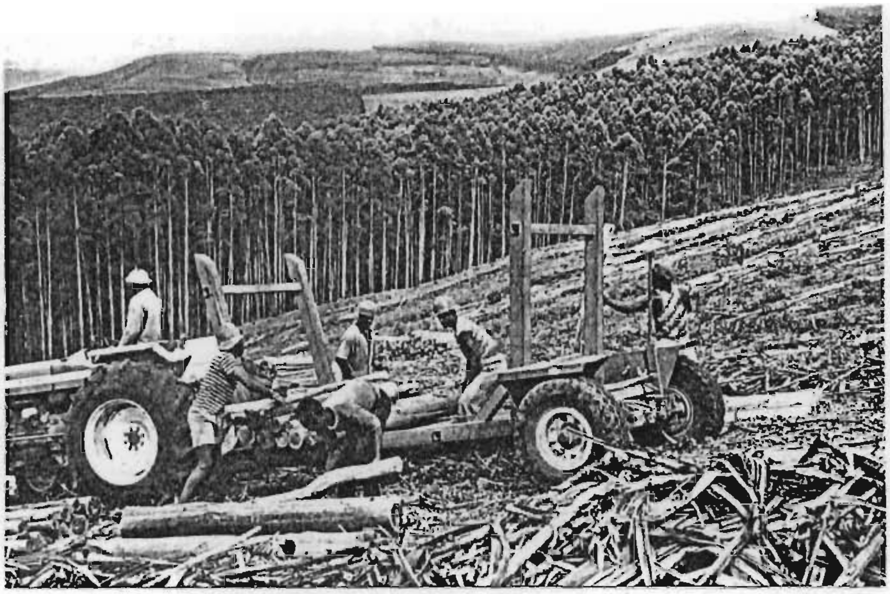
5.6.3 *Shortwood Loading, Offloading and Transshipping*

5.6.3.1 *Loading*

Trailer bed heights range from 0,60 to 1,5 metres from ground level and lorries measured range from 1,0 to 1,5 metres. Manual loading times per ton increase with increased bed height as it is necessary to load higher and worker efficiency declines steeply when loading over 2,7 metres. Examples of low-bed trailer work are shown in Figures 5.5 and 5.6.

Basic minutes to manually load one ton of shortwood poles transversely on a low-bed vehicle (60 cm high) and on a flat-bed vehicle (100 cm high) were regressed on pole mass. The t values of the regression coefficients were highly significant, but the distributions of error residuals were 'U' shaped and expanded to the

FIGURE 5.5



Five labourers load a six-ton low-bed trailer in steep terrain. The bed height is 60 centimetres. Trailer wheels are positioned at the extreme rear of the trailer and at maximum permissible track to maximise stability.

FIGURE 5.6

A female tractor driver negotiates an 18 degree slope with a tractor and low-bed trailer. Even the top poles on the six-ton load are within a comfortable reach.

right. The natural logarithmic transformation of both dependent variables gave a satisfactory distribution. A natural logarithmic transformation of the pole mass increased the t value with the regression model for the low-bed vehicles, but lowered the t value with the regression model for flat-bed vehicles.

Details of the above regression models are given in Table 5.26. Relaxation allowance should be included in certain cases (Section 5.6.2).

Vehicles with beds of 1,4 metres high or more are normally mechanically loaded which is recommended as only about 1,3 to 1,5 metres high of timber can be loaded manually without high reduction of worker productivity. This quantity of timber is far below the usual vehicle capacity and results in low vehicle utilisation. Consequently, no studies have been run on manual loading of high-bed vehicles.

Where the five to six ton low-bed trailers are to be offloaded by crane with the poles in bundled form, as described in Section 5.8.2.1, after loading, four labourers encircle each end of the transverse loaded timber with chains fitted with trip-grip hooks. Before leaving the offloading landing another pair of chains is collected by one of the loader labourers who always accompanies the vehicle. Standard minutes for these semi-variable activities to the nearest half minute are as follows :

Semi-variable activity	No. of observations	Standard minutes: Actual	Standard minutes: To nearest 0,5
Position chains (4 labourers)	21	2,1 (SD 0,4)	2,0
Collect chains	7	0,4 (SD 0,2)	0,5
			2,5 ... 5.71

Table 5.26

Regression models relating basic minutes for manual loading and offload of vehicles to pole mass

Dependent variable	df	r^2	Regression constant	Regression coefficient pole mass (kg)	Equation number
Load low-bed	21	0,7770	4,797040 (16,923)	- 0,828132 (8,554)	5.72
Load flat-bed	11	0,4596	2,940004 (18,767)	- 0,020293 (3,058)	5.73
Offload	2	0,7194	10,75703 (5,894)	- 0,158266 (2,264)	5.74

Lowbed vehicles have a bed height of 60 centrimetres and flatbeds 100 centimetres.
Figures in brackets are t values of regression constants and coefficients.

Regression models are as follows :

Equation number : 5.72 : $\ln Y = \beta_o + \beta_1 \ln X_1 + \varepsilon$

5.73 : $\ln Y = \beta_o + \beta_1 X_1 + \varepsilon$

5.74 : $Y = \beta_o + \beta_1 X_1 + \varepsilon$

5.6.3.2 *Offloading*

There are two vehicle designs used in manual offloading; those with fixed uprights to hold the timber and those with trip sides where the pulling of a lever causes one side's uprights to collapse.

Shortwood poles are ideally loaded transversely as this obviates turning the pole through 90 degrees to offload. For trip sides to assist, poles must be loaded longitudinally.

Basic minutes to manually offload one ton of shortwood poles loaded transversely were regressed on pole mass. Although there were only four observations, pole mass was distributed over a wide range (Tables 5.23 and 5.24) and, therefore, have been included. The t value of the regression coefficient was significant at the 20 per cent level only. In addition, with so few observations, the distribution of residuals could not be used to assist in selecting the regression model. Consequently, estimates made using this equation are regarded as a guide only. Details of the regression model (Equation 5.74) are given in Table 5.26.

Basic minutes to offload a vehicle with trip-sides (TO) are as follows :

$$TO = 5{,}922 - 0{,}087\ PM \qquad 5.75$$

Equation 5.75 is derived from Equation 5.74 as it was found that the trip sides reduce the offloading time by 44,9 per cent. Relaxation allowances should be included in certain cases (Section 5.6.2).

5.6.3.3 *Transshipping*

Transshipping of timber to rail trucks is the only such manual operation noted. Haulage vehicles should draw close alongside the rail truck to offload the timber so as to minimise carrying of poles.

In this situation, the offloading times given by Equations 5.74 or 5.75 are used as is applicable. The relationship between times for loading timber on a rail truck to pole mass was found to be the same as for loading a low-bed trailer, (Equation 5.72), if each of the billets of five to seven tons is regarded separately. Thus, the basic minutes per labourer to transship (MTS) is

$$MTS = 5(FO \text{ or } TO + LL) \quad \ldots \quad 5.76$$

Where FO = Equation 5.74

TO = Equation 5.75

LL = Equation 5.72

Where it is impossible to offload near the rail truck, Equation 5.68 and Equation 5.69 should be included with correction of the carrying distance. Normally however, there is a separate team to load rail trucks in such situations and the lorry or tractor-trailer team only offloads. By combining whichever of the above five equations are appropriate, times for all normal situations can be calculated. Relaxation allowances should be included in certain cases (Section 5.6.2).

5.6.4 *Loading and Transshipping of 5,7 to 7,5 Metre Long Poles*

With manual loading of longer poles, normally six labourers are provided per vehicle. Loading times for shortwood poles can be applied if there is approximately one labourer per 2,5 metres of pole.

By establishing the mean pole mass, the mass carried by each labourer can be calculated and either Equations 5.73 or 5.74 applied as is appropriate. Six labourers provide a convenient multiple as they separate into three groups of two or two groups of three for pole length between 4,3 to 5,7 metres and 6,1 to 7,5 metres respectively.

As a simple guide to loading of 5,7 to 7,5 metre poles, the following basic times in terms of one labourer apply :

Operation	No. of poles loaded during studies	Basic minutes in terms of one labourer
Load 1 t of 5,7 to 7,5 m poles	288	32,24 (SD 0,44) 5.77
Transship 1 t of 5,7 to 7,5 m poles	169	18,21 (SD 3,30) 5.78

Relaxation allowances should be included in certain cases (Section 5.6.2).

5.7 MECHANICAL TIMBER EXTRACTION

In this section, prime timber movers are considered. Operating times and performances of lorries and road haulage tractor-trailers, either with mounted cranes or loaded by mobile cranes, but which load from stump are discussed in Section 5.8. Three-wheel loaders until recently were used in southern Africa for timber handling at landings, roadsides and sidings only. However, recently their use in bunching or stacking timber infield was introduced.

This particular application of the loader is currently under investigation. Possible major adversities of this application include soil compaction particularly in sandy soils as discussed in Section 4.5.1.2, stump damage where re-establishment by coppicing is intended and excessive wear and tear especially to tyres.

Observations by the writer show that damage can be reduced. Felling with a maximum stump height of seven centimetres reduces the angle of contact of tyres thus reducing stump and tyre damage. High flotation tyres run at low pressures reduce apparent soil compaction. Leaving bark and branches broadcast over the site cushions tyre contact and scuffing and protects stumps to a limited extent but stumps intended for coppice re-establishment must be cleared after completion of the operation (de Laborde, 1984b).

Production rates given verbally to the writer indicate that 200 tons are stacked per day on regular terrain dropping to 100 tons as slopes increase up to 19 degrees or terrain becomes more difficult. Chainsaw felling with this system is on the contour. Experiments with walking beam axles, as shown on the rear wheels of the forwarder in Figures 3.9 and 3.10 fitted to the conventional one ton loader, are being conducted on 15 to 20 degree slopes. The configuration is referred to as a five-wheel loader.

Infield observations of the five-wheel loader operating on a 19 degree side slope carrying approximately 0,4 tons were impressive. However, tyres on the walking beam axles scuffed causing furrows which would require subsequent restification.

In consideration of the above, it is concluded that it is premature to present results of the scheduled analyses of production rates of this system.

Table 5.27 lists the major studies undertaken in mechanical timber handling with their circumstance, type and duration. The results are discussed in the following sections.

5.7.1 *Highleads and Skylines*

Highlead productivity declines as the timber length being extracted becomes shorter (Sections 3.1 and 6.8.2). Therefore, compared with other forms of mechanical timber extraction, highleading may give lower productivity. However, in cases of steep slopes, compaction - sensitive soils or terrain prohibitive to infield vehicles, highleads or skylines may provide the only justifiable technique of timber extraction.

Currently an eight-ton highlead with a 250 metre maximum lead distance and a locally made highlead with a 350 to 400 metre lead distance and an hydraulic drive are being introduced and initial investigations into skylines are to commence shortly. Hitherto essentially the four-ton highlead with a 165 metre maximum lead distance was used in Southern Africa (Figure 3.1).

As the new highleads accommodate appreciably heavier loads, have longer reaches and have higher winch speeds, their efficiency is considerably higher than the four-ton highlead and their application wider. Additional benefits of the new highleads are that with the greater lead distance road density can be reduced and with the locally made highlead setting-up time is shorter as it has only one stay and it is highly manoeuvrable.

Crowther and Forester (1964) and Zaremba (1976) have described the application of highleads. Winch times are influenced,

TABLE 5.27

Circumstance, type and duration of mechanical timber handling studies.

Subject	Tree species	Area	Combined no. of studies	Pole diameter range (cm)	Mean pole/ log mass (kg)	Poles/logs per grab on extraction	Slope (degrees)	Ambient day temperatures[2]	Type of study	Duration of study (min)	No. of readings (RAS[1] only)
Highlead extraction	*P. patula*	Creighton	2		24	10	8 to 23	Cool to warm	RAS/TS[3]	135/416	296
Forwarder extraction	*P. patula*	Karkloof	1		61	6	0 to 7	Warm	TS	46	
"	*P. patula*	Creighton	1	7,6 to 22,9	46,9	9	4 to 9	Warm	TS	98	
"	*P. patula*	Richmond	1		19,2	13	0 to 5	Warm	TS	286	
				Bundle mass (t)							
Pole bundle handling	*E. grandis*	Natal Midlands	3	4,8 to 6,3			0	Warm	TS	175	
P. patula saw-log handling by mobile crane	*P. patula*	Singisi	4		290,1	8	0	Cold to warm	TS	366	
P. patula pulpwood handling by mobile crane	*P. patula*	Singisi			66,1	3,5	0	Cold to warm	TS		
Three-wheel loaders loading & trans-shipping poles	*E. grandis* & wattle	Karkloof	1		20,6	19,2	0	Warm	TS	467	
"	*E. grandis*	Mid Illovo	1		19,1	19,1	0	Warm	TS	129	
Lorry loading & offloading short-wood poles with self-mounted cranes	*E. grandis*	Richmond	1		19,2	23,8	0	Warm to hot	TS	304	
Lorry loading & transshipping 9,3 m poles	*E. grandis*		3		193,4		0	Cool	RAS		614

Note: [1] RAS is an abbreviation for rated activity sampling.
[2] See Note 3, Table 5.1 classifying temperature ranges.
[3] TS is an abbreviation for time study. RAS/TS indicates a combined study.

inter alia, by the tractor engine power and the drive sprocket size. The medium, 23 tooth sprocket was fitted to the highleads studied. The times below are inclusive of sundry winching delays, such as loads snagging. It must be noted that these data only apply to the Igland 4000 winch fitted with the above drive sprocket.

Basic minutes for winching a load in and for returning the carriage were both regressed on lead distance in metres. t Values of regression coefficients were highly significant. Distributions of error residuals plotted against the variables were satisfactory. Transformations of the independent variables did not improve the models. Details of both regression models are given in Table 5.28.

Semi-variable activities and fixed activities per 360 minute working day noted are as follows where there is one choker setter; one labourer positioning poles, if crosscut, and releasing chokers, and one operator cum driver.

Activity	No. of observations	Standard minutes	
Set choker chain	109	0,68 (SD 0,22)	
Release choker chain	109	0,22 (SD 0,12)	
Total		0,90	5.81

Fixed activities	No. of observations	Standard minutes	
Change highlead position[1]	6	16,3 (SD 3,2)	5.82
Sundry delays, repairs and maintenance (average of 2 day's work)		12,0	5.83

Note[1] The operator and two labourers work together during these changes.

Table 5.28

Regression models relating basic minutes for highlead operations to lead distance

Dependent variable	df	r^2	Regression constant	Regression coefficient of lead distance (m)	Equation number
Winch load	70	0,9431 (P< 0,01)	0,008161 (0,305) (NS)	0,012411 (34,074) (P<0,001)	5.79
Return carriage	69	0,9536 (P<0,01)	0,133055 6,099) (P <0,001)	0,011158 (37,658) (P<0,001)	5.80

Times are only for the Igland 4 000 winch fitted with a 23 tooth sprocket
Figures in brackets are t values of regression constants and coefficients.
Both regression models are as follows :

$$Y = \beta_0 + \beta_1 X + \varepsilon$$

No total is given for fixed activities as compartment conditions will determine the number of times highlead positions are changed. Further, this activity varies considerably. Howe (1982) reported nine minutes to change positions. Distances travelled between positions also influence the activity.

Due to using one choker chain, setting times have been found to be excessive in some situations. Using two choker chains permits setting to be completed during winching. Where heavy stems or logs are being winched a third choker chain permits the one arriving with the timber to be exchanged for a free one without delay. Time is then available to release the choker during winching. The operation is similar to the tag-line systems described in Section 5.7.3.1. Where a single stack of poles or logs or single stems are presented on a bearer to facilitate setting the choker, tag-lines can be unnecessary.

5.7.2 *Forwarders*

Forwarder studies shown in Table 5.27 were in respect of shortwood extraction of clearfelled *P.patula*, first thinning of *P.patula* and clearfelled *E.grandis*, respectively. Crane operating time was influenced by operator expertise and not log mass.

Variable activities per cycle of each crane load included travel empty (return); grab load, logs or poles (grab); travel with load (load|offload) and position load on the forwarder or stack if loading or offloading, respectively (position). The following operating times per cycle were recorded using a 0,25 square metre grapple on a 4,85 ton-metre crane.

Element	No. of cycles	Loading (std min)	No. of cycles	Offloading (std min)
Return	71	0,11 (SD 0,04)	56	0,10 (SD 0,06)
Grab	71	0,13 (SD 0,07)	56	0,14 (SD 0,06)
Load/offload	71	0,12 (SD 0,03)	56	0,09 (SD 0,03)
Position	71	0,10 (SD 0,05)	56	0,09 (SD 0,03)
Total cycle time		0,46 (SD 0,10)		0,42 (SD 0,08)

Variable activities	No. of cycles	Standard minutes	
Crane cycle : load	318	0,428 (SD 0,121)	5.84
offload	251	0,438 (SD 0,141)	5.85
Total	569	0,866	5.86

Semi-variable activities	No. of observations	Standard minutes	
Travel during loading per 10 m	69	0,72 (SD 0,31)	5.87
Prepare to travel after loading or offloading	20	0,39 (SD 0,15)	5.88

	Terrain	Average speed (km/h)	
Infield travelling:			
With load	Open, slopes 4° to 9°	4	5.89
Empty	Open, slopes 4° to 9°	5	5.90
With load	Rocky, slopes 0° to 7°	1,8	5.91

Estimated load capacities of the 0,25 square metre grapples were as follows :

mass per grab	: *P.patula* clearfellings	370 kg
	P.patula thinnings	390 kg
	E.grandis clearfellings	
	load	250 kg
	offload	300 kg
volume per grab for both species and conditions for the densities given below		0,40 m^3

Note : Differences in mass between species are principally due to timber density at various drying stages. Densities were approximately 900, 1 000 and 630 kg/m^3 for the three species, respectively.

5.7.3 *Skidders and Choker Setting*

Skidding operations are undertaken by two-wheel drive agricultural tractors through to the largest specialised skidders. Studies revealed that the operating routine influences skidder output considerably (de Laborde, 1982c).

5.7.3.1 *Double and Triple Tag-line Systems*

Results of a pilot study (de Laborde, 1982c) on an average, but inefficient, operation undertaken on a medium-sized two-wheel-drive agricultural tractor fitted with a four-ton, double-drum winch shows the following time distribution for the two choker setters, skidder operator and the labourer releasing the choker chains. Detail of the log sizes and distance were,

Distance skidded (one way)	100 to 200 m
Slope	fairly level terrain
Mean log mid-point diameter	25,1 cm
Mean log length	4,4 m
Mean log volume	0,216 m^3

Study results are given in Table 5.29.

Choker setters' delay of 65 per cent was caused by having to wait for the return of the skidder carrying the choker chains. The majority of the 45 per cent delay to the skidder driver was through waiting for the choker chains to be set on the four to six logs hauled with each skid. There was a further delay while chokers were released. Finally, skidder travelling time was augmented distinctly, but immeasurably, by the driver making about turns at both ends of the extraction run.

Other brief studies, not included here, and observations by the writer have shown these inefficiencies to be common among growers and contractors and are common in other countries (Section 3.2.4).

By having the skidder return in reverse, the turning delay is obviated. Operators soon learn to travel as fast in reverse as forwards.

Choker setter and skidder delays may be overcome by having only 10 to 12 metres of main line wire rope connected to the winch drum and ending with a quick-release couple. On to the couple a further desired length of the same diameter cable, a tag line, is attached which carries the required number of choker chains.

TABLE 5.29

Division of skidder and worker time in an inefficient skidding operation

Activity	Proportion of time spent by workers on activities		
	Choker setters	Driver/operator	Labourer releasing choker chains
	(%)	(%)	(%)
Set chokers	30		
Unjam winch cable	1	5	
Clear away obstacles	4		
Winch logs		11	
Drive		39	
Unhitch			22
stack logs			58
Wait	65	45	20
TOTAL	100	100	100

Where lighter timber is being extracted, each drum of the winch is provided with three sets of tag-lines with choker chains. Labourers attach the one set of chokers. The second set is with the skidder either hauling or being returned and the third is being released at the landing.

Assuming two winch drums, on arrival of the skidder, the fresh tag-lines are taken for chokers to be set, the attached tag-lines are coupled to the main line, the load winched in and the skidder hauls to the landing. At the point where the load is to be deposited, the winch brakes are released and the tag-lines run out until the quick-release couples are reached whereupon they are uncoupled. By this time, the third pair of tag-lines will have been freed by the labourer at the landing who then drapes them over the front of the skidder and the driver reverses infield to commence the next cycle of skidding.

Difficulty is experienced in manually wrenching choker chains free from heavier logs. It is then necessary for the labourer to unlook the chokers and have the skidder pull them free. In this situation two sets of tag-lines are employed with none being left at the landing. When the skidder arrives infield the tag-lines are still attached to the main lines and it is necessary for the skidder to travel past the logs that have been set and return in order to run the tag-lines out. These are released, the set lines attached and skidding continues as above.

Cable damage from quick-release couples is a common objection to this system especially with large skidders. Any damage can be reduced considerably by the use of a shortening clutch which is small, rounded and never jams.

5.7.3.2 *Skidder and Accompanying Labourer Operating Times*

Skidder operators and accompanying labourers using the above double-tag-line system were studied using combined activity sampling and time studies (Section 4.6.4). Skidder travelling times varied considerably. Terrain, weather, operator skill, machine make, load size and slope, *inter alia*, all have influence on skidder operating times more extensively than with other harvesting operations. The mean standard minutes per 10 metres travelled are given in Table 5.30.

It was found that when using the double-tag-line system, the skidder travels 1,9 times further infield than the lead infield distance to deposit the tag-line being returned. Allowance for this distance is incorporated in the above times.

Other skidder driver activities are summarised below :

Skidder driver activity	Standard minutes	
Wait for labourers, connect tag-line and re-set choker chains	0,69 (SD 0,62)	
Winch	0,51 (SD 0,31)	
Drop load, assist to de-choker and drop tag-line	3,36 (SD 1,07)	
Wait for chokers to be set	0,19 (SD 0,60)	
Total	4,75	5.92

In addition, delays in turning from the field onto the road with a load takes 0,62 (SD 0,44) standard minutes but occurs irregularly at between 20 and 53 per cent of skids. Refuelling takes 6 minutes daily. Both these data and those below are taken from 33 skidder extraction cycles during which 258 stems were handled.

TABLE 5.30

Mean standard minutes (std min) per 10 metres for skidders in various terrain

Conditions	Load volume (m^3)	Travelling time/ 10 m (Std min)	Number of trips	Mean distance travelled per load (m)
Infield with load:				
6° to 14° downhill	7,47	0,245 (SD 0,131)	15	28
0° to 5° downhill	4,28	0,110 (SD 0,015)	20	78
On road with load:				
0° to 5° up- and downhill	7,47	0,120 (SD 0,120)	15	65
0° to 7° downhill	4,28	0,066 (SD 0,010)	20	139
On road with no load:				
0° to 5° up- and downhill	-	0,070 (SD 0,014)	35	124
Infield with no load:				
6° to 14° up- and downhill	-	0,205 (SD 0,051)	15	55
0° to 5° uphill	-	0,122 (SD 0,051)	20	148

Choker setter activities per log are listed below. Standard minutes shown should be divided by the intended number of labourers.

Activity	Standard minutes per log
Walk	0,08 (SD 0,20)
Set chokers	1,37 (SD 0,27)
Haul out and carry tag-lines	0,09 (SD 0,09)
Connect tag-lines	0,11 (SD 0,07)
Re-set chokers and assist with winching	0,20 (SD 0,32)
	1,85 .... 5.93

Due to characteristics of the studies which resulted in various numbers of activities being acceptable for analysis, standard deviations of the above two totals are meaningless.

It is necessary to have one labourer per skidder to uncouple chokers. Unless additional work is allocated, the labourer only works during the activities 'drop load' and 'dechoker'.

5.7.4 *Application of Highlead and Forwarder Data*

To establish highlead or forwarder extraction time per hectare, average cycle time per extraction is developed using the appropriate data above. From the felled stem, crosscut pole or log frequency per hectare and the estimated mean mass per piece, total machine time for the specific area can be determined.

Assuming an even distribution of timber in the field, the average lead distance is simply taken as half the average maximum lead distance. The quantity of timber chokered per highlead winch cycle may have to be determined by brief experiments with the differences in terrain and timber.

Forwarder loading and offloading times are determinable once load capacity is known and thus the number of crane cycles required to provide the load. Travelling distance during loading is estimated knowing what distance of swathe between brush lines will provide the required timber mass or volume for the load.

Refuelling time and travelling time for the highlead or forwarder to reach and return from the work area should be established and subtracted from the total length of the working day. Forwarder travelling time on roads can be determined by road analyses (Section 5.9). Although it is normally incorrect usage of a forwarder to undertake road haulage, exceptions were noted in Section 4.4.6.

5.8 TRANSPORT

Major studies undertaken on mechanical timber loading, offloading and transshipping are listed in Table 5.27 with their circumstance, study type and duration. A 10 per cent relaxation allowance is applied in all cases in this section. Where mean waiting times exceed the allowance, times should be reduced by this amount.

5.8.1 *Three-wheel Loaders*

5.8.1.1 *Eucalyptus grandis Shortwood Poles*

Three-wheel loaders studied were all nominally of a one ton capacity and equipped with an 0,33 square metre grapple. The major studies were on machines having a telescopic boom (teleboom) and minor observations were on the high boom. The only significant operating difference noted between the two boom types is that the high boom can load to a maximum height of 3,5 metres and the teleboom 4,0 metres (Figure 4.1).

Transport lorries and trailers carrying payloads of 20 to 35 tons have bed heights of approximately 1,5 metres. Loading to a height of 3,5 to 4,0 metres means the difference of a 2 or 2,5 metre height of load. Clearly, the additional 25 per cent load per vehicle obtainable by using the teleboom is important, provided that it is within the legal limit of the vehicle.

Standard minutes for elements per cycle of loading (defined in Section 5.7.2) are given below for transshipping directly from tractor-trailers and lorries and loading from stacks of timber to timber rail trucks. In both cases the shortwood poles were 12 metres away from the rail trucks.

Element	No. of cycles	Trailers & lorries (std min)	No. of cycles	Stacks (std min)
Return	168	0,15 (SD 0,06)	88	0,14 (SD 0,02)
Grab	168	0,18 (SD 0,08)	88	0,24 (SD 0,15)
Transship/load	168	0,19 (SD 0,06)	88	0,16 (SD 0,05)
Position	168	0,14 (SD 0,06)	88	0,14 (SD 0,06)
Total cycle time		0,66		0,68

Return times are slightly lower for stacks because there is a 90 degree turn instead of 180 degrees. Grab time is distinctly slower and more variable from the stacks. Transshipping times are considerably higher from trailers and lorries as the loader makes a 180 degree turn instead of only 90 degrees from the stack and, with the load, the loader's movement is retarded.

When loading a lorry or semi-trailer with shortwood poles, it is necessary to neaten each grapple load by swinging the load until the poles are vertical and striking the buts on the ground. This neatening compacts the total length of the three to five billets of poles (Figure 5.7).

Standard minutes for elements of the trailer and rail truck loading cycles are given below. All loading was from stacks 12 to 17 metres away from the vehicle being loaded. The loader was fitted with a teleboom.

Element	No. of cycles	12 m distance (std min)	No. of cycles	17 m distance (std min)
Return	50	0,11 (SD 0,03)	14	0,19 (SD 0,04)
Grab	50	0,21 (SD 0,12)	14	0,21 (SD 0,11)
Neaten	50	0,16 (SD 0,09)	14	0,16 (SD 0,08)
Load	50	0,16 (SD 0,07)	14	0,19 (SD 0,03)
Position	50	0,17 (SD 0,09)	14	0,16 (SD 0,05)
Total cycle time		0,81		0,91

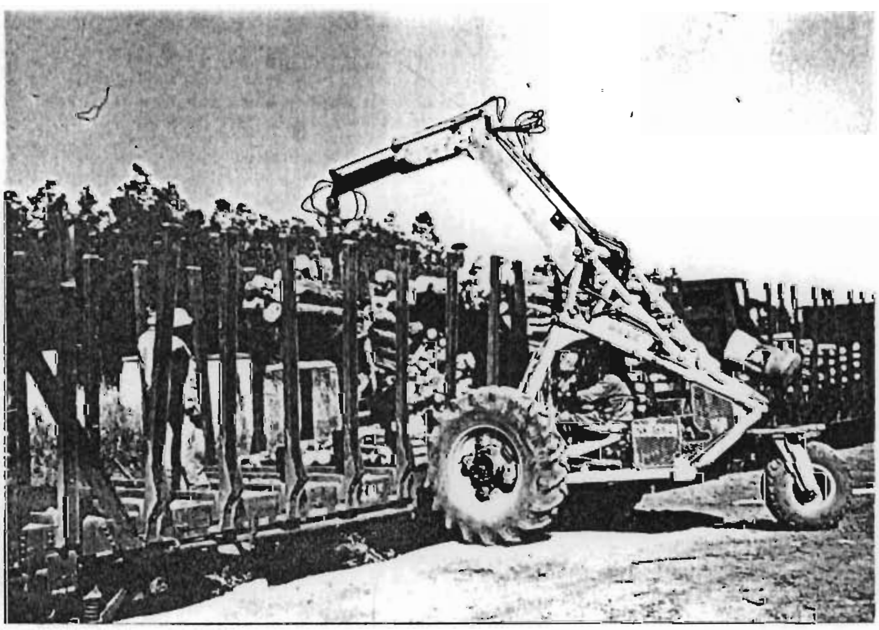
The effect of the greater lead distance is distinct for both the travelling elements, return and load.

Cycle times from 516 loading cycles were as follows:

Activity	Standard minutes	
Mean loading cycle	0,66 (SD 0,02)	5.94
Mean loading cycle with 'neaten'	0,81	5.95
Minimum loading cycle	0,62	5,96
Minimum loading cycle with 'neaten'	0,78	5.97

FIGURE 5.7

A three-wheel loader 'neatening' its load.



The loader places its load in a rail truck

The minimum time is obtained from summing minimum times for each element which gives the approximate situation if the lorries and trailer reversed up to the rail truck or vehicle to be loaded thus reducing the loader's lead distance and having a 90 degree turn only.

Estimated handling capacities of timber per loading cycle are given below :

Mass per grab :	*E.grandis*	402,5 kg
	Wattle	368,0 kg
Mean pole mass :	*E.grandis*	21,6 kg
	Wattle	18,7 kg
Volume per grab :	*E.grandis* (at 1,47 m^3/t)	0,592 m^3
	Wattle (at 1,19 m^3/t)	0,438 m^3

The essential reason for the greater grapple volume and mass for *E.grandis* compared with wattle is the straightness of the *E.grandis* poles. This is in agreement with the findings of Schönau and Boden (1980).

From all the above data, compilation of the offloading, loading and transshipping times for three wheel loaders should be simple, once load masses are available. However, as with all such fleet offloading operations, the waiting line, or queuing, problem will arise increasingly as the loader's demand increases. Tip offloading as near to the vehicle being loaded as possible obviates the problem.

The first 2,2 ton capacity three-wheel loader was manufactured during the first half of 1983, but machines have not yet been made available for initial trials. They can be equipped with a 0,6 square metre grapple and have a teleboom as an option which will reach to 4 metre maximum loading height according to personal discussions with the manufacturers.

5.8.1.2 *Sorting and Stacking of Pinus patula after Crosscutting*

Following crosscutting (Section 5.5.3) logs are normally sorted and stacked preparatory to being loaded (Section 5.8.2.2). Although other techniques are used in small-scale operations (Section 4.3.4.1) the half-ton three-wheeled loader is used almost exclusively in larger-scale operations.

Observations revealed that it is necessary to have one loader per large specialised skidder. The work volume obviously varies but it is impracticable in most situations to divide a loader's work between several skidders. Balancing of work and accommodating it as work-site locations diverge are principal objections.

5.8.2 *Mobile Cranes*

Two broad descriptions of mobile cranes are used in forestry. Those handling shortwood poles in bundled form and those used to load shortwood and longer length poles or logs. Analysis of the latter is identical to the data for forwarder and haulage-lorry-mounted cranes. (Section 5.7.2 and 5.8.3.1).

5.8.2.1 *Bundled Shortwood Poles*

Application of crane handling of bundled timber presented below is described by de Laborde (1983a). Times are rounded off to the nearest half minute.

Crane operation	No. of observations	Standard minutes per unit indicated	
		Actual	To nearest 0,5
Off load low-bed[1] trailer (Figure 5,8)	18	0,97 (SD 0,56)	1,0 ..... 5.98
Offload and place bundle in stock pile[2]	6	1,83 (SD 0,33)	2,0 ..... 5.99
Transship from low-bed trailer or stack to road haulage tractor's trailer[3], per bundle	12	2,42 (SD 0,38)	2,5 ..... 5.100
Transship from low-bed trailer or stack to lorry[4], per bundle	12	3,48 (SD 0,52)	3,5 ..... 5.101
Remove bundles' chains returned by haulage tractor-trailer or lorry	4	1,93 (SD 0,30)	2,0 ..... 5.102

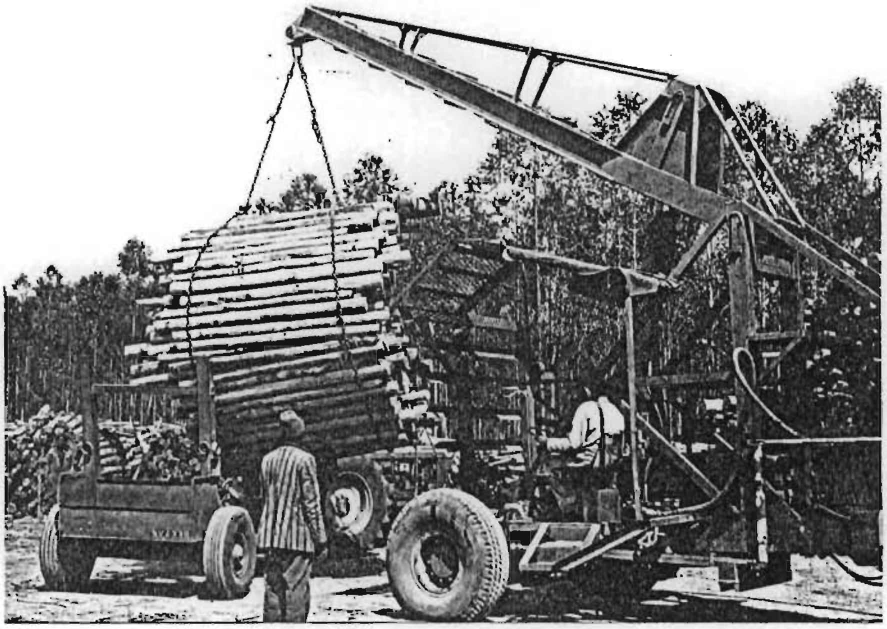
Notes : [1] Low-bed trailer capacity is nominally five to six tons and is cross-loaded. (Figures 5.5 and 5.6). Cane chains are positioned infield (Section 5.6.3.1).

[2] Where a haulage vehicle is not available, pole bundles are placed in a buffer stock.

[3] These trailers accommodate three bundles positioned transversely (Figure 5.9).

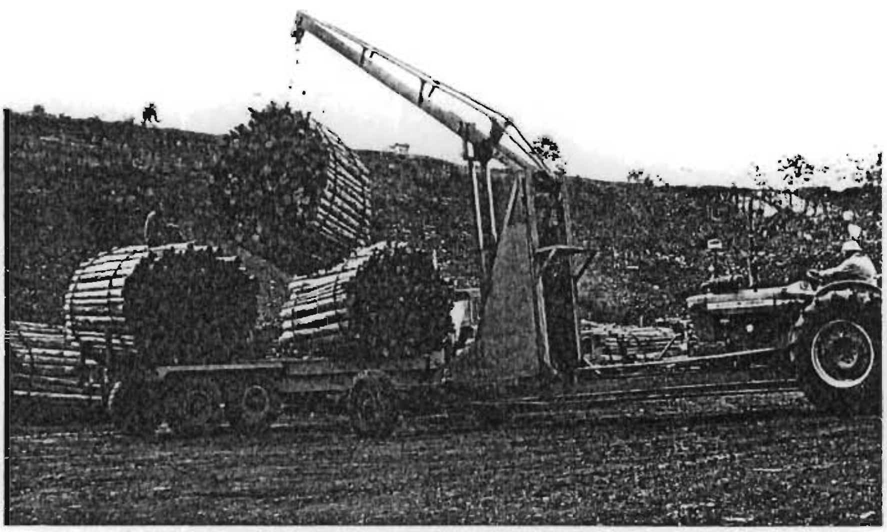
[4] Lorries accommodate five to six bundles loaded longitudinally. To fit the bundle between the vehicle's uprights, the crane operator drops and drags the bundle until it is in an ovalled form. This, plus the increased time in fitting bundles between uprights results in the greater loading time with lorries. These difficulties are illustrated in Figure 5.10.

FIGURE 5.8



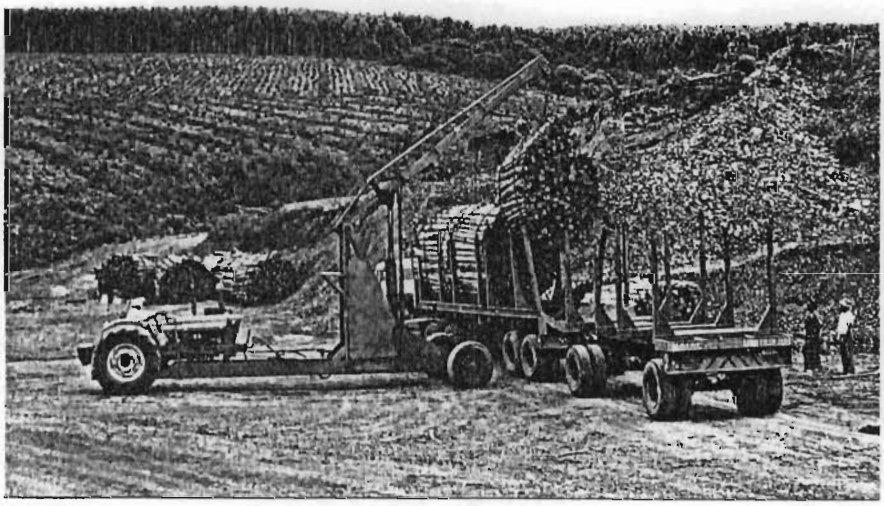
Offloading the low-bed trailers with a front-wheel-drive crane

FIGURE 5.9



Loading an 18-ton trailer transversely

FIGURE 5.10



Loading a 30-ton lorry longitudinally

5.8.2.2 *Pinus patula Sawlogs and Pulpwood*

Mobile cranes for pine timber loading are either mounted on light two-wheel-drive tractors or on modified lorries. Although the fuel consumption is reported by growers to be 3,5 ± 0,5 and 7,5 ± 0,5 litres per hour, respectively, lorries are preferred where there is much travelling involved.

Variable activities for each loading cycle are as given for forwarder cranes in Section 5.7.2. Cranes are usually equipped with 0,4 square metre grapples or smaller grapples for large logs to prevent crane overloading. The following are the standard minutes for the work elements per cycle (Section 5.7.2) for a eight ton-metre crane.

Element	No. of cycles	Sawlogs (std min)	No. of cycles	Pulpwood (std min)
Return	136	0,12 (SD 0,03)	130	0,13 (SD 0,03)
Grab	136	0,18 (SD 0,05)	130	0,18 (SD 0,07)
Load	136	0,19 (SD 0,02)	130	0,18 (SD 0,03)
Position	136	0,24 (SD 0,07)	130	0,17 (SD 0,04)
Total		0,72 (SD 0,11)		0,66 (SD 0,13)

Total mean cycle times are as follows :

Variable activities	No. of cycles	Standard minutes
Crane cycle : sawlogs	136	0,741 (SD 0,103) 5.103
pulpwood	130	0,683 (SD 0,124) 5.104

The total element time is slightly lower than the cycle time as the latter includes unavoidable sundry delays. Semi-variable activities are as follows :

Semi-variable activity	Occurrence for 266 cycles	Standard minutes
Change position during loading	9	1,52 (SD 0,67) 5.105

Handling capacity of 0,40 square metre grapples were as follows :

Mass and volume[1] per grab :	sawlogs	1 028 (SD 100) kg and m^3
	pulpwood	592 (SD 53) kg and m^3

Note[1] Timber density was approximately 1,0 tons per cubic metre.

Application of the above data is similar to the description in Section 5.7.4. The 'change position during loading' requires its time to be proportioned to each cycle time once its frequency is established for a given situation. In the above situation, it will be 0,05 standard minutes per crane cycle.

5.8.3 *Lorries with Mounted Cranes*

5.8.3.1 *Shortwood Poles*

Lorries equipped with six ton-metre mounted cranes having 0,4 square metre grapples were studied loading and offloading shortwood *E.grandis* poles. Standard minutes per cycle for the elements comprising the load and offload cycles are given below in addition to mean cycle times and semi-variable activities for these two operations.

Element	No. of cycles	Loading (std min)	No. of cycles	Offloading (std min)
Return	49	0,12 (SD 0,06)	48	0,15 (SD 0,06)
Grab	49	0,16 (SD 0,07)	48	0,13 (SD 0,05)
Load/offload	49	0,15 (SD 0,05)	48	0,14 (SD 0,04)
Position	49	0,12 (SD 0,04)	48	0,06 (SD 0,03)
Total cycle time		0,55 (SD 0,10)		0,48 (SD 0,07)

Variable activity	No. of cycles	Standard minutes	
Crane cycle : load	148	0,546 (SD 0,107)	5.106
offload	152	0,492 (SD 0,090)	5.107
Total	300	1,038	5.108

Semi-variable activities	No. of readings	Standard minutes	
Prepare to travel	13	0,95 (SD 0,31)	
Position and set outriggers	13	0,75 (SD 0,32)	
Total		1,70	5.109

Estimated load capacity of the 0,4 square metre grapples for *E.grandis* shortwood poles were as follows :

Mass per grab	475 kg
Volume per grab at 1,47 m^3/t	0,70 m^3

Vehicle travelling times are discussed in Section 5.9.

5.8.3.2 *Poles 9,3 metre long*

Loading and transshipping of 9,3 metre long *E.grandis* poles onto a timber rail truck for the pole size quoted in Table 5.28 are as follows :

Variable activity	No. of poles handled	Standard minutes
Per pole : load	71	0,76 (SD 0,19)
offload	127	0,95 (SD 0,28)
Total		1,71 .... 5.110

5.9 VEHICLE POWER REQUIREMENTS AND PERFORMANCE

Where vehicles are operating in difficult terrain, travelling times can be established through timing reliable drivers negotiating these routes. Such information is provided for skidder operations in Section 5.7.3.2.

Low-bed tractor-trailers discussed in Section 5.6.3.1 and 5.8.2.1 were found to travel infield and on forest roads in steep terrain at an average speed of 5,40 (SD 1,24) minutes per kilometre which was rounded off to 6 minutes per kilometre or 10 kilometres per hour on a round trip.

Establishment of vehicle engine power and gear ratios for given gross vehicle masses to negotiate all road conditions at stated speeds can be established simply from road analyses and application of existing data except where conditions enforce reduced speed. These data are internationally available in such publications as the Transport Manager's Handbook (1982/83).

With the recent legal requirement that lorries and tractors, with special exceptions, must be fitted with the Atlantis Diesel Engine, this publication has provided details of expected fuel usage, torque and power output for each engine size.

Road analyses require that distances, gradients and road surface types be recorded for the vehicle's intended route. Major factors in establishing engine power and vehicle speed include gross mass, road speed, rolling resistance, air resistance, drag coefficient and gradeability which is the sum of the slope expressed as a per cent and the rolling resistance determined by road surface type.

From the above analysis and engine performance data, gear ratios can be selected to ensure that the engine will be able to operate within its optimum performance range on most sections of the route.

Vehicle configuration and optimum size are determined by undertaking the above analysis on viable options also considering terrain, lead distances, scales of operation and categories of timber to be transported. Costs supplied by the Economics Division of the South African Timber Growers' Association (1982) show that the larger the transport vehicle's payload, the lower the cost per ton kilometre. In addition, tractor-trailers have a considerably higher running cost than lorries.

Although this is correct in the majority of situations, in mountainous terrain and poor road conditions several contractors have reported verbally that smaller lorries are more cost efficient than larger lorries. Further, the above cost analyses have shown that costs vary considerably between different vehicle makes of a given capacity.

CHAPTER 6

HARVESTING AND TRANSPORT SYSTEM SELECTION, PLANNING AND CONTROL

6.1 SELECTION CRITERIA

Factors for selecting the harvesting and transport systems identified include, *inter alia,* tree species; terrain; soil type; scale of operations; labour availability; capital equipment availability, reliability of it remaining on the market and its standard of after-sales service; size and availability of working capital; anticipated market trends and anticipated enterprise growth. Moreover, there may be company or government policies which dictate criteria. For example, certain countries' government policies require that labour intensive systems be employed to combat their excessive unemployment.

Many of these factors are clearly interrelated and cannot be discussed in total isolation. Nevertheless, as far as possible, each topic is discussed independently.

6.1.1 *Selection of Systems for Primary Conversion*

As discussed in Chapters 4 and 5, certain systems for primary conversions relate specifically to wattle, *E.grandis* or *P.patula*. Table 6.1 shows possible options when selecting systems for primary conversion in which consideration is given to tree species, scale of operation, terrain type, forest produce types and the level of labour or capital intensiveness of the various systems.

Scales of operation noted in Table 6.1 are defined in Table 6.2. The bowsaw system in *E.grandis* only should be applied where production is about 16 trees per day (about 3 cubic metres or 2 tons of timber) which can be processed by four labourers.

Where the scale of operation for wattle is approaching the level of one, as defined, the bowsaw system is only advocated (de Laborde, 1979, p2) "where the following circumstances apply :

- labour overheads are low
- there is an adequate supply of suitable labour
- harvesting if far from close supervision or where access is difficult
- the grower is not mechanically inclined nor the operation large enough to warrant employing a mechanic."

Levels of labour and capital intensiveness of systems is again an arbitrary indicator. Definition of the symbols are as follows :

Labour and capital intensive symbol	Definition
A	Labour at maximum intensiveness. Only hand tools and the simplest transport vehicles are used.
B	Labour intensive, but chainsaws are used to fell and crosscut and light mechanization such as tip transport vehicles employed.
C	An approximately equal balance of labour and capital intensive techniques are used. This may include a semi-bench harvesting system in wattle and *E.grandis*.

TABLE 6.1

Guide to selecting systems for primary conversion for wattle, *E.grandis* and *P.patula*

Harvesting system	Tree species	Scale of operation[1]	Terrain type	Wattle		*E. grandis*		*P. patula*		Labour/ capital Intensive[2]
				Bark	Shortwood	Shortwood or fixed pole length	Variable pole length from shortwood to transmission	Sawlogs	Pulpwood	
Bowsaw	Wattle	1	any	✓	✓					A
	E. grandis	<1	any			✓	✓			A
Conventional	Wattle	1 to 4	any	✓	✓					B
	E. grandis	1 to 4	any			✓	✓[3]			B
Semi-bench	Wattle	3 to 4	any	✓	✓					C
	E. grandis	3 to 4	any			✓				C
Bench	Wattle	3 to 4	any	✓	✓					D
	E. grandis	3 to 4	any			✓				D
Integrated[4]	Wattle[5]	4 to 4	difficult[6]	✓	✓					C/D
	E. grandis	1 to 4	difficult			✓	✓[3]			C/D
	P. patula	1 to 4	all					✓	✓	C/D

Notes: [1] Scales of operation are defined in Table 6.2.

[2] Definition of the coding in the last column is given in Section 6.1.1.

[3] Where longer lengths are cut either markers are employed who can mark ahead of crosscutting without delaying the chainsawyer or marking is undertaken after the timber has dried to reduce splitting. In this case the deferred crosscutting is done by a separate team usually using chainsaws but occasionally bowsaws if labour is plentiful.

[4] In difficult terrain where slopes exceed 22 degrees, timber will have to be winched, highleaded or skylined as well as,or in the place of, the skidding operation.

[5] Wattle harvesting by this sytem is suggested for large scale operations as skidding may deteriorate the bark quality. Therefore, it is advocated only when enforced by an undersupply of labourers or direct loading system.

[6] Difficult terrain is as defined in Section 5.5.1.

Table 6.2

Arbitrary definitions of scales of operation for wattle, *E.grandis* and *P.patula*

Scale of operation	Species	Daily production rate			
		Trees	Volume (m^3)	Mass [2] (t)	Bark (t)
1	Wattle	150	19	16	3,5
	E.grandis	200	35	24	
	P.patula	165	100	100	
2	Wattle	150 to 400	19 to 50	16 to 42	3,5 to 9,5
	E.grandis	100 to 500	35 to 90	24 to 60	
	P.patula	165 to 550	100 to 333	100 to 333	
3	Wattle	400 to 1300	50 to 165	42 to 140	9,5 to 30
	E.grandis	500 to 1650	90 to 300	60 to 205	
	P.patula	550 to 1000	333 to 600	333 to 600	
4	Wattle	≦ 1300	≦ 165	≦ 140	≦ 30
	E.grandis	≦ 1650	≦ 300	≦ 205	
	P.patula	≦ 1000	≦ 600	≦ 600	

Notes: [1] Daily production rates for the three three species differ mainly because of the harvesting systems required and characteristics of the tree specie.

[2] Mass for wattle and *E.grandis* are calculated on being 1,19 and 1,47 m^3/t after 6 weeks air drying. *P.patula* is calculated wet with bark on at 1 m^3/t.

Chainsaw felling and crosscutting and manual debranching of *P.patula*. Manual loading of shortwood poles, but mechanical offloading and transshipping.

D — Capital intensive. Using the bench system in wattle and *E.grandis*. Chainsaw felling, debranching and crosscutting in *P.patula*. Timber extraction and transport is by forwarders, skidders, highleads, skylines, various loaders and crane operations.

E — Capital at maximum intensiveness using such techniques as radio controlled winches or highleads, harvesters, feller-bunchers, infield chippers, mechanical delimbers and crosscutters, plain or clam-bunk skidders, forwarders and crane transshipping to large transport lorries with possibly gantry offloading. Here every attempt is made to minimise all human work.

6.1.2 *Labour Availability*

In southern Africa, E level capital intensive systems are being used by several of the largest companies, others are investigating the feasibility of such systems.

As discussed in Section 2.2 there is a national urgency to provide employment for rural Black Africans especially with the expected increase in their economically active numbers (Terblanche, 1981, p. 17). Where there are only marginal benefits from the use of more capital intensive systems, cognizance should be taken of the long-term macro-economic benefits of having a greater number of economically viable persons.

Factors discouraging more labour intensive systems include, *inter alia*, resistance to strenuous manual work such as timber loading, debranching, stacking and debarking; demands for higher wages that make capital intensive systems attractive; increased education causing a resistance to return to labourer-type work and the necessity of providing high-cost housing, medical care and food as fringe benefits free to employees.

Conversely, escalating costs of machinery and their maintenance tend to compel growers to meet the higher labour costs. Furthermore, it has been noted repeatedly (observations by the writer and by Horton, 1981) that labour availability for the grower is strongly influenced by the quality of personnel management. Albeit that there is the general trend cited in Chapter 2 towards mechanization.

6.2 SYSTEM SELECTION FOR LIGHT TO MODERATE TERRAIN

6.2.1 *Extracting and Transporting Wattle Bark and Wattle and Eucalyptus grandis Shortwood Poles*

Manual loading of timber was found to be the most common method in 1982 (de Laborde, 1982). However, current investigations by the writer show a distinct decline over the two years. In areas where labour is still available, manual extraction and loading of timber can be less expensive than other methods. Infield manual loading also is efficient when timber is taken from where it was left either lying scattered between brush lines, but clear away from the centre of the swathe to permit the vehicle passing, or with the timber bunched. In either situations detailed cost comparisons with alternative systems are necessary for selection.

Results show that low-bed trailers are easier to load and because shortwood poles only can be loaded efficiently to a maximum of approximately 2,7 metres the low bed allows a greater height of timber to be loaded (Section 5.6.3.1). Thus a tip lorry or trailer has approximately a 0,3 metre height disadvantage compared with a flat-bed vehicle. The advantage of having tip offloading requires assessment because of its smaller load or, alternatively, longer loading time.

Where labour is unavailable, with scales1 and 2 operations light grapple cranes (under two ton-metres) can be fitted to tractors' trailers thus forming a forwarder (Sections 3.2.1 and 5.7.2). Since the work usually comprises cycles of loading, travelling 5 to 15 metres and loading again, constant mounting and dismounting reduces productivity significantly. Therefore, controls should be positioned within reach of the tractor's seat. However, to permit the tractor being independent of the trailer, crane controls can be positioned on a support protruding from the trailer (de Laborde, 1984c).

Where lorries are used and mechanical loading is necessary, grapple cranes also usually provide the most satisfactory solution. In all cases boom lengths should be long enough to load a rear billet of timber it applicable.

For scales 3 to 5 operations, articulated forwarders with multi-wheel drive may be used (Figures 3.9 and 3.10). Having formed poles into billets, it can be of advantage for further handling to retain it in this form by using cane chains when moved and storing billets with a single light chain to reduce the numbers of expensive cane chains (Section 5.8.2.1). Billets are moved by special cranes (Figures 5.8 and 5.9). A billet can be loaded in 3,5 minutes (Activity Mean 5.101) whereas from data in Section 5.8.3.1, it takes a grapple crane about 6 minutes to load the same mass of poles.

With any extraction of timber by forwarder, poles must be bunched or stacked. Where there are in excess of three to four categories it is usually preferable to skid tree stems to roadside or a landing before crosscutting (Sections 6.2.4).

6.2.2 *Comparison of Handling Techniques for Wattle Bark and Wattle and Eucalyptus grandis Shortwood Poles*

Wattle bark is handled similarly to the description in Section 6.2.1 only that manual loading maybe supplemented by the particular mechanical timber-loading technique used. Inter-comparisons of five timber extraction systems are made using a computer programme (Section 6.7.2). The following comparisons, however, warrant independent discussion.

6.2.2.1 *Transport Vehicle Mounted Cranes or Independent Mobile Cranes*

In level terrain where lorries are able to load at stump there is the alternative of loading with a mounted crane on each lorry or an independent mobile crane serving a balanced number of lorries sc the waiting-line problem is controllable. An over-riding consideration is whether there are offloading facilities available at the siding, station or sawmill. Where none exist there is the further consideration of the grower or contractor providing a mobile offloading crane albeit operating at another company's sawmill.

Such mobile cranes only require to be mounted on old, but reliable, small two-wheel drive tractors. Without an individual company's transport situation and precise cost structure it is impossible to evaluate the superiority of either option accurately. Components of the cost are the payload lost and power absorbed in transporting transport-vehicle-mounted cranes continuously and the extent of its daily crane operating time. A most influential factor is the transport distance. The shorter the distance, the greater is the crane utilisation and the lower the above relative wastages. Further with short cycle times for transport vehicles the waiting line problem will be more serious with the use of an independent crane.

The only relative cost data available are on 7 ton plain lorries and lorries with mounted cranes as quoted by the Economic Division, South African Timber Growers' Association (1982, p. 15). These costs are 8,9 and 19,5 cents per ton kilometre excluding labour, respectively. The cost, excluding labour, is taken as the driver may be regarded as a sunk cost because only crane loading is being considered. However, it is a frequent practice for a driver of a lorry with a mounted crane to have an assistant. This is ignored in the calculations that follow.

These lorry costs are biased as the vehicles carried mean payloads of 7,1 and 6,9 tons, respectively. Correcting for this, the costs become 8,9 x 7,1/7 = 9,0 cents per ton kilometre and 19,5 x 6,9/7 = 19,2 cents per ton kilometre. The cost of carrying the crane of mass 1,85 tonsis incorporated in the cost. Carrying the crane plus a 7 ton payload is illegal and opposed, the overloaded lorries suffer increased wear and there is increased road damage. However, the 6,9 tons recorded shows that overloading is normal. Consequently, the following comparisons are made to accommodate the normal situation.

Loading by independent mobile crane is given as 0,69 cents per tons including labour. Labour overhead costs for Natal are given as R1,44 per day. Assuming the crane operator loads a vehicle every 15 minutes of a 360 minute working day, the labour overhead costs are R1,44 x 15/360 = 6 cents. Thus the total cost of loading each 7 ton lorry is (0,69 x 7) + 0,06 = R4,89. The difference in cost of operating the two lorry types is 19,2 - 9,0 = 10,2 cents per ton kilometre.

Therefore, the lead distance at which the break-even cost occurs for the options is 4,89/0,102 = 48 kilometres. In the event of the timber supplier having loading and offloading independent mobile cranes, this distance must be doubled. Conversely, where there are more than one haulage vehicle operating, this distance must be divided by that number of vehicles.

Where the timber supplier loads to the legal limit the lorry with the crane only will carry 7 - 1,85 = 5,15 tons of timber. Thus the cost will rise to 19,5 x 6,9/5,15 = 26,1 cents per ton kilometre. The cost differential between the two lorry types is 26,1/9,0 = 17,10 cents per ton kilometre thereby reducing the break-even cost lead distance to 4,89/0,171 = 28,6 kilometres for a single haulage vehicle operating with one mobile crane.

6.2.2.2 *Three-Wheel Loaders or Crane Loading and Transshipping*

From the data provided in Section 5.7.2, 5.8.1 and 5.8.3.1 comparison can be made between three-wheel loaders fitted with the teleboom and 0,33 square metre grapple and cranes capable of accommodating 0,25 and 0,40 square metre grapples mounted on the rear of a tractor of about 45 kilowatt capacity or lorry chassis.

Machine	Cycle time per loading (Std min)	Mass per cycle (kg)	Mass of *E. grandis* short-wood poles loaded per min (t)
1 t 3-wheel loader with 0,33 m^2 grapple	0,62	403	0,65
Tractor-mounted crane with 0,25 m^2 grapple	0,44	300	0,68
Tractor-mounted crane with 0,40 m^2 grapple	0,55	475	0,86

Major advantages of the cranes are, firstly, that they do not have the 3,5 or 4,0 metre height restriction of the loaders (Section 5.8.1). Capital outlay of the larger crane with four out-riggers is currently near R31 000. The vehicle on which the crane is mounted can be established only for a specific case as they could range from small second-hand tractors to new lorries. The current cost of a three-wheel loader is approximately R41 000. (Prices are as supplied by local distributors and manufacturers during September 1984).

Although cranes can be repositioned in 1,52 standard minutes (Activity Mean 5.105) the essential disadvantage of the crane is that loading and offloading points must be positioned within their reach. With a 5,5 metre boom a maximum of 11 metres between the two timber lots may not be exceeded. However, with transshipping of timber this disadvantage is counteracted when comparing cranes with the three-wheel loader by the necessity of having the vehicles parked about 12 metre apart to maximise productivity of the loader.

Further disadvantages of the three-wheel loader compared with the crane are damage to the operating site especially in wet weather where surface damage can be considerable with the constant movement. Accident risks increase in wet conditions particularly on slopes. Soil compaction and stump damage as were discussed previously (Section 5.7).

Enquiries made of a number of users of light tractors who were driving machines off their power-take-offs and three-wheel loaders indicate that fuel consumption is of similar order. Variable costs of the tractor and larger crane are 9,7 and 11,4 cents per ton, respectively, totalling 21,1 cents per ton. The loaders' variable costs are 28,0 cents per ton. The difference in cent per ton is approximately inversely proportional to the tons loaded per minute. Both costs were kindly supplied by large-scale contracting and forestry organisations during August, 1983.

6.2.3 *Extraction and Transport of Eucalyptus grandis Timber over 2,5 metres Long*

Choice of systems for 3 to 7,5 metre *E.grandis* timber extraction and transport for scales 1 and 2 of operations are similar to those discussed for shortwood poles provided the lorries or trailers are able to accommodate longitudinal loading.

Manual loading from stump is acceptable and can be applied as described in Section 5.6.3. Transport vehicle mounted cranes are an option especially where labour is scarce or costly. If labour is available the systems will require individual cost analysis for selection.

Pole lengths of over 7,5 metres become awkward for manual loading indicating need for mechanical loading. A logging heel may have to be fitted to cranes. Where there are a variety of pole or log categories, an individual product cost analysis is advocated to assess whether net profits warrant their inclusion in the product mix.

The Natal Road Ordinance, Regulation 88(1) disallows vehicle-bed lengths to exceed eight metres except in the case of semi-trailers with a "fifth wheel" coupling. A maximum of 1,8 metres rear load projection and a 0,3 metre front load projection is permitted. As the front projection usually cannot be accommodated, this restricts pole lengths to 9,8 metres unless there are sufficient numbers to warrant hiring or purchasing a semi-trailered vehicle.

Where there is a substantial proportion of transmission poles that require strapping or gang-nailing to prevent splitting, a grower may prefer to extract the poles to roadside or a landing. In this situation skidding is a consideration. The magnitude of the operation will determine the skidder and winch size, but there should be a reasonably high proportion of poles infield. With lighter timbers an agricultural tractor with a four-ton double-drum winch is normally preferred as it will accommodate a high number of poles or stems per skidder cycle. Where contour or downhill skidding is applied, a 50 to 65 kilowatt, two wheel-drive tractor is normally adequate.

An alternative system is to strap or gang-nail poles in-field then crane-load either with a mounted crane or an independent mobile crane, directly onto the transport vehicle. Individual productivity and cost efficiency analyses are required to make this choice (Section 6.7). Irrespective of which system is used, initial removal of shorter length poles facilitates locating the larger poles and accommodating their extraction.

6.2.4 *Extracting Wattle and Eucalyptus grandis Timber with a High Product Mix*

Particularly where there are in excess of four categories of timber products, acceptance of each product should follow an assessment of its net contribution to profits.

Measuring, crosscutting, extracting and/or loading a high product mix onto transport vehicles can result in increasing and complicating plantation work considerably as found by Murphy (1978) and Corey (1981) with highlead productivity. To reduce the problem, it has been advised that timbers be cut to the largest common multiple that can be handled. Thus where poles of 0,9, 1,8 and 3,6 metres are required, a single 7,3 metre could be cut with an allowance for kerf wastage (timber lost from the width of the cut). Further size reduction normally can be accommodated at a sawmill at lower cost and inconvenience and, because of having more easily controlled conditions, with greater accuracy and thus less timber wastage (de Laborde, 1984d).

6.2.5 *Transporting Pinus patula Sawlogs and Pulpwood*

Due to the high log mass of *P.patula* even after crosscutting to pulpwood, the integrated system (Sections 4.3.4.2 and 5.5) is popular as it includes skidding to roadside or landing. Thus only loading, offloading techniques and transport vehicle types require selection.

Choice of transport vehicle mounted cranes or independent mobile cranes was discussed in Section 6.2.2.1 as far as possible without a specific grower or contractor's respective costs. Vehicle selection was discussed in Section 5.9.

6.3 SYSTEM SELECTION FOR DIFFICULT TERRAIN

Techniques for extracting timber from difficult terrain are limited and include manual, mule, skidder, highlead, skyline or plastic shutes.

In Section 5.6.1 manual timber extraction was discussed and equations for daily tasks provided. This is recommended only where such terrain has limited occurrence except where labour is plentiful and their total daily costs below that of suitable mechanical alternatives. Legislation in some states may enforce the use of labour.

Plastic shutes remove much of the manual handling and incur no soil damage. However, shutes are still labour intensive and early obsolescence could be encounted. Compared with highleads, they lack versatility in extracting timber from awkward small valleys and, obviously, can be used only where downhill extraction is possible or slopes sufficiently steep. Where long lengths or whole-tree lengths are to be extracted, shute loading and offloading and shute damage could be prohibitive (de Laborde, 1984d).

Mule extraction (slipping) has considerable popularity in the steep areas of the southern Cape, southern Natal, Eastern Transvaal and Swaziland. However, they are normally used for thinning extraction except in Swaziland where they are used for extracting clearfelled pine pulpwood. Daily production has not been studied, but is reported verbally by foresters in all the above areas to range between 10 to 20 tons of timber per day per mule depending on the lead distance. Mules are often used in pairs for slipping heavier timbers.

Skidder extraction was discussed in Section 5.7.3. Observations indicate that a specialised, large skidder generally can negotiate up to 22 degree slopes. However, on these slopes, pressure and gouging by their tyres often results in considerable soil compaction and erosion.

Highleads were discussed in Section 5.7.1 with the probable considerable increase in productivity by using the new eight-ton highlead and locally-made hydraulic highlead instead of the normal four-ton highleads especially in large-scale operations.

Skylines currently cost in the order of R70 000 to R80 000. They are currently being introduced in southern Africa thus no studies have been undertaken.

6.4 ACCOMMODATING SUPPLY AND DEMAND FLUCTUATIONS IN SYSTEM SELECTION

Growers and contractors often face a situation with fluctuations in total timber demand; lengths of poles or logs required, *viz* product mix; the reliability of supply of capital equipment and its related aftersales service; and growth rate of their organisation.

Ignoring lost income, capital intensive systems will incur more severe costs with slack capacity than more labour intensive systems through reduced returns on the relatively high capital investment.

Usually only a fixed pole length is accommodated by the bench system and its variations because the chainsawyer measures the lengths himself. Should an organisation decide to supply various pole lengths they probably will have to convert to using the conventional system with three to four products, or the integrated systems which accommodate any product mix. The change will cause a surplus of chainsaws, their operators and create a demand for labourers. Training also may be required.

Most extraction and transport systems accommodate flexibility in types of products handled except all vehicles designed specifically for transverse loading of shortwood poles. Although some large-scale growers may be assured of supplying their subsidiary or parent companies with shortwood poles, others, essentially small-scale growers, face distinct uncertainty as has occurred with the recent collapse of the pulpwood market. Assessment should be made of the likelihood of having to accommodate longitudinal loading.

Another factor of risk is the reliability of companies marketing forestry machinery. Should a company supplying equipment collapse after their machinery is purchased, it may become obsolete. Hence it is normally advocated that well-known makes be purchased. Further, enquiries should be made as to the quality of after-sales service provided in the particular district being considered.

6.5 PLANNING OF HARVESTING AND TRANSPORT

6.5.1 *Planning Before Planting*

Harvesting planning commences prior to planting. Harvesting and transporting constitute approximately two thirds of the total direct cost of delivered timber (Table 1.1). Much of this cost frequently can be avoided through correct spacing between roads for the various terrain encountered and by having the tree rows in a direction that accommodates harvesting and transport. In addition, if an approximately square espacement is used, there will be wider options of systems and greater freedom for decisions at the time of harvesting.

Typical poor planning except where highleading or skylining is intended, is the provision of roads on a ridge with no roads at the bottom of the valley or above any cliffs which usually results in excessively expensive uphill timber extraction, soil damage and even unnecessary use of highleads or skylines. Roads must be designed to avoid too steep gradients, but to provide as direct access as possible to arterial roads.

Soil compaction (Section 4.5.1.2) can be lessened by establishing cross-strip roads (infield) after felling. These roads reduce the distance between plantation roads and lessening the number of infield vehicle passes. Where possible, the use of such strip roads is preferred as frequent plantation roads decrease the total planted area considerably.

Where highleading or skylining is intended, road distances need to accommodate the lead distances of 165 to 400 metres as described in Section 5.7.1. In addition, they should be wide enough to take both the highlead or skyline and possible timber stacking or provision made for timber stacking above the road with downhill extraction.

6.5.2 *Enterprise Size and Financial Resources*

Consideration should be given to future expansion of an enterprise if adopting labour intensive systems or using such equipment as a crude crane, light tractors or trailers. When expansion occurs and more sophisticated or capital intensive systems are necessary, existing machinery becomes redundant. Redundancy can be avoided by purchasing slightly more sophisticated equipment initially with consideration to future expansion. Conversely, over capitalisation should be guarded against. The extent of investment in capital equipment will be governed by the amount of working capital available. Such a complex assessment will vary with each grower or contractor.

6.5.3 *Planning of Systems*

Prior to commencing harvesting a compartment, tree dimensions, stocking per hectare and, in steeper terrain, slope should be measured. Where undergrowth, rock outcrops and cliffs are likely to cause interference with any of the operation, these should be recorded also. If full surveys have been undertaken and a computerised growth model is available, tree dimensions can be forcasted.

Forest mensuration data have two major functions in planning of harvesting and transport. Firstly, to supply data for regression equations (Chapter 5) from which daily tasks, labour and capital equipment requirements, daily production rates from the various teams and standard cost projections are established. This information also provides the basis for control.

Secondly, the mensuration data permit conversion of the above information into terms of output levels and harvesting rates per hectare.

Assessment and collation of the above calculations is protracted especially in large-scale operations when a number of sites are harvested concurrently by different teams and conditions may change frequently.

6.5.4 *Computerised Planning*

To overcome the calculation difficulties, a number of computer systems were investigated. Available computer programmes are stochastic simulation models which have their principal origin in the United States and Canada. Another solution was to write a semi-optimising programme containing all the data in Chapter 5 which would provide rapid and inexpensive analyses of all options available to a grower or contractor. The chosen system from this programme would also act as a supplement when using linear programming for overall planning thus simplifying its application.

6.5.5 *Stochastic Simulation Models*

As stated, most stochastic simulation models have their origin in North America and apply to the selective harvesting of natural forests. Plantation harvesting has considerable differences from natural forest harvesting thereby rendering these programmes non-applicable to southern Africa without considerable modification.

Such a modification known as Harvesting and Transport Simulation (HATSIM) was undertaken by Eaton (1981) by modifying a programme called Timber Harvesting and Transport Simulation (THATS). Goulet, *et al* (1979, p. 52) summarises the operation of THATS as "a modified fixed-time increment, FORTRAN model that simulates the standard harvesting configurations of felling-limbing-topping, bunching, skidding, breaking, loading, and hauling and includes a road building and cost accounting component".

This programme provides much information, but it is specific to the normal type of harvesting systems employed in North America. Eaton (1981, p. 4) states that HATSIM "in its present form is not suitable for simulating piece work operations." All data provided in Chapter 5 is based on the piece work approach as this is used in the majority of cases in southern Africa.

THATS is stated as operating "from either given averages and standard deviations, or from collected data.", which does not indicate its acceptability of regression equations. Analysis of the output of HATSIM shows that much of the output data is immediately available from the equations given in Chapter 5. As the programmes are not based on daily tasking and because tree dimensions and factors such as strippability in *E.grandis* affect worker daily output considerably, the programmes will not be able to forecast labour requirements. This is important as most forestry operations in southern Africa are labour intensive. Further, without the prediction of labour requirements, standard costs cannot be projected.

HATSIM assumes that this above information is to hand by the grower or contractor as a mean and standard deviation of the "Number of felling crews", "Felling cycle delay time" and similar data for crosscutting, extraction and transport (Eaton, 1981, p. 34). Operation times, labour requirements and standard costs are the very information that the forester does not know and on which he requires advice. With timber loading and offloading, growers and contractors request such data as machine operating times and production rates as are provided in Section 6.2.2 because information on alternative techniques of timber handling are not to hand.

The possibility of converting HATSIM to incorporate Chapter 5's data was considered, but it would require such restructuring that an independent programme was developed.

6.6 SPECIALISED PROGRAMME FOR TECHNO-ECONOMIC ANALYSIS OF LOGGING (TEAL)

The computer programme "Techno-Economic Analysis of Logging" (TEAL) was written solely by the writer in FORTRAN 77. Major objectives of the programme are, firstly, to include all final data listed in Chapter 5 from which a detailed optimising of labour, machinery and production rates could be calculated with both physical and cost analyses. Secondly, to construct the programme so it could be updated and expanded without difficulty. Thirdly, to provide a rapid and inexpensive service to the timber industry. Appendix E contains an example of a TEAL analysis.

6.6.1 *Application of TEAL*

TEAL is a semi-optimising programme. A grower or contractor selects which timber primary conversion, extraction and/or transport systems are feasible for his situation taking cognizance, *inter alia,* of scales of operation, tree species, terrain, size and availability of working capital, labour supply, local availability of capital equipment, lead distance of various stages of extraction and transport and labour and capital equipment required for each operation or system. A consideration with mixed farming is whether forestry is the major activity of the enterprise or whether the suitability of the other farming equipment is to be modified marginally to facilitate forestry operations.

Screening of the possible systems by assessing the above factors should be undertaken in consultation with a 'specialist in harvesting and transport'. Normally only one, or a few, of the options will remain after the screening and TEAL is used to analyse each remaining option. There may be only minor differences between the productivity or costs of the options, and the grower or contractor still makes the final choice considering such factors as personal preference or general convenience.

Within TEAL's analyses there is full optimisation. All output levels of factors of production are maximised; numbers of workers of each category balanced which includes all supervisors, clerical workers and infield chainsaw mechanics; all vehicles fully utilised; and the number of categories of vehicles balanced. Cost data are presented in a form directly comparable with the historical cost analysis service provided by the Economics Division, South African Timber Growers' Association.

6.6.2 *Internal Operation of TEAL*

TEAL is essentially comprised of all the data presented in Chapter 5 and control statements guiding it in the selection and manipulation of these data. The control statements' information is read in from the addition of a simple data file which contains the answers supplied by the grower or contractor to a questionnaire.

Figure 6.1 gives the current flow diagram of TEAL. This could become obsolete as soon as additional data and analyses are entered into the programme.

Initial data read in include a title or reference number and whether primary conversion and/or extraction and transport are to be analysed. Cost analysis is optional as growers either may only require worker daily task rates and vehicle or machine daily production rates, or they may have inadequate cost information.

FIGURE 6.1

Flow diagram of the computer programme Techno-Economic Analysis of Logging, TEAL

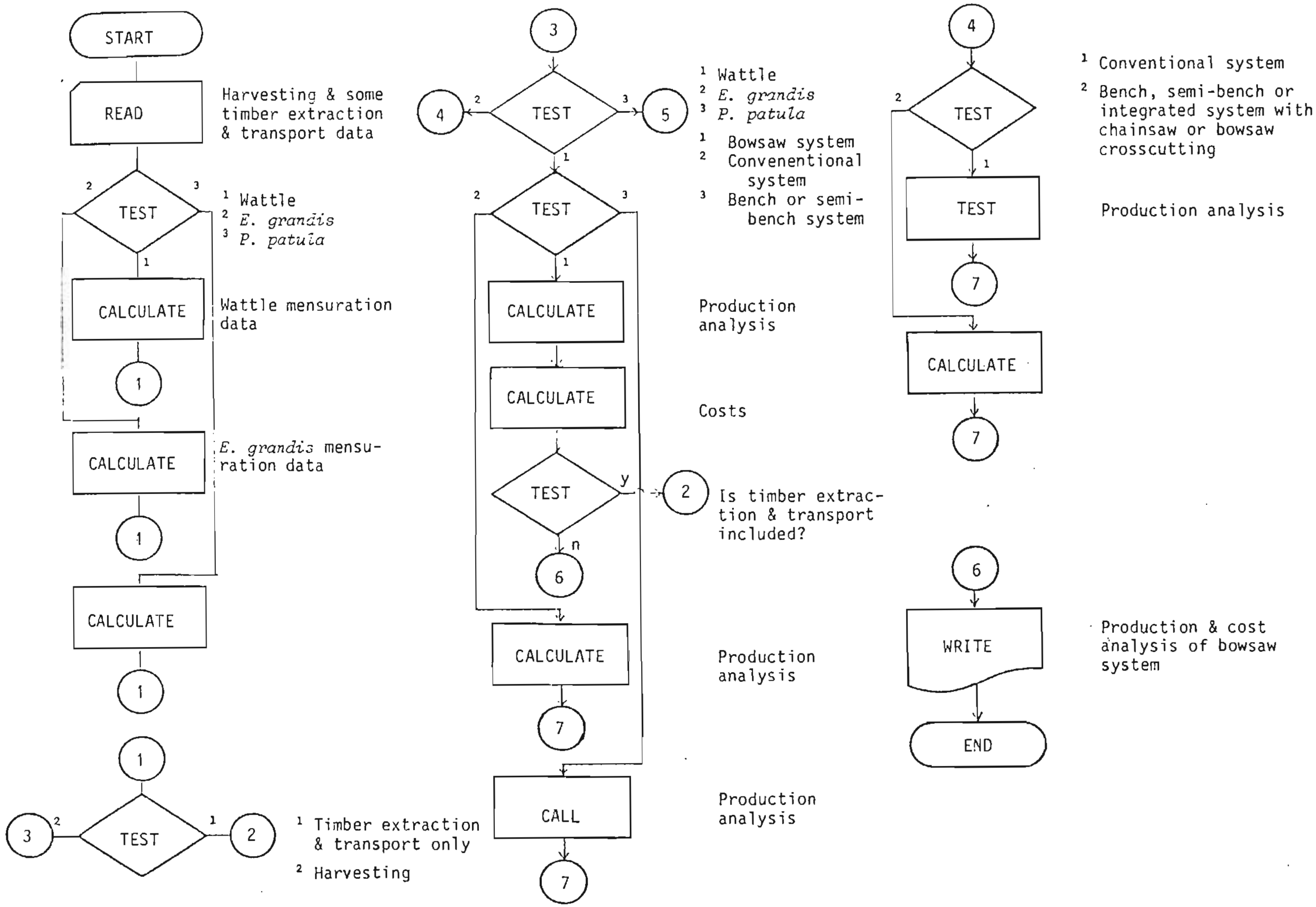
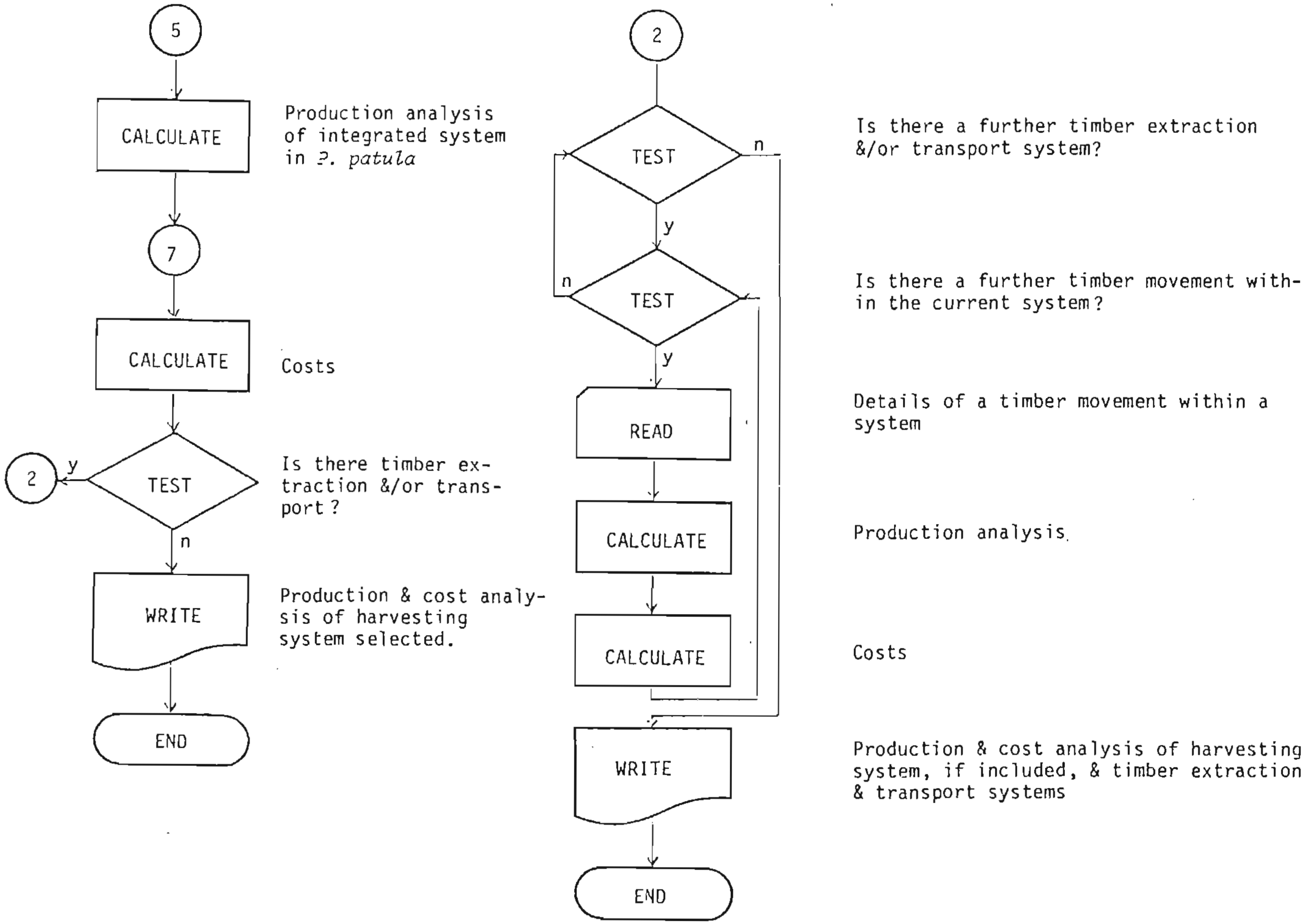


FIGURE 6.1 (continued)



Due to it being relatively simple compared with the other harvesting systems, the wattle bowsaw system is calculated independently and has its own format statements for printing out data.

Other wattle, *E.grandis* and *P.patula* systems are similar in the results of production analyses and their cost analyses, when the cost option is chosen. Therefore, data is presented in the same format although there are considerable differences in calculations.

Many safeguards are incorporated to ensure that no calculation results in greater than plus or minus five per cent of the specified daily task for workers. An exception is when a vehicle is manually loaded and possibly offloaded by a single team and there is a considerable travelling time. Thus a situation could arise where the team work for only several hours daily so provision is made to extend the length of any specified working day up to 552 minutes.

Frequently a sub-optimal daily production rate is specified by the grower or contractor. After the programme has established the daily production of a primary conversion, extraction or transport team, the specified production rate is corrected to an optimal rate before the programme proceeds.

As a team undertaking the primary conversion is the first unit of output, daily output from timber extraction and transport are calculated to match this as closely as possible unless otherwise specified, with the further option of analysing either primary conversion or extraction and transport separately. Obviously, it is impossible to attain a precise balance and inequalities are accommodated by assuming that in-process inventories are established and by varying the efficiency factor with extraction and transport as discussed below.

Due to the large quantities of data that would require transferring, subroutining is not used in the primary conversion section of the programme. However, extraction and transport analyses are facilitated by subroutines.

Inadequate supply by a preceeding operation in the system, absenteeism, inclement weather, maintenance and accidents results in actual production being below a predicted standard. To incorporate this aspect of reality, the efficiency factor, Equation 4.11 is introduced for final production rates and cost calculations for extraction and transport which are more sensitive to these factors than primary conversion which is usually more labour-intensive.

6.6.3 *Uses of TEAL*

There are three major uses for which TEAL analyses are intended. Firstly, to provide a means of systems selection through accurate analysis.

Secondly, to provide daily task rates for all categories of workers. At present, with a few exceptions in the entire forestry industry, tasking is undertaken by guessing or past experience of what appeared to be a reasonable task achieved by a grower or his neighbour. From data in Chapter 5, the TEAL analyses supplies the numbers of labour and capital equipment for all categories; daily, weekly, monthly and annual production rates where applicable; and the rate at which hectares of forest are harvested. All this information is necessary for planning.

Thirdly, the detailed standard cost projections enable financial planning, provide a basis for costing, contracting and to establish a system of management control when used in conjunction with historical costing.

6.7 ANALYSIS OF HARVESTING AND TRANSPORT SYSTEMS USING TEAL

To demonstrate the application of TEAL and show the influences of changes in parameters or components, *ceteria paribus*, three primary conversion systems and five timber extraction and transport systems used in *E.grandis* are analysed below. Where available, costs were as recorded by the Economics Division, South African Timber Growers' Association (1982). Very recently updated costs were received. These did not differ appreciably from the costs used and as the analyses are chiefly intended for intercomparisons complete re-analyses would have been purposeless.

6.7.1 *Primary Conversion*

The conventional, integrated and bench systems were investigated with a target output of 250 tons of air-dried timber per day. Influences of changes of system, total labour cost, wage rate and chainsaw costs on tons of timber produced per man-day and timber processing cost per ton, from analyses using TEAL, are summarised in Table 6.3.

In all cases the conventional system has a higher cost efficiency than the integrated and bench systems for the three levels of total labour cost tested. Comparison is made by dividing the cost per ton of timber of the other two systems by that of the conventional system. The results are as follows :

Table 6.3

Comparison of the influence of three primary conversion systems[1], three levels of total labour costs and three levels of chainsaw costs on tons of timber produced per man-day (t/m-d) and harvesting cost (R/t) with an output of 250 tons of *E. grandis* shortwood poles from average size trees[2]

Production rates and total labour and chainsaw costs[3]	Primary harvesting systems					
	Conventional		Integrated		Bench	
	(t/m-d)	(R/t)	(t/m-d)	(R/t)	(t/m-d)	(R/t)
Production rate	2,59		2,44		2,72	
Current chainsaw costs and total labour costs being :						
Current		2,54		2,83		3,45
Double		4,36		4,53		5,26
Triple		6,18		6,28		7,06
Current total labour costs and chainsaw costs :						
Current		2,54		2,83		3,45
Double		3,24		3,53		5,06
Triple		3,94		4,23		6,67

Notes: [1] Input data to TEAL, where applicable, are as shown in Appendix E.

[2] An average size tree is taken as having diameter at breast height of 16,0 cm and a total height of 22,0 m.

[3] These are as published by the Economic Division, South African Timber Growers Association (1982) or, where not provided there, as shown in Appendix E.

Total labour cost	Ratio of total cost per ton of timber: Integrated system/ Conventional system	Bench system/ Conventional system
Current	1,11	1,36
Double	1,05	1,21
Triple	1,01	1,14

Repeated analyses using higher total labour costs in TEAL analyses showed that the break-even level occurs at 3,5 times the current level for the integrated system and 6,8 times the current level for the bench system when compared with the conventional system. This demonstrates that the integrated system, ignoring its timber extraction aspect, becomes increasingly cost efficient compared with the conventional system as total labour costs rise.

Due to being more capital intensive, the bench system has a higher tons of timber harvested per man-day compared with the conventional system (Section 4.3.3 and Table 6.3). Therefore, rising total labour cost levels increase its relative cost efficiency.

Taking the total cost per ton of timber for the conventional system as unity and comparing the influences of doubling and tripling chainsaw costs shown in Table 6.3 for the three systems, the following comparisons are made :

Chainsaw cost	Ratio of total cost per ton: Integrated system/ Conventional system	Bench system/ Conventional system
Current	1,11	1,37
Double	1,09	1,56
Triple	1,07	1,78

The difference in cost per ton between the conventional and integrated systems is a constant 28 cents for the three cost levels thus giving the above diminishing influence with rising costs. However, the relatively high chainsaw usage causes the bench system to be sensitive to chainsaw prices. Rising chainsaw prices will result in an even higher break-even point in the wage level than that quoted above.

Semi-bench systems would give intermediate values between those derived for the conventional and bench systems.

Conclusions of these analyses are that, with the cost structure used, the conventional system is recommended as being the most cost efficient. Where individual growers' cost levels are above this, variations of the semi-bench system should be analysed for possible greater cost efficiency. Finally, where total labour costs exceed 6,8 times this level the bench system may be preferable. However, despite these analyses, labour availability is an over-riding consideration which may enforce more expensive harvesting systems.

Disadvantages of the integrated system apparent from the analyses provided by TEAL were the difficulty of matching the required daily output and balancing the worker composition of the harvesting team. Chainsawyer daily output was 80 tons. To optimise operational efficiency, this means that the daily output could be a maximum of 80/2 = 40 tons above or below that which was specified (Appendix E).

Further, where a 'hot logging' process is being followed, *viz* where trees are felled, processed and the timber transported forthwith, work-sites are kept separate to facilitate roadside processing and timber transport which could make it impracticable for teams to share markers and crosscut chainsawyers. Table 7, Appendix C shows the extent to which daily tasks in crosscutting vary. Thus under or over capacity will normally be experienced. Where timber is left infield to dry and marking and crosscutting performed subsequent to timber extraction, these balancing problems are obviated.

6.7.2 *Timber Extraction and Transport*

Five timber extraction and transport systems currently used by growers for shortwood poles were analysed using TEAL. A target output rate of 250 tons per day was taken. The systems, their descriptions and assumptions are as follows with analyses shown in Table 6.4:

System number	Description
1	bundled, or billetted, system described in Sections 5.6.3.1 and 5.8.2.1.
2	lorries manually loaded infield and manually offloaded by five labourers, which is a system particularly popular in the south-eastern Transvaal.
3	a locally made 12 ton forwarder (Figure 3.7) to extract the timber to the roadside. It is assumed that the forwarders load onto stockpiles from which the lorries are loaded and that the forwarders never transship timber directly to a lorry. Lorries are loaded by cranes with 0,4 square metre grapples and mounted on light tractors.
4	skidding with an agricultural tractor and four-ton, double drum winch, sorting and stacking by three-wheel loader and timber loading and transporting using the same cranes and lorries described for System 3.
5	a similar system to System 4, but where the stems are initially extracted by highlead.

Table 6.4

Comparison of tons of timber produced per man-day (t/m-d) and extraction and transport costs per ton (R/t) for five systems moving a target of 250 tons of *E.grandis* shortwood poles per day with a 25 kilometre lead distance

System[1]	Output rate (t/m-d)	Extraction, transport costs at stated total labour cost levels			No. of lorries	Actual daily output (t)
		Current (R/t)	Double (R/t)	Triple (R/t)		
1. Bundled timber: tractor and low-bed trailers, mobile cranes and lorries	11,45	3,95	4,45	4,95	4	244
2. Lorries: manually loaded infield, manually offloaded	7,87	2,67	3,36	4,05	5	238
3. Forwarders, lorries and mobile grapple cranes	22,60	3,43	3,72	4,00	4	250
4. Skidders, 3-wheel loaders to sort and stack, lorries and mobile grapple cranes (costs without loaders)	6,76	4,09 (3,57)	4,95 (4,34)	5,81 (5,11)	4	250
5. Highleads preceeding skidder in the above system (costs without loaders)	5,07	4,66 (4,14)	5,79 (5,18)	6,92 (6,22)	4	250

Notes: [1] In all analyses, 12 ton lorries were used. With exception to System 2, it is assumed that the timber is offloaded at a mill providing its own offloading facilities or that the lorry offloads by tipping. In these cases 10 minutes were allowed for offloading.

Input data to TEAL, including current costs, where applicable, are as shown in Appendix E.

Loading times affect the number of lorries required (Column 6, Table 6,4). Thus System 2 requires five lorries and the other systems four lorries. Although System 1 employs manual loading, the remainder of the system is mechanised and also highly efficient. Thereby, the tons timber per man-day is exceeded only by System 3. System 2, which is labour intensive, has the highest cost efficiency at the current wage rate. System 3 has the highest output per man-day and is also the most cost efficient at the highest level of total labour cost.

In most cases, the lorries constitute the highest single cost (Appendix E), the only exception is with System 2 at the highest wage level of labour costs where the costs per ton are R2,08 and R1,98 for labour and lorries, respectively. The analyses show that the three-wheel loaders will increase the costs of the systems by R0,52 to R0,70 per ton. However, with the need to have a loader per skidder (Section 5.8.1.2) the loader is under-utilized here.

Various conclusions may be drawn from the above analyses. THe use of highleads only increases costs by R0,57, R0,84 and R1,11 per ton timber, respectively, for the three levels of total labour costs. However, these costs are low because tree lengths are being winched with the highlead operating at a two-ton capacity per haul. Under these conditions, highleading is cost competitive compared with any other prime movement technique analysed. This is of particular importance with the stump and soil damage being incurred by infield vehicles. The highlead technique applied in the analyses assumed the use of the triple-tag-line system to maximise productivity.

Where terrain permits infield loading, System 2 is an obvious choice provided the necessary labourers are available.

System 3 is of interest where labourers to load timber are unavailable, However, where smaller forwarders are used, their efficiency will be lower due to smaller loads resulting in increased travelling for the same daily output. In addition, smaller cranes are usually fitted to these forwarders causing slower loading times. Therefore, the larger forwarder is preferred.

6.8 NON-COMPUTERISED SYSTEMS ANALYSIS

Frequently, analysis of systems must be made away from the computer, or the grower or contractor may wish to make his own assessment of the work rate while infield.

To accommodate such situations the tables in Appendix B and C are included. These provide guides in an average situation with various provisos and correction factors. As well as brief descriptions of the application of certain systems.

Manual calculation of primary conversion operations in wattle and *E.grandis* is simple. Mean tree yields of timber and bark for wattle, are calculated or read from tables (Schönau, 1971 & 1972) then after daily tasks have been read from the appropriate tables in Appendix C, the team must be balanced and the workers daily production converted into all possible output units. Finally, man-days per hectare for worker categories are calculated. To assist calculations, a form is used (Figure 6.2). A completed form and the technique for compiling vehicle times are given in the conclusion to Appendix B.

FIGURE 6.2

Ref : ___________

WATTLE RESEARCH INSTITUTE

LABOUR AND PRODUCTION ESTIMATES

Plantation : _____________ Block : _______ Date : ________

Tree Species : ____________ Age:____y Approximate stocking : ______stems/h

Mean Tree Dimensions

Bark thickness .. ..mm
DBH (overbark) .. ..cm
Height .. .. m
Estimated bark mass (wattle) .. ..kg
Estimated total timber volume .. .. m³
Less : stump & kerf wastage at ... cm ....%
crown wastage at ... cm tip diam ....%
Estimated utilized timber volume . .. . m³
converted at 1,19 1,47 m³/t .. .. .. t
Estimated no. of m poles/tree .. .. .. poles

Estimated Yield per Hectare

Bark mass .. .. t
Timber volume .. .. m³
Timber mass .. .. t

Workers' Daily Task in Trees & Team Size for the Bowsaw/Conventional Chainsaw/Bench Method

	Normal	Max
....	....	....
....	....	....
....	....	....

Team Size : ....

....

Workers' Output per Day at Normal Task

	Bark Mass (kg)	Timber Vol (m³)	Timber Mass (t)	Poles (m)
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....

Labourer Requirements per Hectare at Normal Task

.... man-days
.... man-days
.... man-days

Note : 1. All above information is provided as a guide only
2. Variances are minimised with high tree uniformity

6.9 CONTROL

6.9.1 *Supervision*

A major cause of poor productivity is too few, unsuitable or inadequately trained infield supervisory staff (de Laborde, 1982b). Especially in the case of scale 1 growers (Table 6.2), the supervisor is often selected through such criteria as age.

Infield supervisors are the key personnel in achieving high productivity. Selection should be made using professionally developed selection tests. Once selected, they should receive formal training in personnel management, in particular the principles of Management by Objectives (Appendix D).

In addition to this initial training, supervisors require to be instructed in all aspects of daily tasking, the operations or systems they will be supervising and finally the specifications for quality control of the products. This second aspect of training will necessitate studying and being trained in the application of the system(s) such as those described for harvesting wattle and *E.grandis* using the conventional and bench systems and skidder used in Appendix B and the integrated system for *P.patula* in Appendix C.

In scale 1 operations (Table 6.2), one supervisor may suffice for all harvesting and transport operations. Scale 2 operations may need independent supervisors for harvesting and timber extraction and transport where terrain is difficult and these operations more complex. At this level it may be necessary to introduce a senior supervisor to co-ordinate operations.

Scales 3 and 4 operations require a supervisor per two teams for the conventional chainsaw system. Should there be an odd number of teams, a supervisor will have three teams under his control. To permit greater concentration on supervision, it is recommended that a tally clerk be included to assist by checking whether workers achieved their daily tasks and for assessing the additional output for incentive payment.

Where the bench, semi-bench or integrated systems are used, it is normal to have independent supervisors for chainsawyers and labourers. Here the numbers per supervisor may vary, but in wattle and *E.grandis* a guide is 10 chainsawyers and 25 labourers, respectively, for the two categories of supervisors. Because of the extent to which operations vary it is impossible to be specific about the numbers of extraction and transport supervisors.

At scale 3 operations, a senior supervisor is imperative and at scale 4, there could be several senior supervisors who may require a chief supervisor, or forester, to co-ordinate their work.

TEAL has provision to calculate the numbers of supervisory staff where no such information is included, but also can accommodate individual requirements by having statements introducing this information which then takes precedence over the normal calculations.

At scales 3 and 4 operations, supervision also may require the inclusion of infield chainsaw mechanics. TEAL accommodates this, but only at a specified number of chainsaws per mechanic.

6.9.2 *Accounting Control*

Standard costing should be employed with a complementing historical accounting system. Data for the historical costing should be rapidly attainable to facilitate close monitoring. Differences between projected and historical costs indicate to management the exact location of declining efficiency so corrective action can be taken. However, care should be taken not to employ an over-zealous efficiency factor.

As TEAL projects fuel, machine and vehicle usage, differences in costs also reflect losses if these are a component of an effected cost.

CHAPTER 7

DISCUSSION AND CONCLUSIONS

Investigation into and predictions of the supply of labour and capital equipment for the forestry industry is a major factor in placing selection of harvesting and transport systems into perspective. Another important factor is the direction in which developed countries have progressed in this field and the context in which these developments should be interpreted.

Certain work measurement techniques were selected and applied to harvesting and transport systems. The resultant field data were analysed by appropriate statistical methods. These data may be used to estimate labour and machine requirements, production rates for each category of worker and machine and detailed standard costs. As this calculation from all information contained in Chapter 5 was particularly cumbersome, a computer programme (TEAL) was written. TEAL permits data manipulation to provide analyses of any normal efficient system for most circumstances found in forestry.

Popular harvesting and transport systems were selected and compared using TEAL analyses. Results are discussed below. Actual productivity of growers in the small to medium category were compared with their potential productivity provided by TEAL analyses. Results show serious inefficiencies in certain operations.

7.1 COMPARISON OF OVERSEAS HARVESTING AND TRANSPORT SYSTEMS

Conclusions can be reached by studying trends in overseas and local harvesting and transport equipment.

Harvesting and transport practices in most of western and northern Europe are similar to those in Sweden which Skogsarbeten has described. Dates of changes in harvesting and transport practices reported by Skogsarbeten and observed by equipment suppliers and the writer for South Africa are compared below. Differences between the dates are given also.

Operation	Sweden	South Africa	Difference (years)
Animal extraction almost ceased	1970	1983	13
Chainsaw usage : commenced	1947	1960	13
peaked	1968	1982	14
Mechanised primary conversion commenced effectively	1970	1983	13

Thus it can be concluded that there has been a fairly constant 13 year lag between Sweden and South Africa in harvesting and transport practice and Swedish developments may provide valuable guidance for southern Africa. However, retaining jobs for Blacks with a current population growth rate of 2,9 per cent may result in a lower proportion of capital intensive systems being employed unless housing costs and wages continue to rise at the present rate.

7.2 COSTS OF LABOUR AND CAPITAL EQUIPMENT

Of Black South Africans employed in forestry, 22 380, *viz* 62 per cent, have no formal education. However, with government policies directed towards compulsory education for all Blacks the supply of this labour category is disappearing rapidly.

It is anticipated that the educational pattern for Blacks from adjacent states will be similar to South Africa. Thus the 69 180 Blacks employed in the 1982/83 period could drop considerably. Although the rate of decrease cannot be predicted reliably and also differs in severity between areas, Black labourers will become increasingly scarse. Thus labour intensive systems will be replaced by capital intensive systems.

This conclusion seriously effects medium and long term selection of harvesting and transport systems and plantation layout to accommodate the systems.

The rise in the cost of capital equipment has increased steeply with the drop in the rand exchange rate since mid-1983. Thus American equipment has approximately doubled in price while European equipment has risen to a lesser extent. Although higher costs of equipment encourages greater use of labour, its unavailability will cause worker costs to rise. Thus steep increases could occur in harvesting and transport costs which already constitute 65 per cent of total direct forestry costs.

However, this cost increase probably will occur in the long term only. There is considerable inefficiency in some sectors of the industry, discussed below, which initially will be absorbed by efficient management and the use of efficient contractors.

7.3 ANALYSIS OF PRODUCTIVITY OF PRIVATE TIMBER GROWERS

By comparing production rates achieved by private growers monitored by the Economics Division of the South African Timber Growers' Association (1984) with TEAL analyses it is possible to identify the extent of efficiency. As tree dimensions, precise harvesting systems used, terrain conditions and lead distances for extraction are unavailable, average data estimated from studies and advisory work undertaken by the writer were used. In the TEAL analyses the conventional chainsaw system was used for wattle and *E.grandis* and the integrated system with labourers debranching by limbing axe was used for pine. *P.patula* analyses were used although *P.elliottii* and *P.taeda* were harvested also. However, due to its dense branching, *P.patula* is more difficult to work than the other two pine species. Thus pine analyses are biased with the more difficult species to harvest and the most labour intensive variation of the system. Although TEAL analyses are not a direct comparison, they provide a definite indication of the level of productivity being achieved. All necessary forest workers including supervisors were included in these analyses. Details of comparisons are given in Table 7.1.

Considering the serious drought experienced during the period 1 March 1982 to 28 February 1983 covered in the data, the wattle bark production rate is acceptable, but *E.grandis* shows a margin for improvement. However, productivity for wattle timber and pine, particularly in Natal, is very poor.

Skidder productivity varies considerably with different terrain conditions and lead distances. Thus data are given for difficult and moderate terrain. The considerable inefficiency shown for skidders is supported by the 45 per cent delay in overall time noted previously (Section 5.7.3.1) and the findings of other researchers (Section 3.2.4).

Major reasons for poor productivity noted by the writer include numerous extraneous workers, poor tasking, lack of supervision, poor systems, lack of synchronisation of operations and no balancing of number of workers of different categories. Hence particular attention has been paid to these factors in this thesis.

Table 7.1

Actual output rates for harvesting for timber growers compared with potential rates given by TEAL analyses

Operation and tree specie	Actual output (t/m-d)	Potential output (t/m-d)	Percentage of actual to potential output	Improvement possible (to nearest 5%)
Primary conversion				
Wattle :				
Bark	0,234	0,268	87	15
Timber	2,9	10,3	28	255
E. grandis :				
Natal	1,3	1,7	76	30
Pine :				
Natal	3,2	14,9	21	365
N E Transvaal	7,9	14,9	53	90
Extraction	(t/h)	(t/h)		
Skidder :				
Conditions unknown	11,1			
Difficult conditions		15,7	71	40
Moderate conditions		24,3	46	120

Notes : Actual output rates are as monitored by the Economics Division, South African Timber Growers Association (1984).

Skidder output is calculated with a 72 per cent overall efficiency included.

Costs were not included in the analyses because existing rates were misleading due to the differences between actual and potential productivity.

7.4 COMPARATIVE COST EFFICIENCY OF HARVESTING AND TRANSPORT SYSTEMS

TEAL analyses of systems for primary conversion show that the bench system is approximately 15 per cent less labour intensive than the conventional and integrated systems and, therefore, less sensitive to changes in the total labour cost. However, the bench system uses 2,6 and 3,9 times more chainsaw time per ton timber to prepare *E.grandis* and wattle, respectively, than the other two systems. Therefore the bench system is considerably more sensitive to changes in chainsaw costs than alternate systems. Thus it may be concluded that the bench system has a lower predictability of cost efficiency than the conventional and integrated systems.

Lorries loaded manually infield where terrain permits, and manually offloaded is the most simple to manage and is cost competitive with other systems where the lead distance is 25 kilometres and total daily cost per worker including indirect and fixed costs such as food, clothing and housing is below approximately R8,50. A single timber movement is envisaged with this system. Nevertheless under the conditions described above, the TEAL analysis showed that only 7,9 tons per man-day are obtained which is low. The system is recommended for small-scale operations in particular, provided log mass is not too high.

A highly capital intensive system was sought by TEAL analyses for conditions where labour is unavailable or costly, the scale of operation large, only a few easily identifiable pole or log categories and terrain conditions are moderate. Forwarder extraction followed by crane loading and offloading of lorries was superior to other systems analysed as it can attain in excess of 22,5 tons per man-day. It is, therefore, recommended in this situation.

In situations where skidders, highleads or skylines are used, the integrated system is normally recommended for a large product mix or where pole lengths are below two metres, as measuring and crosscutting are normally accommodated far better at roadside or a landing than infield. It is further recommended for most situations that timbers be kept in the largest common multiples of lengths required and sizes reduced further at the sawmill. The extent to which this procedure lessons plantation work cannot be calculated without assuming a specific product mix, but it is considerable. For example, loading pole lengths of over seven metres is at least eight times faster than loading poles 0,9 metres long as the time per cycle of crane operation will be virtually unchanged by pole length.

Handling crosscut timbers in bundled form can be particularly rapid with loading times of 2,5 to 3,5 minutes per bundle and offloading times of 2,5 minutes per bundle. Each bundle, or billet, usually has a mass of five to six tons.

The decision of whether cranes should be mounted on transport vehicles or independently on a tractor or lorry chassis can be estimated. The calculation is made by establishing the independent cranes cost to load the size being considered. The difference in rand per ton-kilometre between lorries with mounted cranes and plain lorries is divided into the crane's loading cost. This value gives the lead distance in kilometres at which the break-even cost of the option occurs. In calculating the rand per ton-kilometre of the lorry with a mounted crane, cognizance must be taken of reduced tare caused by the crane.

CHAPTER 8

SUMMARY

Timber harvesting and transport systems collectively account for 65 per cent of the total direct cost of forestry in South Africa. Although there is national concern about reducing these costs, techniques of quantifying systems have been limited which has contributed to a subjective approach to their selection by the industry.

Three major uncertainties have been identified. These are the type of primary conversion, extraction and transport systems that should be selected, the correct daily output for tasked (piece) workers and what the acceptable cost of these operations should be.

To provide the timber industry with answers to these problems, a three-directional approach has been adopted. Firstly, assess the supply of Black labour to establish the current situation and estimate the future supply. Secondly, undertake surveys of local and overseas systems. Thirdly, measure the activities which comprise the systems that are identified in southern Africa.

This study describes techniques for undertaking these investigations and the results obtained by their application.

Forest workers in southern Africa including the lowest management level are mostly Blacks with the exception of the southern Cape where Coloureds are employed. Most forestry areas are in close proximity to Black homelands, yet it was found that workers' homes were beyond a reasonable daily commuting distance. Consequently there is much

migrant labour which necessitates employers providing villages. Additional fringe benefits for workers such as free transport home at weekends and free medical attention, food and clothing have increased the semi-direct and overhead costs appreciably since the early 1970's.

From 1970 to 1980 there has been a 12 per cent drop in Black forestry workers. A contributory factor to the drop is believed to be Blacks unwillingness to do heavy manual work. Women are now undertaking work previously done by men. It is expected that as a greater proportion of Blacks are better educated fewer will accept heavy manual work.

Comparisons were made of the ratio of total man-days of all Black labour to total litres of liquid fuel used. Data for the past six years showed a definite, and increasing transfer from labour to capital intensive systems.

There has been a high degree of mechanisation in overseas harvesting practices, although the use of the chainsaw is still popular for felling and crosscutting trees. Overseas cable extracting, essentially by highleads, is receiving attention, *inter alia*, because of increasing concern about soil damage caused by vehicles operating infield.

Highlead operating costs may be higher than alternate timber extraction techniques, but the findings of this study are that where *E.grandis* stems are winched, costs compare favourably with skidding in more difficult terrain.

Among many harvesting machines that have been developed, American designs tend to be based on the articulated front-end loader while European machines are more in the form of forwarders with various heads attached to the cranes. Recently, the South African innovated three-wheel loader was adapted to permit fitting various felling heads. This combination is lighter and moves faster than most American machines.

A number of harvesters that are able to fell, debranch and crosscut the trees and carry the poles to a convenient offloading point have been developed in America and Europe. Infield chippers have not gained much popularity as they do not give uniformity of quality control. The main advantages are that they give high timber utilization and reduce timber handling.

Axe felling which was used almost exclusively in wattle and *E.grandis* has been discontinued. Bowsaws were particularly popular for crosscutting, and occassionally used for felling in small-scale operations, but their use is disappearing.

Chainsaws are used for almost all felling and crosscutting in southern Africa and although systems vary they fall into four categories. Firstly, the conventional system where the chainsawyer fells and crosscuts the trees and labourers using hatchets debranch and stack the brush, debark and bundle and stack the bark if harvesting wattle and, frequently, loosely stack the poles where they are crosscut to shortwood lengths.

Secondly, the bench system is used where labour is scarce or total costs per worker are assessed as being high. The chainsawyer fells the tree usually onto the brushline or previously cut timber, trims the butt, debranches and marks the stem for crosscutting, stacks the brush and finally crosscuts the stem. Labourers using hatchets debark the poles, prepare the bark, if it is wattle, and stack the poles.

The third system is the semi-bench system. It incorporates the chainsawyer undertaking labourer operations listed for the conventional system, but without completing all the activities listed for the bench system. Fourthly, in the integrated system, one chainsawyer fells the tree and debranches and tops the stem. Where labour is available and cost competitive it is used to debranch and top the trees. A skidder or highlead removes the stems to roadside or a landing where they are marked for crosscutting by chainsaw.

In wattle and *E.grandis*, the conventional system is the most popular, but the bench and semi-bench systems are also used. The integrated system is used almost exclusively in *P.patula*, and in recent years growers have started using it in *E.grandis*.

Where terrain is steep or difficult, highleads are used for heavy timber extraction. Manual timber extraction was used extensively for shortwood wattle and *E.grandis* poles, but its use has dropped considerably and is expected to discontinue with the anticipated shortage of labour that will accept this type of work.

Forwarders, which includes any tractor-trailer with a mounted crane, are used frequently in lighter terrain for the initial timber movement. Lorries of a wide size range and rail trucks are used for longer distance transportation. Loading and offloading is done mainly by transport vehicle mounted crane, independent vehicle mounted crane or three-wheel loader.

Attempts have been made to estimate the performance of labour and machinery by keeping records of their daily infield work, plantation measurements and output rates. Work measurement techniques using a stopwatch for time studies were found to provide penetrating and accurate results. Accompanying each study is a record of all measurements and characteristics of trees, timber, terrain and climatic conditions that could influence the work.

Forestry work is divided into variable, semi-variable and fixed activities. Felling trees by chainsaw provides an example of the three activity types. Felling is a variable activity as it is influenced, *inter alia*, by the tree size. Walking between fellings is semi-variable as it is independent of tree size, but it occurs for every felling. Refuelling the chainsaw at an interval chiefly determined by the fuel-tank size is a fixed activity. Variable and semi-variable activities are added together, but fixed activities are subtracted from the length of the working day. Finally, the daily task is determined by dividing the added activities into the remaining length of the working day.

All time measurements of work were regressed on tree or terrain characteristics which have significant influence. Where no significant variable was encountered, mean times were calculated. The analyses of all activities comprising the timber harvesting and transport systems in the above manner, have been presented in this study.

A computer programme was written which incorporates all work analyses and any costs supplied. The programme is named Techno-Economic Analysis of Logging (TEAL) and is written in FORTRAN 77.

TEAL has three major uses. Firstly, it provides a means of system selection using quantitive data. Secondly, it provides a detail of all the numbers required for each category of worker and machine and also supplies their daily task rates, where applicable. Thirdly, by supplying a grower's costs, standard cost analyses are provided.

Features incorporated in the programme include safeguards against the over or under tasking of workers and an efficiency factor consisting of the average percentage of the target daily task that is achieved and the average percentage machine utilization. As it is a specialised programme, the time taken to operate it and its running costs are minimal.

TEAL is written to optimise systems so that labour and machinery are utilized as fully as possible. The initial selection of systems should be made following an analysis of the growers specific conditions, mix of tree species and product, scale of operation, labour supply, situation, capital availability and costs.

To demonstrate some of its applications, TEAL is used to analyse the four primary conversion systems described above. For each system only the total labour cost per ton of timber was altered to compare its influence on output costs of the system. Results showed that, under the average conditions selected, the conventional system had the lowest cost when compared with the bench and integrated systems. The bench system could only compete when the total labour cost was raised to seven times the current level.

Similar analyses of these four systems were undertaken, but labour costs were kept constant and chainsaw costs varied which demonstrated the bench system's sensitivity to changes in this cost compared with the conventional and integrated systems.

Major conclusions of the thesis show that there has been a 13 year lag before changes in harvesting and transport systems in Sweden are experienced in South Africa. The labourer category of Black worker are disappearing while the cost of other categories is rising rapidly. The changes in labour are resulting in labour intensive systems being replaced by capital intensive systems.

Considerable inefficiency exists in most harvesting operations undertaken by small to medium scale growers was shown by comparing reliable historical output data with potential output obtained from TEAL analyses. Essential causes of inefficiency include lack of managerial expertise and the detailed information on systems contained in this thesis.

Various timber extraction and transport systems are compared using TEAL analyses. Where feasible, manual loading of lorries in-field is the more cost efficient system analysed at lower total labour costs. However, the use of forwarders and crane loading of lorries gave the highest output per man-day.

APPENDIX A

RELAXATION ALLOWANCES

Relaxation allowances for primary harvesting are reproduced from a previous work (de Laborde, 1980). The system used to determine allowances was given by the International Labour Office (1979, p. 425 - 433).

Allowances are developed by allocating points supplied in tables to provide weightings for the strain types listed. A points conversion table is given from which the percentage relaxation allowance is obtained.

Certain work such as manual timber extraction and tractor driving contain a wide range of variables of which the most common situation is taken to obviate excessive complexity. However, in an abnormal situation an independent allowance should be used.

TABLE B1

RELAXATION ALLOWANCE ANALYSIS

Element Symbol	Element Description	Type of strain															Allowance (Points)	Allowance (%)
		Force	Posture	Vibration	Short cycle	Restrictive clothing	Concentration Anxiety	Monotony	Eye strain	Noise	Temperature	Ventilation	Fumes	Dust	Dirt	Wet		
		A1	A2	A3	A4	A5	B1	B2	B3	B4	C1	C2	C3	C4	C5	C6		
	Labourers																	
T	Test tree	16	4	1												1	22	13
CT	Clean tree	16	4													1	21	13
B	Debranch	39	6	4			4									1	54	26
S	Stack brush	41	12													1	54	26
L	Debark basal 1,2m	34	12	2			4	1								1	53	26
AR	Rip-strip standing tree	34	8	4			4	1								1	47	22
A	Debark	34	12	2			4	1								1	53	26
CA	Chip off bark	34	12	3			4	5								1	59	29
MT	Move tree	50	8													1	59	29
GB	Gather bark	25	7													1	33	16
BU	Bundle bark	25	10	3			2									1	41	19
CB	Carry bundle	58	8													1	67	34
N	Notch	39	6	4			4									1	54	26
SW	Swing pole	58	8													1	66	34
DT	Dislodge tree	34	5				4									1	44	21
W	Walk		4													1	5	10

TABLE B1 (continued)

RELAXATION ALLOWANCE ANALYSIS

Element Symbol	Element Description	Type of strain: Force A1	Posture A2	Vibration A3	Short cycle A4	Restrictive clothing A5	Concentration Anxiety B1	Monotony B2	Eye strain B3	Noise B4	Temperature C1	Ventilation C2	Fumes C3	Dust C4	Dirt C5	Wet C6	Allowance (Points)	Allowance (%)
	Axemen																	
PF	Prepare to fell	3	2													1	6	10
F	Fell	42	16	4			4									1	67	34
	Bowsawyers																	
PF	Prepare to fell	3	2													1	6	10
F	Fell	39	12	2			4	5								1	63	32
CH	Chop	39	8	4			3	3								1	56	27
RM	Reposition and measure	15	8				1									1	25	14
X	Crosscut	34	12	2			4	5								1	58	28
	Chainsawyers																	
	Wearing all safety clothing																	
RF	Refuel	3	2													1	6	10
TS	Tend saw	3	2													1	6	10
PF	Prepare to fell	3	2													1	6	10
F	Fell	23	12	8		2	6			1			2			1	55	27
MB	Measure and debranch	21	9	8		2	6			1			2			1	50	24

TABLE B1 (continued)

RELAXATION ALLOWANCE ANALYSIS

Element Symbol	Element Description	Type of strain															Allowance (Points)	Allowance (%)
		Force	Posture	Vibration	Short cycle	Restrictive clothing	Concentration Anxiety	Monotony	Eye strain	Noise	Temperature	Ventilation	Fumes	Dust	Dirt	Wet		
		A1	A2	A3	A4	A5	B1	B2	B3	B4	C1	C2	C3	C4	C5	C6		
	Chainsawyers (continued)																	
S	Stack brush	41	12													1	54	26
X and BC	Crosscut and butt-cut	23	10	8		2	6			1			2			1	53	26
P	Move short-wood poles	57	10													1	67	34
W	Walk with chainsaw	23	6													1	30	15
	Without all safety clothing[1)]																	
F	Fell	23	12	10			12			9			2			1	69	36
X	Crosscut	21	12	10			12			9			2			1	67	34

1) Although growers are most strongly advised to provide all safety clothes listed in Appendix J, some employers, especially those using the conventional chainsaw method, have not equipped their chainsawyers. Therefore, it is necessary to include allowances that accommodate the increased risk.

TABLE B1 (continued)

RELAXATION ALLOWANCE ANALYSIS

Element Symbol	Element Description	Force A1	Posture A2	Vibration A3	Short cycle A4	Restrictive clothing A5	Concentration Anxiety B1	Monotony B2	Eye strain B3	Noise B4	Temperature C1	Ventilation C2	Fumes C3	Dust C4	Dirt C5	Wet C6	Allowance (Points)	Allowance (%)
	Type of strain																	
	Drivers																	
	On roads & regular terrain	10		3			2			1							16	10
	As above, but no enclosed cab & awkwardly placed controls	10	5	3			2			1						1	22	13
	Rough terrain for steep slopes	27	6	3			15			1							52	25
	Manual Timber Handling																	
E	Walk unladened		4					3								1	8	10
G	gather poles)																	
PU	Pick up pole) Force variable		6				2	9								1	18 + Force(see Table B2)	
L	Carry pole)																	
S	Stack pole)																	
NS	Neaten stack	34	8				2	3								1	48	23

TABLE B2

Relaxation allowances[1] (RA) for manual timber handling.

Mass (kg)	Total % R A	Mass (kg)	Total % R A	Mass (kg)	Total % R A
2	13	25	38	48	71
3	15	26	39	49	72
4	16	27	40	50	74
5	17	28	42	51	77
6	17	29	43	52	79
7	18	30	44	53	80
8	19	31	46	54	82
9	20	32	48	55	83
10	21	33	48	56	83
11	22	34	50	57	84
12	23	35	52	58	85
13	24	36	53	59	87
14	26	37	54	60	88
15	27	38	55	61	89
16	28	39	56	62	90
17	29	40	58	63	96
18	30	41	59	64	97
19	31	42	61	65	99
20	32	43	62	66	101
21	33	44	64	67	101
22	35	45	65	68	103
23	36	46	68		
24	37	47	70		

Note [1] Total percentage relaxation allowance is calculated by adding the 18 points from Table B1 to the appropriate 'force' point for the particular mean pole mass.

APPENDIX B

SYSTEMS AND DAILY TASKS FOR HARVESTING AND TRANSPORT OF WATTLE AND *E. GRANDIS* FOREST PRODUCE

1 GENERAL

Information provided below is a reproduction of part of a publication (de Laborde, 1982) the basis of which was given in Sections 5.4 and 5.6. Data in Chapter 5 is intended either for inclusion in a computer programme in its entirety or for specific equations to be applied to a given situation.

For easy practical application of systems and daily task tables by foresters, it has been necessary to simplify some of the data in Section 5 using less sophisticated analyses, therefore equations, in conjunction with correction factors. Consequently, these tables' task rates and times may differ slightly in particular with slope allowances and manual handling of crosscut timbers.

2 PRIMARY HARVESTING SYSTEMS

As distinct from integrated harvesting systems, primary harvesting systems referred to here include all operations involved in felling (either by axe, bowsaw or chainsaw), debranching, removal of bark and presenting the shortwood without bark ready for extraction (Section 2, below). In the case of wattle, primary harvesting includes bundling bark and stacking the bundles. From the analyses of numerous harvesting methods, three methods have been developed to accommodate differences in labour supply and costs, proximity of supervision to the harvesting site and scale of the operation (de Laborde, *loc cit*).

Because of stump and kerf wastage and in the case of *E. grandis*, the effect of cambium damage which will impair coppicing ability, felling by axe is not recommended.

Planning of primary harvesting is essential for optimum productivity and guidelines to this are provided at the end of this Appendix.

2.1 BOWSAW SYSTEM

2.1.1 *Scale of Operation*

This method is intended only for small-scale operations in wattle under special circumstances. In *E. grandis*, the higher number of trees harvested per labourer per day when trees are felled for them by chainsaw, nullifies any advantages of using a bowsaw, except at production levels of 2 t timber per day, i.e. four labourers' work.

In wattle the bowsaw may be considered (de Laborde, *loc cit*) for daily production levels of below 150 medium-sized trees per day (i.e. 4 t bark or 16 t timber) when labour overheads are low, there is an adequate supply of suitable labour, harvesting is far from close supervision or where access is difficult or when the grower is not mechanically apt and the operation is not large enough to warrant employing a mechanic.

2.1.2 Bowsaw usage

A most suitable bowsaw for forestry is the two-man 915m (36-inch) heavy duty, Sandvik bowsaw, which has a 38mm cross-section steel frame at the widest part of the oval. Other frames are 32 mm cross-section. Two types of blades usually used include the following :

Sandvik No 21, for use in wet timber. It has a series of two teeth followed by a swallow-tail-shaped raker;

Sandvik No 51, which is a plain blade for use in dry timber.

Both blades must be hard-tipped. Teeth must be set daily using a tooth-set tool. Adjustment of the tool is made by trial and error comparing the set with that of a new blade. The team's foreman should set the teeth during his day's work. Blade life depends on the care of the blade and having the correct frame. In dense wood, e.g. wattle, a blade should last two weeks and in less dense wood, e.g. *E.grandis* and pine, four weeks.

2.1.3 Method of application

Harvesting teams should have the same layout as described for the conventional chainsaw method (see para 2.2). Labourers pair off to fell one another's trees. Only two or three trees for each labourer should be felled at a time. The labourers then debranch, stack brush, debark, bundle and stack the bundles for their individual trees. This work cycle is continued until the completion of the daily task given in Table 1 below.

The bowsaw felling technique is similar to that of the chainsaw. The frontal cut penetrates to just short of halfway. A wedge is then cut, usually using a 0,9 kg hatchet, following which the back-cut is made. It is important that the cuts are never down-sloping and that the back-cut ends slightly above the frontal cut. This will ensure accurate directional felling which increases productivity and decreases accidents.

Crosscutting is undertaken by a separate team ideally closely following the felling team so that the wet timber is crosscut.

2.1.4 Daily tasks

Daily tasks for the felling and crosscut teams are given in Tables 1 and 2, respectively. From the daily tasks, the felling and crosscutting teams can be balanced by dividing the task of a crosscutter by a feller.

TABLE 1

Wattle : Tasks per manday in number of trees to fell by bowsaw, debranch, stack brush, debark, and bundle and stack bark

Mean Dbh (cm)	Mean tree height (metres)												
	13	14	15	16	17	18	19	20	21	22	23	24	25
	Normal daily tasks (trees)												
11	18	18	18	17	17	17	17						
12		16	16	15	15	15	15	15					
13		14	14	14	14	14	13	13	13				
14			13	13	12	12	12	12	12	12			
15			12	11	11	11	11	11	11	11	11		
16			11	11	10	10	10	10	10	10	10	10	
17				10	10	10	9	9	9	9	9	9	9
18				9	9	9	9	9	9	8	8	8	8
19				8	8	8	8	8	8	8	8	8	8
20					8	8	8	8	7	7	7	7	7
	Maximum daily tasks (trees)												
11	24	24	23	23	23	23	22						
12		21	21	21	20	20	20	20					
13		19	19	18	18	18	18	18	18				
14			17	17	17	16	16	16	16	16			
15			15	15	15	15	15	15	14	14	14		
16			14	14	14	14	14	13	13	13	13	13	
17				13	13	13	13	12	12	12	12	12	12
18				12	12	12	12	12	11	11	11	11	11
19				11	11	11	11	11	11	11	10	10	10
20					10	10	10	10	10	10	10	10	10

TABLE 2

Wattle : Daily tasks in number of trees per bowsaw (2 bowsawyers) to crosscut and crosscut and bunch wet poles.

DBH (cm)	Poles per tree	Crosscut		Crosscut,carry(7m) and bunch poles	
		Norm	Max	Norm	Max
9	3	147	196	118	157
10	5	88	118	71	94
11	5	85	113	67	89
12	6	69	92	54	72
13	6	67	89	49	66
14	7	56	75	42	56
15	7	54	73	38	51
16	7	53	70	35	47
17	7	51	68	32	43
18	7	49	66	29	38
19	7	48	63	27	36
20	7	46	62	25	34

2.2 Conventional chainsaw system

2.2.1 Scale of operation

The conventional chainsaw method is the most popular, versatile and abused method of all. In both wattle and *E.grandis* it can be used for daily production levels too large for bowsaw usage. The limiting factor is labour supply and overheads as the method is labour-intensive.

2.2.2 Method of application in wattle

2.2.2.1 Team layout

Team layout is vital to the efficiency of a method. Normally a four-tree row brushline is used. Labourers operate abreast across a front each taking two tree rows parallel with the brushline. Unless conditions require a two-tree safety row, two labourers will work between brushlines. The total width of the front being worked will be about 80 m depending on the number of labourers per chainsawyer.

All labourers' work sites must be kept roughly adjacent. Strong workers who process an above normal daily task should be alternated with weaker workers every day or so to maintain an even working front.

The purpose of this layout is to minimise the total area covered by each chainsawyer and thereby maximise his and the team's productivity. If this layout is not adhered to strictly, chainsawyer daily task rates will not be achieved and must be reduced by 20 per cent. This reduction is necessary also in poor stand quality (see Section 2.2.3.3 below for description)

2.2.2.2 Work designation

Chainsawyers must receive formal training in basic maintenance and use of chainsaws and in applying any system selected.

In the conventional chainsaw system it is necessary that each chainsawyer be supplied with an assistant who is provided with a steel-pronged 2,5- to 3-metre stick to guide trees in the desired felling direction. Two shortened 15 cm nails welded to a collar forms an ideal prong. This stick may serve also as a marker for crosscutting.

The chainsawyer's objective is to keep all labourers supplied with suitably presented work. Felling 10 to 15 trees per labourer, then leaving them to debark tree lengths will reduce team productivity seriously. Two to a maximum of three trees should be felled per labourer with the chainsawyer moving across the front. On reaching the last labourer, the chainsawyer returns to the first one and commences crosscutting. Tree lengths will be ready for crosscutting as the labourers will have debranched and stacked the brush of the felled trees and should be ready to commence debarking. The chainsawyer continues the work cycles until daily tasks are completed.

To prevent mass loss of the team's total bark production through drying out, bark should be bundled as soon as sufficient for a bundle is obtained then stacked in the shade and covered with brush.

Labourers should swing or partially bunch shortwood to clear the centre between brushlines and so permit infield loading of bark and timber.

2.2.2.3 Daily tasks

Daily tasks for labourers and chainsawyers are given in Tables 3 and 4, respectively. Table 5 gives a guide to the expected number of poles per tree. For slope correction, see Table 11. Balancing the outputs of labourers per chainsawyer is done as explained in para 4.1.3 and Appendix 1.

TABLE 3

Wattle : Daily tasks in number of trees for labourers following the conventional chainsaw system

Mean dbh (cm)	Mean tree height (metres)												
	13	14	15	16	17	18	19	20	21	22	23	24	25
	Normal daily tasks (trees)												
11	23	22	22	22	22	21	21						
12	20	20	20	19	19	19	19	18					
13		18	17	17	17	17	16	16	16				
14		16	16	15	15	15	15	15	15	14			
15			14	14	14	14	13	13	13	13	13		
16			13	13	13	13	12	12	12	12	12	12	
17				12	12	12	11	11	11	11	11	11	
18				11	11	11	11	10	10	10	10	10	10
19				10	10	10	10	10	10	9	9	9	9
20					9	9	9	9	9	9	9	9	9
	Maximum daily tasks (trees)												
11	30	30	30	29	29	28	28						
12	27	26	26	26	25	25	25	24					
13		24	23	23	23	22	22	22	21				
14		21	21	21	20	20	20	20	19	19			
15			19	19	18	18	18	18	18	17	17		
16			17	17	17	17	16	16	16	16	16	16	
17				16	16	15	15	15	15	15	14	14	
18				15	14	14	14	14	14	14	13	13	13
19				14	13	13	13	13	13	13	12	12	12
20					12	12	12	12	12	12	12	11	11

TABLE 4

Wattle : Daily tasks[1)2)] to the nearest five trees, for a chainsawyer felling and crosscutting to shortwood lengths

Mean dbh (cm)	Mean tree height (metres)												
	13	14	15	16	17	18	19	20	21	22	23	24	25
	Normal daily task (to nearest 5 trees)												
10	310	300	285	275	270	260							
11	295	285	270	265	255	245	240						
12		270	260	250	240	235	225	220					
13		255	245	240	230	225	215	210	205				
14			235	230	220	215	205	200	195	190			
15			225	220	210	205	200	195	185	180	175		
16			215	210	200	195	190	185	180	175	170	165	
17				200	195	190	185	180	175	170	165	160	155
18				195	185	180	175	170	165	160	160	155	150
19				185	180	175	170	165	160	155	155	150	145
20					175	170	165	160	155	150	145	145	140
	Maximum daily tasks (to nearest 5 trees)[3)]												
10	415	400	385	370	355	345							
11	390	375	365	350	340	330	315						
12		360	345	335	320	310	300	295					
13		340	330	320	305	300	290	280	270				
14			315	305	295	285	275	270	260	255			
15			300	290	280	275	265	255	250	245	235		
16			290	280	270	260	255	245	240	235	225	220	
17				265	260	250	245	235	230	225	220	215	210
18				255	250	240	235	230	220	215	210	205	200
19				250	240	235	225	220	215	210	205	200	195
20					230	225	220	215	205	200	195	190	185

Notes: 1) Reduce daily tasks by 10 per cent. if a two-tree row safety belt between labourers is used or stand quality is poor.

2) Chainsawyer must be trained to follow the prescribed method and be provided with an assistant who is equipped with a pronged, 2,5 m long pushing stick. If this is not done, reduce tasks by 20 per cent.

3) These daily tasks assume that the numbers of accompanying labourers are not increased, but produce maximum output. If labourers work at normal rate and their numbers are increased, these daily chainsawyer tasks must be reduced by 5 per cent.

TABLE 5

Wattle : Guide to the expected number of 2,27 m poles for various tree heights

Height (m)	No of Poles/tree [1)]
13	3,2
14	3,7
15	4,1
16	4,5
17	4,9
18	5,3
19	5,7
20	6,1
21	6,6
22	7,0
23	7,4
24	7,8
25	8,2

1) To convert the number of poles/tree from 2,27 m to 2,44 m poles use the following equation :

$$\text{No of Poles/tree in Table} \times \frac{2{,}27}{2{,}44} = \text{No of 2,44 m poles/tree}$$

2.2.3 Method of application in *E.grandis*

2.2.3.1 Team layout

Normally a five-tree row brushline is used in *E.grandis*. Labourers select a single line of trees parallel with the brushline. They work abreast across front, leaving two tree rows as safety rows. Each successive day all labourers move over one tree row, keeping the same width safety belt, until that rectangle of trees is finished. If labourers work four-tree rows instead of one, studies show that the chainsawyer's crosscutting activity increases 20 per cent., which results in an overall productivity loss of 12 per cent.

For the same reasons described for wattle, as the team moves deeper into the plantation, stronger labourers must be changed about with weaker ones to maintain even progress of the team.

2.2.3.2 Work designation

Once felled, tree lengths are difficult to debark. To overcome this, the chainsawyer should fell only a third of each labourer's intended output of trees per day, so he can return and crosscut. This gives time for debranching and stacking brush while not delaying labourers requiring crosscut poles.

Labourers should rip-strip standing trees to the maximum extent possible. Where strippability permits, chainsawyers should delay felling to allow labourers time to rip-strip a third of their trees before felling. Rip-stripping in this way reduces debarking time by a third thus giving the fifth class of strippability shown in Table 6, but extreme care must be taken not to rip-strip the butts of sturdy trees downwards and so impair coppicing ability.

Chainsawyers should be trained and provided with an assistant who is equipped with a pronged pole described for use in wattle.

As poles are debarked, labourers should clear them from the centre between brushlines and swing or partially bunch the poles in preparation for infield loading.

2.2.3.3 Daily tasks

Daily tasks for labourers are given in Table 6 from which the harvesting teams must be balanced as before. Tables 7 and 8 give chainsawyer daily tasks for felling and crosscutting first rotation and coppice respectively. Table 9 shows chainsawyer's daily task corrections for slope. Table 10 gives a guide to the expected number of 2,27 m poles per tree.

Ease of debarking, strippability, is the most important single factor in tasking labourers in *E.grandis*. Another important factor is stand quality. Classification of these two factors are given below :

Strippability classification

Strippability class	Description
1	Bark has to be part chiselled off the poles and part comes off in up to 30 cm strips
2	Bark comes off in 1 to 2 m long strips. Occasional poles may require chiselling while other poles strip freely.
3	Nearly all poles strip freely. There should be no chiselling.
4	Most trees are rip-stripped to half the usable height before felling. All poles strip easily.
5	All trees are rip-stripped to their usable height before felling. Only the top pole

Where strippability is below Class 1, growers are advised to suspend harvesting until the drought has passed. Class 5 strippability has been noted only in peak rainfall periods in the warmer low-lying areas in Zululand.

Stand quality

Stand quality	Description
Very good	Over 1 400 stems/ha, all stems between 12 and 20 cm diameter at breast height (dbh) and no dead trees. Tree rows in both major directions must be straight and espacement even. No undergrowth, slopes less than 10 degrees.
Average	Over 1 200 stems/ha, reasonable stem uniformity and only occasional dead trees, tree rows straight in two directions. No excessive undergrowth. Slopes less than 20 degrees.
Poor	1 000 stems/ha or less, a fair proportion of stems below 9 cm dbh and dead trees. Poorly aligned tree rows. Espacement irregular. Slope over 20 degrees. (Most, but not all these factors need be present).

2.2.3.4 Felling and crosscutting poles for creosoting

Where poles are intended for creosoting it is common practice to mark and crosscut accurately in a separate operation. Due to the high variability of this operation, daily tasks vary accordingly. For bowsaw crosscutting daily tasks can be built up from the data provided in Table 10.

Chainsaw crosscutting is even more unpredictable because of the caution required to obtain accuracy, and because often timber is cut at various stages of air-drying. A rough guide is that two crosscut chainsawyers are required for every chainsawyer felling.

TABLE 6

E.grandis : Daily tasks in number of trees for labourers following the conventional chainsaw system

Strippability class 1)	Arbitrary stand quality 2)		
	Very good	Average	Poor
	Average-size trees (22 m high)		
	Normal daily tasks (trees)		
1	19	18	16
2	25	23	21
3	33	29	25
4	41	36	30
5	50	43	34
	Maximum daily tasks (trees)		
1	25	24	21
2	34	31	27
3	44	39	33
4	54	48	39
5	67	58	46
	Short trees (17 m high)		
	Normal daily tasks (trees)		
1	25	23	20
2	33	30	25
3	42	37	31
4 3)	52	44	35
5 3)	64	53	40
	Maximum daily tasks (trees)		
1	33	31	27
2	44	40	34
3	57	49	41
4 3)	70	59	47
5 3)	86	71	54
	Tall trees (27 m high)		
	Normal daily tasks (trees)		
1	16	15	14
2	21	20	18
3	28	25	22
4	35	31	26
5	43	38	31
	Maximum daily tasks (trees)		
1	21	20	19
2	29	27	24
3	37	34	30
4	46	42	35
5	58	51	41

Notes: 1) Refer description of strippability classes above
2) Refer description of stand quality given above
3) These classes for short trees are not normally encountered. Daily tasks have been extrapolated as a guide only.

TABLE 7

E.grandis : Daily tasks to the nearest five trees for a chainsawyer to fell and crosscut to shortwood lengths - first rotation

Mean DBH	Mean tree height (metres)														
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
(cm)	Normal daily tasks (trees)														
12	430	415	405	395	385	370									
13	395	380	370	360	345	335	325								
14		345	335	325	315	305	295	285							
15			305	295	290	280	270	260	255						
16				275	265	255	245	235	230	220					
17					240	230	225	215	205	200	195				
18						210	205	195	185	180	175	165			
19							185	175	170	165	155	155	145		
20								160	155	150	145	135	135	125	125
	Maximum daily tasks (trees)														
12	575	555	545	525	510	495									
13	525	505	495	480	465	450	435								
14		465	450	435	425	410	395	385							
15			410	395	385	375	360	345	335						
16				365	350	340	325	315	305	295					
17					320	310	295	285	275	265	255				
18						280	270	260	250	245	235	225			
19							245	235	225	220	210	205	195		
20								215	205	200	190	185	175	170	165

TABLE 8

E.grandis : Daily tasks to the nearest five trees for a chainsawyer to fell and crosscut to shortwood lengths - coppice crops

Mean DBH (cm)	Mean tree height (metres) 15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
	Normal daily tasks (trees)														
12	385	375	365	355	345	335									
13	350	345	335	325	315	305	295								
14		315	305	295	285	280	270	265							
15			275	270	260	255	245	235	230						
16				245	235	230	225	215	210	205					
17					215	210	205	195	190	185	175				
18						195	185	180	175	165	165	155			
19							170	165	155	155	145	140	135		
20								145	145	135	135	125	125	120	115
	Maximum daily tasks (trees)														
12	515	500	485	475	465	450									
13	465	455	445	435	420	405	398								
14		415	405	395	385	375	360	350							
15			370	360	350	340	325	315	305						
16				325	315	305	300	290	280	270					
17					290	280	275	265	255	245	235				
18						255	245	240	235	225	215	205			
19							225	215	210	205	195	190	185		
20								195	190	185	175	170	165	160	155

TABLE 9

E.grandis : Daily tasks to the nearest 10 trees for chainsawyers felling

Tree DBH (cm)	Daily tasks (trees)			
	First rotation		Coppice	
	Normal	Maximum	Normal	Maximum
10	1 040	1 390	850	1 130
11	980	1 300	790	1 050
12	920	1 220	730	980
13	860	1 150	680	910
14	810	1 090	640	850
15	770	1 030	600	800
16	730	970	560	750
17	690	920	530	710
18	660	880	500	670
19	630	830	480	640
20	590	790	450	600

N.B. To attain these production rates the layout, provision of a chainsawyer's assistant and use of the pronged stick, all described in the above references, must be followed.

TABLE 10

E.grandis : Standard minutes from which can be developed bowsaw crosscut times per tree for poles of various diameters

Pole diameter at crosscut (cm)	Standard time to measure and crosscut (minutes)
6	0,54
7	0,58
8	0,62
9	0,67
10	0,73
11	0,78
12	0,84
13	0,90
14	0,97
15	1,04
16	1,11
17	1,18
18	1,26
19	1,34
20	1,42
21	1,51

The following example demonstrates how to use these data. Assume an order requires poles of lengths so that the diameters of the cross-cuts are 15 cm, 13 cm, 10 cm and 8 cm for each tree processed that day. The total crosscut time in minutes per tree length will be

1,04 + 0,90 + 0,73 + 0,62 = 3,29 minutes.

The daily task is obtained by dividing 3,29 minutes into 360 minutes and 480 minutes, to give the normal and maximum expected daily tasks, respectively. Thus,

$$\frac{360}{3,29} = 109, \text{ say } 110 \text{ poles normal daily task}$$

$$\frac{480}{3,29} = 146, \text{ say } 150 \text{ poles maximum daily task}$$

TABLE 11

Slope allowances of chainsawyers felling and crosscutting. Multiply chainsawyers' daily tasks by the appropriate factor to allow for the influence of slope

DBH (cm)	Slope in degrees				
	15	20	25	30	35
12	0,96	0,92	0,86	0,78	0,68
13	0,96	0,93	0,87	0,76	0,69
14	0,97	0,93	0,87	0,79	0,70
15	0,97	0,93	0,87	0,80	0,71
16	0,97	0,93	0,88	0,80	0,71
17	0,97	0,94	0,88	0,81	0,73
18	0,97	0,94	0,89	0,82	0,73
19	0,97	0,94	0,89	0,82	0,74
20	0,97	0,94	0,89	0,83	0,75

TABLE 12

E.grandis : Guide to the expected number of 2,27 m poles[1)] for various tree heights

Height	No of poles/tree[1)]
13	3,6
14	4,0
15	4,4
16	4,8
17	5,3
18	5,7
19	6,1
20	6,5
21	6,9
22	7,3
23	7,7
24	8,1
25	8,6

Note: 1) To correct number of poles/tree from 2,27 m to 2,44 m poles use the following equation :

No of poles/tree in Table x $\frac{2,27}{2,44}$ = No of 2,44 m poles/tree

2.3 Bench system

2.3.1 Scale of operation

Only large-scale operations use the bench system of harvesting. It has been shown (de Laborde, *loc cit*) that the method uses roughly triple the chainsaw time per ton of timber produced compared with the conventional chainsaw method, but at an equal level of output there is only a 13 per cent. reduction in labour requirements.

However, because most of the operations are performed by the chainsawyers who are carefully selected and given frequent formal training, their mean daily output is usually above normal and often approaches the maximum shown in Table 13. This can result in up to 35 per cent. decrease in total labour requirements. Where labour overheads are high the cost of the extra chainsaws and highly-paid operators is more than offset.

2.3.2 Application of the method in wattle and *E.grandis*

2.3.2.1 Team layout

A four or five-tree row brushline layout is used. As there are many chainsawyers felling trees, it is necessary to leave a swathe between brushlines as a safety belt between them.

2.3.2.2 Work designation

Chainsawyers move back and forth between brushlines felling, butt cutting (trimming butts), marking and debranching, stacking brush and cross-cutting each tree, in that sequence. Benches are seldom made as they either break or result in damage to the tree being felled.

Labourers follow each chainsawyer debarking poles, bundling bark and stacking the bundles in wattle, and swinging, bunching or sorting and stacking the poles.

2.3.2.3 Daily tasks

Daily tasks for chainsawyers and labourers are given in Tables 13 and 14 respectively. Numbers of labourers per chainsawyer must be correctly balanced. The ratio is calculated by dividing the chainsawyer's daily task by that of a labourer. The ratio usually lies between 2,5 and 4 which means that often every third or fourth labourer will be shared between two chainsawyers. A guide to the number of poles per tree was given in Table 12.

TABLE 13

Wattle : Estimated Daily Tasks in number of trees for chainsawyers using the bench system of harvesting

Mean DBH (cm)	Mean tree height (metres)												
	13	14	15	16	17	18	19	20	21	22	23	24	25
	Normal daily tasks (trees)												
10	86	83	80	77	75	73							
11	77	75	72	70	68	66	64						
12		68	66	64	52	61	59	58					
13		62	61	59	58	56	55	54	52				
14			56	55	53	52	51	50	49	48			
15			52	51	50	49	48	47	46	45	44		
16			49	48	47	46	45	44	43	43	42	41	
17				45	44	43	42	42	41	40	40	39	38
18				42	42	41	40	40	39	38	38	37	36
19				40	39	39	38	38	37	36	36	35	35
20					38	37	36	36	35	35	34	34	33
	Maximum daily tasks (trees)												
10	115	111	107	103	100	97							
11	103	99	96	93	91	88	86						
12		90	88	85	83	81	79	77					
13		83	81	79	77	75	73	71	70				
14			75	73	71	70	68	67	65	64			
15			70	68	67	65	64	62	61	60	59		
16			65	64	62	61	60	59	58	57	56	55	
17				60	59	58	57	56	55	54	53	52	51
18				57	56	55	54	53	52	51	50	49	49
19				54	53	52	51	50	49	48	48	47	46
20					50	49	48	48	47	46	46	45	44

TABLE 14

Wattle : Daily Tasks in number of trees for labourers following the bench system of harvesting

Mean DBH (cm)	Mean tree height (metres)												
	13	14	15	16	17	18	19	20	21	22	23	24	25
	Normal daily tasks (trees)												
11	34	33	33	32	31	31	30						
12	30	29	29	28	28	28	27	26					
13		26	26	25	25	24	24	23	23				
14		24	23	23	22	22	22	21	21	20			
15			21	21	20	20	20	19	19	19	19		
16			19	19	19	18	18	18	17	17	17	17	
17				18	17	17	17	16	16	16	16	15	
18				16	16	16	15	15	15	15	14	14	14
19				15	15	15	14	14	14	14	13	13	13
20					14	14	13	13	13	13	13	12	12
	Maximum daily tasks (trees)												
11	46	45	44	43	42	41	40						
12	40	39	38	38	37	37	36	35					
13		35	34	34	33	32	32	31	31				
14		32	31	30	30	29	29	28	28	27			
15			28	28	27	27	26	26	25	25	24		
16			26	25	25	24	24	24	23	23	22	22	
17				23	23	23	22	22	22	21	21	20	
18				22	21	21	21	20	20	20	19	19	19
19				20	20	20	19	19	19	18	18	18	17
20					19	18	18	18	17	17	17	17	16

TABLE 15

E.grandis : Daily Tasks in number of trees for chainsawyers using the bench system of harvesting

Mean DBH (cm)	Mean tree height (metres) 13	14	15	16	17	18	19	20	21	22	23	24	25
	Normal daily tasks (trees)												
10	148	146	144	142	140	138							
11	135	133	131	129	127	126	124						
12	123	121	120	118	116	115	113	111					
13		112	110	108	107	105	104	102	101				
14			101	100	99	97	96	94	93	91			
15				93	91	90	89	87	86	85	83		
16					85	83	82	81	80	78	77	76	
17						78	76	75	74	73	72	70	69
18							71	70	69	68	67	66	64
19								66	64	63	62	61	60
20									60	59	58	57	56
	Maximum daily tasks (trees)												
10	198	195	192	190	187	185							
11	179	177	175	172	170	168	165						
12	164	162	160	157	155	153	151	149					
13		149	147	145	142	140	138	136	134				
14			135	133	131	129	128	126	124	122			
15				123	122	120	118	116	114	113	111		
16					113	111	110	108	106	104	103	101	
17						104	102	100	99	97	96	94	92
18							95	94	92	90	89	87	86
19								87	86	84	83	81	80
20									80	79	77	76	75

TABLE 16

E.grandis : Daily tasks in numbers of trees and poles for labourers following the bench system of harvesting for three categories of tree heights, combinations of work and three strippability classes

Operations	Tasks in trees			Tasks in poles		
	Class 1 Strippability - poor[1)]					
	Tree sizes			Tree sizes[2)]		
	Short	Medium	Tall	Short	Medium	Tall
	Normal daily tasks (trees)			Normal daily tasks (poles)		
Debark and clear centre of swathe[3)]	26	20	17	151	155	157
Debark and swing and partially bunch poles	25	19	16	145	147	148
Debark and sort, carry and stack poles	21	16	13	122	124	120
	Maximum daily tasks (trees)			Maximum daily tasks (poles)		
Debark and clear centre of swathe[3)]	35	26	22	203	202	203
Debark and swing and partially bunch poles	33	25	21	191	194	194
Debark and sort, carry and stack poles	28	21	18	162	163	166
	Class 2 Strippability - average[1)]					
	Normal daily tasks (trees)			Normal daily tasks (poles)		
Debark and clear centre of swathe[3)]	36	27	23	208	209	212
Debark and swing and partially bunch poles	34	26	22	197	202	203
Debark and sort, carry and stack poles	27	20	17	156	155	157
	Maximum daily tasks (trees)			Maximum daily tasks (poles)		
Debark and clear centre of swathe[3)]	48	36	30	278	279	277
Debark and swing and partially bunch poles	45	34	29	261	264	268
Debark and sort, carry and stack poles	36	27	22	208	209	203
	Class 3 Strippability - good[1)]					
	Normal daily tasks (trees)			Normal daily tasks (poles)		
Debark and clear centre of swathe[3)]	47	35	30	272	271	277
Debark and swing and partially bunch poles	43	33	28	249	256	253
Debark and sort, carry and stack poles	33	24	20	191	186	185
	Maximum daily tasks (trees)			Maximum daily tasks (poles)		
Debark and clear centre of swathe[3)]	63	47	40	365	364	369
Debark and swing and partially bunch poles	58	44	38	336	341	351
Debark and sort, carry and stack poles	44	32	27	255	248	249

Notes: 1) Refer daily tasks for conventional chainsaw method for definition of strippability classes.

2) The following defines tree sizes :

Short	:	17 m high and 5,8 poles/tree
Medium	:	22 m high and 7,8 poles/tree
Tall	:	27 m high and 9,2 poles/tree

3) This includes debark and make a clearing down the centre between brushlines to facilitate infield loading by tractor and lowbed trailer or other vehicle.

3 TIMBER TRANSPORT

In-depth studies of wattle and eucalypt timber extraction systems are still being undertaken, and the following guidelines are provided on the basis of preliminary results :

3.1 Manual extraction of Shortwood Poles

3.1.1 Application and method

Manual shortwood extraction is applied usually only where slopes or terrain prohibit infield loading, to stack timber at roadside or infield for grab loading or mechanical extraction and to sort and stack timber into categories infield or at roadside for subsequent loading. Timber is usually carried manually up or down a slope and stacked at roadside only where infield loading is not possible. Here the top quarter to third is carried up and the remainder down to roadside.

On a 15-degree (27 per cent.) slope, extraction time is decreased by 5,8 per cent. by tumbling poles compared with carrying them down the slope. On slopes greater than 15 degrees this benefit will increase and on slopes less than this only carrying is practicable.

3.1.2 Daily tasks

Apart from the data on tumbling shortwood on slopes of 15 degrees, no further work has been done as yet. As slopes increase the time will decrease, so that the daily tasks shown in Table 17 for carrying timber may be regarded as the lowest number of poles that can be tumbled out.

Table 17 gives the daily tasks in numbers of shortwood poles of various masses that can be carried 20 m and 50 m up an 18-degree slope and down a 15-degree slope, including stacking the poles. It is disadvantageous to carry more than one pole at a time. Pegs to hold stacks were positioned by an additional labourer.

TABLE 17

Shortwood : Daily tasks to the nearest five poles for a labourer carrying shortwood lengths 20 m and 50 m up an 18° slope and down a 15° slope and stack the poles

Poles/ t	Mean Pole mass (kg)	Daily tasks in poles							
		20 m carry distance				50 m carry distance			
		up 18° slope		down 15° slope		up 18° slope		down 15° slope	
		Norm	Max	Norm	Max	Norm	Max	Norm	Max
18	56	165	220	240	320	75	100	120	160
20	50	175	235	260	345	80	105	125	170
25	40	190	255	285	380	85	115	140	185
30	33	210	285	310	410	95	125	150	195
35	29	215	285	325	430	95	130	155	205
40	25	230	305	340	455	100	135	160	210
45	22	235	315	350	465	105	140	165	215
50	20	245	325	360	480	110	145	165	220
55	18	255	340	365	490	110	150	170	225
60	17	260	345	375	495	115	150	170	230
65	15	270	360	380	505	120	155	175	230

3.2 Infield loading, offloading and transshipping of lorries and flat-bed trailers

Wherever terrain permits, infield timber loading should be used. It obviates extracting to roadside and stacking except where it is difficult to differentiate between pole categories. Here small stacks of the various categories are made infield.

Only times for the various loading, offloading and transshipping operations are given. For a given travelling time per vehicle, the time per complete work cycle can be built up from commencing to load the vehicle to its return for reloading. The cycle time in minutes is then divided into 360 or 480 minutes to give normal and maximum daily tasks. Examples of this are given in Appendix 3. In virtually all situations studied loading, offloading or transshipping is followed by a rest period. An exception is when the driver of a crane-mounted lorry correctly loads and drives. In this case, a 10 per cent. rest allowance must be included to calculate the standard minute times involved. If a system is developed where the travelling time during cycles is less than the time of a manual operation, or where labourers continuously perform these operations for a fleet of vehicles, daily tasks given below must be decreased by the amount shown in Table 22.

3.2.1 Manual operation with lorries and flat-bed trailers

The bed height of most lorries and flat-bed trailers and, if loaded correctly, the height to which they are loaded are similar. Differences in total load mass are determined essentially by the length of the bed.

3.2.1.1 Loading, offloading & transshipping shortwood poles

Shortwood mean pole mass has been shown to affect flat-bed loading times. To simplify Table 18, an average pole mass of 20 kg (50 poles/t) is taken which gives 12,61 basic minutes/t, thus for continuous loading, the times must be multiplied by 1.32 to give the rest allowance. For 14,3 kg (70 poles/t) multiply times by 1,12.

TABLE 18

Basic minutes for loading shortwood lengths on lorries and flat-bed trailers for various numbers of labourers and load masses

Load mass (t)	Number of labourers		
	4	5	6
	Loading time (minutes)[1]		
5	16	13	-
6	19	15	-
7	22	18	15
8	25	20	17
9	28	23	19
10	32	25	21
11	-	28	23
12	-	30	25
13	-	-	27

Note: 1) Loading times for masses in excess of those quoted for four and five labourers will rise steeply through fatigue as no rest allowance has been included
Six loaders are too many for loads of 5 and 6 t.

Table 19 is compiled similarly to the above description using 7,20 and 17,34 basic minutes for offloading and transshipping shortwood poles, respectively.

TABLE 19

Basic minutes to offload and transship shortwood lengths from a flat-bed vehicle for different numbers of labourers and load masses

Load mass (t)	Number of labourers					
	4	5	6	4	5	6
	Off-loading time (minutes)1)			Transshipping time (minutes)2)		
5	9	7	6	22	17	14
6	11	9	7	26	21	17
7	13	10	8	30	24	20
8	14	12	10	35	28	23
9	16	13	11	39	31	26
10	18	14	12	-	35	29
11	20	16	13	-	38	32
12	22	17	14	-	-	35
13	23	19	16	-	-	38

Note: 1) This time is to offload vehicles with fixed uprights without any stacking. If there are trip sides multiply times by 0,55

2) Time, for masses in excess of those quoted for four and five labourers will rise steeply through fatigue as no rest allowance has been included. Times are for vehicles with fixed uprights only.

.2.1.2 Loading and transshipping 5,7 m and 7,5 m poles

To handle 5,7 m poles, labourers should work in pairs while with 7,5 m poles there should be three labourers per pole. Only larger loads of these poles have been studied where both 5,7 m and 7,5 m poles were loaded. Consequently, times are for both sizes being handled by six labourers.

Loading and transshipping times are on a basis of 32,55 and 18,21 basic minutes per ton, respectively, used in Table 20. Transshipping times are lower than those for shortwood as the longer poles were thrown directly from the lorry into the rail truck. Shortwood had to be thrown on to the platform, then carried and stacked.

TABLE 20

Basic minutes to load 5,7 m and 7,5 m poles on to and transship from flat-bed vehicles using six labourers

Load mass (t)	Loading time (minutes)	Transshiping time (minutes)
7	38	21
8	43	24
9	49	27
10	54	30
11	60	33
12	65	36
13	71	39

3.2.2 Crane loading and transshipping of 9,3 m poles

Data for these operations are limited. Times are given for loading and transshipping using a lorry with a front-mounted crane which takes one or two poles per grab. It is advised that the crane be driver-operated. Poles should be grouped infield or stacked at roadside to accommodate loading.

Loading and transshipping times in Table 19 are based on 4,38 and 4,92 basic minutes per ton, respectively.

TABLE 21

Times to load and transship 9,3 m poles using a lorry with front-end mounted crane. Crane operating is undertaken by the driver

Load Mass (t)	Loading time (minutes)	Transshipping time (minutes)
11	48	54
12	53	59
13	57	64
14	61	69

3.3 Large-scale shortwood extraction using tractors and low-bed trailers

This system employs 58 kw tractors and low-bed trailers for initial infield timber extraction in approximately six-ton loads on slopes of up to 17 degrees (31 per cent.). Trailers are loaded manually by four or five labourers. After securing the load with two cane chains, the timber bundles are transshipped at a loading bay by crane to either 18 t tractor-trailer units taking three timber bundles or lorries taking five or six timber bundles for road haulage to the railway station or mill, respectively (de Laborde, 1982).

3.3.1 Daily tasks

Daily tasks for the various operations are given below. Examples of applying these data are given in Appendix 3. Loading time for various load sizes for pole sizes between 40 and 65 poles per ton using 4 and 5 manual loaders, are given in Tables 22 and 23, and graphically in Figures 1 and 2, respectively.

Round-trip travelling time and speed for the infield tractor-trailer to the loading bay is 6 min/km, i.e. 10 km/h

Offloading trailers by crane is 2 minutes.

Crane operations to nearest half-minute :

Offload and stack		2,0 minutes
Transship from infield tractor-trailer or take from stocks and load on to road-haulage tractor-trailer	per bundle	2,5 minutes
	per 3-bundle load	7,5 minutes
Transship from infield tractor-trailer or take from stocks and load on to lorry	per bundle	3,5 minutes
	per 5-bundle load	17,5 minutes
	per 6-bundle load	21,0 minutes
Remove chains returned by lorry or tractor-trailer from a railway station or mill		2,0 minutes

TABLE 22

Shortwood : Loading times and rest factors for four manual loaders loading low-bed trailers

Pole size (poles/t)	Basic minute loading times for stated load size					Rest factor 1)
	4,5t (min)	5,0t (min)	5,5t (min)	6,0t (min)	6,5t (min)	
40	8,7	10,0	11,3	12,5	13,8	1,37
45	9,7	11,1	12,5	13,9	15,3	1,34
50	10,6	12,1	13,7	15,3	16,9	1,32
55	11,5	13,2	14,9	16,7	18,4	1,29
60	12,4	14,3	16,2	18,1	20,0	1,28
65	13,3	15,3	17,4	19,4	21,5	1,27

Note: 1) Rest factors are derived from the relaxation allowances prescribed by the International Labour Office.
Times contained in the table must be multiplied by this factor where this product is greater than the total cycle time, i.e. to load, travel to and from the load site and offload.

TABLE 23

Shortwood : Loading times and rest factors for five manual loaders loading low-bed trailers

Pole size (poles/t)	Basic minute loading times for stated load sizes					Rest factor[1]
	4,5t (min)	5,0t (min)	5,5t (min)	6,0t (min)	6,5t (min)	
40	7,0	8,0	9,0	10,0	11,0	1,37
45	7,7	8,9	10,0	11,1	12,3	1,34
50	8,4	9,7	11,0	12,2	13,5	1,32
55	9,2	10,6	12,0	13,3	14,7	1,29
60	9,9	12,0	12,9	14,4	16,0	1,28
65	10,6	12,3	13,9	15,6	17,2	1,27

Note: 1) See Note to Table 1.

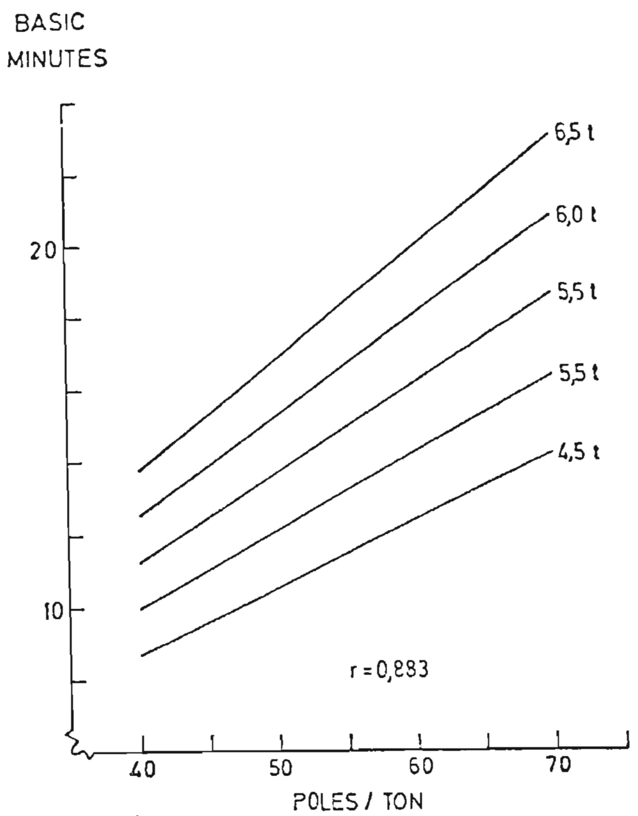


Figure 1. Minutes for four labourers to load various tonnages of shortwood poles on a low-bed

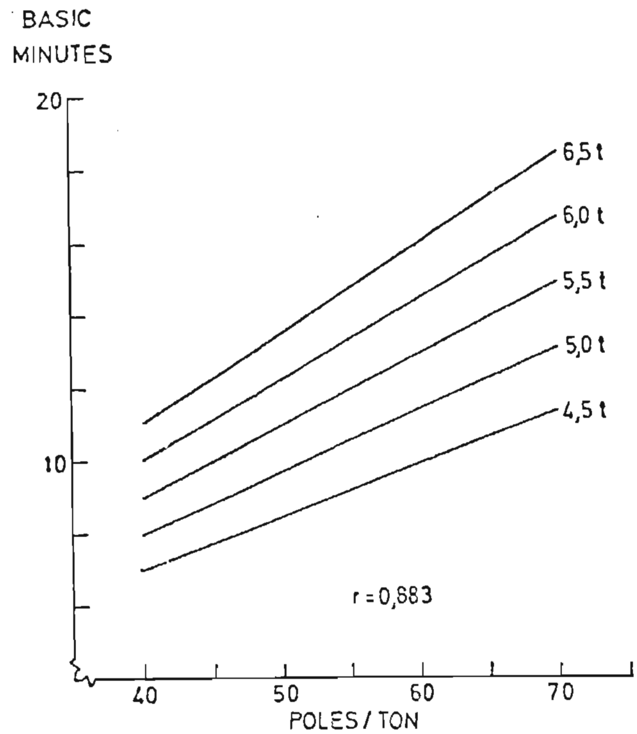


Figure 2. Minutes for five labourers to load various tonnages of shortwood poles on a low-bed trailer for a range of poles per ton.

3.4 Triple-tag-line system for winching, skidding, ox-slipping or high-leading timber

Where a single set of choker chains is used in winching, skidding, ox-slipping or highleading timber, turn-round time equals travelling time. Daily production can be doubled when three sets of choker chains are used, each on their own tag-line. Thereby, a saving is achieved of one ox-slipping team, skidder, winch or highlead for every two (de Laborde, 1982).

3.4.1 Extraction layout

A skidding team usually comprises two labourers who set the choker chains, one driver-cum-winch operator and a labourer who releases the choker chains. Skidding distances have been found to vary between 100 and 200 m. An ox-slipping team differs only in that there is the span driver, and only one choker setter is required.

3.4.2 Triple-tag-line system

Each winch cable, or trek chain, has a quick release couple fitted to its end to which a wire rope tag-line is connected. All tag-lines carry the required number of choker chains for a particular skidding operation. There are three such tag-lines for each winch cable.

Choker setters prepare logs for skidding by attaching the choker chains, removing serious obstacles and laying the tag-line(s) out ready to be coupled to the winch cable(s). The skidder returns a tag-line (or pair of tag-lines for double-drum winches) on arrival at the site. Thereafter, the choker setters couple the prepared tag-line(s) and stand by to assist should jams occur during winching. Once no further assistance is required, they commence setting the next load of logs.

On arrival of the skidder at the unhitching point, the driver runs out the winch line, the labourer uncouples the tag-line(s) and the third set is loaded on to the skidder, which then returns for the following cycle. The labourer releases the choker chains, using logging hooks to release and wrench the chokers free, and repositions or stacks the logs as required. Where the timber is heavy, the latter activity is performed mechanically or by a team of labourers. For ox-slipping, obvious changes are made to the above description, but the basic system remains.

Further time can be saved if, where possible, the skidder returns in reverse, thus saving difficult about-turns. Tag-lines being returned in this instance are draped on the front of the skidder.

Presentation of the logs is important, especially in pine thinning operations. Logs should be felled and/or bunched pointing towards where the skidder will approach and between 45 degrees left and right to the line of winching.

3.4.3 Machinery and equipment

Skidder incorporates any vehicle such as two-wheel-drive agricultural tractor, four-wheel-drive tractor with or without large front wheels or the special forestry skidders. Choice of vehicles depends on scale of operation, timber size and terrain.

Double-drum winches are preferred as they allow logs to be winched in from two directions, and because they offer the option of providing a haul-back line for any highlead type operation. For two- or four-wheel-drive tractors, a 4-t double-drum winch provides most versatility unless the timber is very light and winch distances short.

Single-drum winches can be fitted to the three-point linkage of a tractor, and are suitable for small-scale operations where the tractor only skids for short periods of the year. Currently, special forestry skidders are all fitted with large single-drum winches.

PLANNING TIMBER HARVESTING

Labour and Production Estimates

A form has been drawn up to assist growers estimate their labour requirements and production. Although the completed "Labour and Production Estimates" form contained in this Appendix is for wattle, data to apply it to *E.grandis* are available. To complete the form, it is necessary to measure the mean bark thickness, dbh, and tree height and assess the stocking in trees per ha. From tables available from the WRI (Schönau, 1971, 1972 and 1973) bark mass (for wattle), timber mass and timber density per tree and per ha is estimated.

From the daily tasks provided, the number of workers in the harvesting team can be calculated, and the tasks expressed in bark mass (for wattle), timber volume, timber mass and number of poles. Labour requirement per hectare is calculated by dividing daily tasks into the number of trees per ha. Where a grower has the necessary costs these can be applied to the above data to project labour and chainsaw costs per ha, and costs per t of bark and/or timber, or timber volume.

Ref : ________

LABOUR AND PRODUCTION ESTIMATES

Plantation : ____________ Block : ______ Date : ________

Tree Species : Wattle Age: ____ y Approximate stocking : 1 200 stems/ha

Mean Tree Dimensions

Bark thickness .. 5,0 mm
DBH (overbark) .. 15,0 cm
Height .. 17,5 m
Estimated bark mass (wattle) 22,9 x 93% .. 21,3 kg
Estimated total timber volume .. 0,125 m³
Less : stump & kerf wastage at 12 cm 1,7 %
crown wastage at 5 cm tip diam 0 %
Estimated utilized timber volume .. 0,123 m³
converted at 1,19 ~~[illegible]~~ m³/t .. 0,103 t
Estimated no. of 2,27m poles/tree .. 5,6 poles (see Table 5)

Estimated Yield per Hectare

Bark mass .. 26 t
Timber volume .. 148 m³
Timber mass .. 124 t

Workers' Daily Task in Trees & Team Size for the ~~Bowsaw~~/Conventional Chainsaw/~~Bench~~ Method

	Normal	Max
Labourers (Table 3)	14	18
Chainsawyer (Table 4)	205	275
Actual chainsaw and team output (14 trees x 14 labourers)	196	

Team Size : Labourers 205/14 = 14 Labourers,
1 chainsawyer and 1 chainsawyer's assistant = 16 workers

Workers' Output per Day at Normal Task

	Bark Mass (kg)	Timber Vol (m³)	Timber Mass (t)	Poles (2,27m)
Each labourer	300	1,72	1,44	78
Chainsawyer (whole team)	4 175	24,1	20,2	1 098

Labourer Requirements per Hectare at Normal Task

Labourers .. 86 man-days
Chainsawyer .. 6,1 man-days
Chainsawyer's assistant .. 6,1 man-days

Note : 1. All above information is provided as a guide only
2. Variances are minimised with high tree uniformity

Examples of setting daily tasks for primary timber extraction

EXAMPLE 1 (ref Section 5.3)

Situation :	Pole mass	45 poles per t
	Round-trip distance for tractor-trailer	2 km
	Number of loaders	5
	Mean mass of loads	5,5 t
Assessment :	Loading (Table 23 or Figure 2)	10,0 minutes
	Travelling	12,0 "
	Offload & collect 2 cane chains	2,0 "
	TOTAL	24,0

A normal working day is taken as 360 minutes concentrated work and the voluntary maximum under incentive schemes, 480 minutes of concentrated work.

Normal daily task : 360/24,0 = 15 loads or 15 x 5,5 = 82,5 t, giving 16,5 t per labourer per day.

Maximum daily task : 480/24,0 = 20 loads or 20 x 5,5 = 110 t, giving 22,0 t per labourer per day.

EXAMPLE 2 (ref Section 5.3)

Situation :	Pole mass	65 poles per t
	Round-trip distance for tractor-trailer	0,5 km
	Number of loaders	4
	Mean mass of loads	6,0 t
Assessment :	Loading (Table 22 or Figure 1)	19,4 minutes
	Travelling	3,0 "
	Offload and collect	2,0 "
	TOTAL	24,4

As the travelling time is so low, it is necessary to check whether the labourers are obtaining sufficient rest. To be adequate, the total cycle time, 24,4 minutes, must equal or exceed the product of the loading time and rest factor given in the Table, as follows :

Total cycle time $\geqslant$ Loading time x Rest factor, i.e.
24,4 minutes $\geqslant$ 19,4 x 1,27 = 24,6 standard minutes.

These two times equate with sufficient accuracy, so no additional allowance needs to be made.

Daily tasks are calculated following the description given in Example 1, as follows :

Normal daily task : 360/24,4 = 15 loads or 15 x 6,0 = 90 t, giving 22,5 t per labourer per day.
Maximum daily task: 480/24,4 = 20 loads or 20 x 6,0 = 120 t, giving 30 t per labourer per day.

APPENDIX C

DAILY TASKS FOR THE INTEGRATED SYSTEM IN *PINUS PATULA*

Tables provided below are taken from the equations in Section 5.5. Tables 1 and 2 involve three independent variables, *viz* tree diameter at breast height, total height and pruning height. To facilitate simplicity of application, the mean of the pruning heights shown in Table 5.10 was taken, thereby, obviating multiple tables.

The Appendix is a reproduction of a recent publication (de Laborde, 1983b) and should be applied in conjunction with the system description in Section 5.5.

TABLE 1

P.patula : Normal daily task[1], to the nearest five trees, for chainsaw clearfelling uphill at 60 degrees to the line of extraction

Conditions : Light

Mean dbh (cm)	Mean tree height (m)													
	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Normal daily task (to nearest 5 trees)													
19	535	530	525	520	515	515	510							
20	515	510	510	505	500	495	490	485						
21	500	495	490	485	480	475	470	465	460					
22	480	475	470	465	460	455	455	450	445					
23	460	455	455	450	445	440	435	430	425	425				
24	445	440	435	430	425	425	420	415	410	405	400			
25	425	420	420	415	410	405	400	400	395	390	385			
26	410	405	400	400	395	390	385	380	380	375	370	365		
27		390	385	380	380	375	370	365	365	360	355	350		
28			370	365	360	360	355	350	350	345	340	335	335	
29			355	350	350	345	340	335	335	330	325	325	320	
30				335	335	330	325	325	320	315	310	310	305	305
31				320	320	315	310	310	305	300	300	295	295	290
32				310	305	300	300	295	290	290	285	285	280	275
33					290	290	285	285	280	275	275	270	270	265
34					280	275	275	270	265	265	260	260	255	255
35						265	260	260	255	255	250	245	245	240
36						255	250	245	245	240	240	235	235	230
37						240	240	235	235	230	230	225	225	220
38							230	225	225	220	220	215	215	210
39							215	215	210	210	210	205	205	200
40							205	205	205	200	200	195	195	190

Note : [1]To calculate the maximum daily task, multiply the appropriate normal daily task by 1,33

TABLE 2

P.patula : Normal daily task[1], to the nearest five trees, for chainsaw clearfelling uphill at 60 degrees to the line of extraction

Conditions : Difficult

Mean dbh (cm)	Mean tree height (m)													
	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Normal daily task (to nearest 5 trees)													
19	365	365	360	360	355	355	350							
20	355	355	350	349	345	345	340	340						
21	45	345	340	340	335	335	330	330	325					
22	335	335	330	330	325	325	325	320	320					
23	325	325	325	320	320	315	315	310	310	305				
24	320	315	315	310	310	305	305	300	300	295	295			
25	310	305	305	300	300	295	295	290	290	290	285			
26		295	295	290	290	290	285	285	280	280	275	275		
27		290	285	285	280	280	275	275	270	270	270	265		
28			265	275	270	270	265	265	265	260	260	255	255	
29			265	265	265	260	260	255	255	250	250	250	245	
30				255	255	250	250	250	245	245	240	240	235	235
31				250	245	245	240	240	235	235	235	230	230	225
32				240	235	235	235	230	230	225	225	225	220	220
33					230	225	225	220	220	220	215	215	210	210
34					220	220	215	215	210	210	210	205	205	205
35						210	210	205	205	205	200	200	195	195
36						200	200	200	195	195	195	190	190	185
37						195	195	190	190	185	185	185	180	180
38							185	185	180	180	180	175	175	175
39							180	175	175	175	170	170	170	165
40							170	170	170	165	165	165	160	160

Note : [1]To calculate the maximum daily task, multiply the appropriate normal daily task by 1,33

TABLE 3

P.patula : Normal daily task[1], to the nearest five trees, for chainsaw clearfelling uphill at 60 degrees to the line of extraction and debranching

Mean dbh (cm)	Light Conditions: Mean tree height (m) 15	20	25	30	Mean dbh (cm)	Difficult Conditions: Mean tree height (m) 15	20	25	30
	Normal daily task (to nearest 5 trees)					Normal daily task (to nearest 5 trees)			
19	145	135			19	135	120		
20	140	130			20	130	120		
21	135	125	115		21	125	115	110	
22	130	120	110		22	120	110	105	
23	125	115	110		23	115	110	100	
24	120	110	105		24	115	105	100	
25	120	110	105		25	110	100	95	
26	115	105	100		26	105	100	95	
27	110	105	100		27	105	95	90	
28		100	95		28		95	90	
29		100	95		29		90	85	
30		95	90	85	30		90	85	80
31		95	90	85	31		90	85	80
32			85	80	32			80	80
33			85	80	33			80	75
34			80	80	34			80	75
35			80	75	35			75	75
36			80	75	36			75	70
37			75	75	37			70	70
38			75	70	38			70	70
39			75	70	39			70	65
40			70	70	40			70	65

Note : [1]To calculate the maximum daily task, multiply the appropriate normal daily task by 1,33

TABLE 4

P.patula : Normal daily task[1], to the nearest five trees, for chainsaw clearfelling downhill

Mean dbh (cm)	Normal daily task (to nearest 5 trees) Conditions: Light	Difficult
22	490	350
23	470	345
24	455	335
25	440	325
26	425	320
27	410	310
28	400	300
29	385	295
30	375	290
31	365	280
32	355	275
33	345	270

Mean dbh (cm)	Normal daily task (to nearest 5 trees) Conditions: Light	Difficult
34	335	265
35	325	260
36	320	255
37	310	250
38	305	245
39	295	240
40	290	235
41	280	230
42	275	225
43	270	220
44	265	215
43	260	210

Note : [1]To calculate the maximum daily task, multiply the appropriate normal daily task by 1,33

TABLE 5

P.patula : Normal daily task[1], to the nearest five trees, for chainsaw clearfelling downhill and debranching

Light Conditions					Difficult Conditions				
Mean dbh (cm)	Mean tree height (m)				Mean dbh (cm)	Mean tree height (m)			
	15	20	25	30		15	20	25	30
	Normal daily task (to nearest 5 trees)					Normal daily task (to nearest 5 trees)			
22	130	120	115		22	120	110	105	
23	125	115	110		23	115	110	105	
24	120	115	110		24	115	105	100	
25	120	110	105	100	25	110	105	100	95
26	115	108	105	100	26	105	100	95	95
27	110	105	100	95	27	105	100	95	90
28		105	100	95	28		95	90	90
29		100	95	95	29		95	90	85
30		100	95	90	30		90	90	85
31		95	90	90	31		90	85	85
32		95	90	90	32		90	85	80
33		90	90	85	33		85	85	80
34		90	85	85	34		85	80	80
35		90	85	85	35		85	80	80
36			85	80	36			80	75
37			85	80	73			80	75
38			80	80	38			75	75
39			80	80	39			75	75
40			80	75	40			75	75
41			80	75	41			75	70
42			75	75	42			75	70
43			75	75	43			70	70
44			75	75	44			70	70
45			75	70	45			70	70

Note :[1]To calculate the maximum daily task, multiply the appropriate normal daily task by 1,33

TABLE 6

P.patula : Normal and maximum daily tasks in trees for labourers debranching and topping clearfelled 28 year-old trees

Mean dbh (cm)	Daily tasks Normal	Daily tasks Maximum	Mean dbh (cm)	Daily tasks Normal	Daily tasks Maximum
	(nearest 5 trees)			(nearest 5 trees)	
22	135	180	31	80	105
23	125	165	32	75	100
24	115	155	33	70	95
25	110	145	34	70	90
26	105	135	35	65	85
27	95	130	36	60	85
28	90	125	37	60	80
29	85	115	38	55	75
30	85	110	39	55	75

TABLE 7

P.patula : Normal daily tasks[1)2)], to the nearest five logs for chainsaw cross-cutting at roadside after marking

Mean dbh (cm)	Mean number of logs crosscut per stem 3,4	3,6	3,8	4,0	4,2	4,4	4,6	4,8	5,0	5,2	5,4	5,6	5,8
	Normal daily task (to nearest 5 logs)												
27	380	370	360	355	345	335	330	320	315	310	300	295	290
28	365	355	345	335	330	325	315	310	300	295	290	285	280
29	345	340	330	325	315	310	305	295	290	285	280	275	270
30	330	325	315	310	305	295	290	285	280	275	270	265	260
31	315	310	305	295	290	285	280	275	270	265	260	255	250
32	305	295	290	285	280	275	270	265	260	255	250	245	240
33	290	285	280	275	270	265	260	255	250	245	245	240	235
34	280	275	270	265	260	255	250	245	245	240	235	230	230
35	270	265	260	255	250	245	245	240	235	230	230	225	220
36	260	255	250	245	245	240	235	230	230	225	220	220	215

Notes : [1)] To calculate the maximum daily task, multiply the normal daily task by 1,33

[2)] If it is required of chainsawyers to walk some distance between stacks of stems, the total anticipated walking time should be assessed and the normal daily task reduced by the following equation :

New normal daily task = Normal daily task x 325 - walking time (std min)/325

APPENDIX D

BLACK LABOUR MOTIVATION AND SAFETY

Although a detailed treatment of Black labour motivation is an extensive topic beyond the scope of this thesis, it is a vital component of productivity. Throughout the discussions and embraced in all equations in Section 5, it has been assumed that the labour is motivated. Ministers holding the portfolio of Forestry have stated on radio and television news that forestry is the second to most dangerous industry in South Africa.

Incorporated in safety is the ergonomic design of machinery. From the above, it is indicated that this thesis would be incomplete without summarised guidelines for these subjects. As described by Belcher (1962), short-term worker motivation is achieved by pecuniary remuneration, long-term motivation and job satisfaction is attained by non-monetary benefits. He also notes that there is an inverse ratio between the extent of monetary rewards and job satisfaction. However, this is only once remuneration is in excess of that required to cover certain basic needs (Maslow, 1954; Herzberg, Mausner & Snyderman, 1959, p. 59).

Thus to maximise labour motivation and minimise absenteeism workers must accept the equitability of compensation.

1 SHORT-TERM LABOUR MOTIVATION

Wherever possible, line workers' pecuniary remuneration should be a direct function of output per day or other specified period, although a minimum rate may be stipulated. A set daily wage normally will not encourage workers to increase their output per unit time.

Employers must establish approximately what the equity of monetary payment is for specific work in their particular district. Nevertheless, this can be below parity and acceptable to the worker given circumstance that will be discussed. In establishing the pay rate per piece of work, employees must be able to define clearly the relationship between the daily piece work output and their reward. Further, motivation increases for a given rate per work piece as the period before payment decreases. (Belcher, 1961, ch. 3)

Incentive schemes are established to encourage production workers to exceed the normal daily task rate. The benefit of this to employers is to decrease fixed costs, *viz* overheads. The objective of an incentive scheme is to share with the worker a proportion of the fixed costs saved by their above-normal output.

Workers must perceive this increased rate of remuneration as being encouragement. Therefore, the benefits should be shared at least equally with them.

Accounting simplicity is important to minimise administration costs of the scheme. A simple stepped system where possibly three rates are paid and calculated on the total daily, or period's, output is easier to administer (de Laborde, 1984). In addition, it usually is more significant to the worker than if calculated only on the amount in excess of normality as this is easier for labourers, in particular, to understand.

2 LONG TERM LABOUR MOTIVATION AND JOB SATISFACTION

Long term labour motivation and job satisfaction are more complex than simply providing fringe benefits. In fact, it appears that the establishment of non-mandatory benefits should be developed in consultation with Black employees and not prescribed by the management.

2.1 THE CONCEPT OF COMMUNITY

Development of long-term labour motivation and contentment incurs developing among employees a sense of being part of a community.

Development of a community will not motivate workers in the short-term as will high wages and an incentive scheme. As it grows, though, it will increase the stability and reliability of the work-force and attract more suitable workers.

Communitites take time to develop. The experience of both Horton (1978) and Beggs (1978) are that it takes many years to realise the benefits of ones concentrated efforts. In an informal discussion with Horton and Beggs, 10 years was suggested.

2.2 COMPONENTS OF COMMUNITY DEVELOPMENT AND ASSOCIATED MANAGEMENT TECHNIQUES

The following points were noted by the writer during a discussion between Horton and a Community Development Study Group. Certain points have been expanded in the light of other studies.

- Labour shortage or surplus is a result of the farmer's or employer's reputation of how he treats and cares for his workers.
- Workers need to be compatible with one another. Tribal differences lead to disharmony and dissension.
- It is disadvantageous to employ younger workers, and a fairly strong labour turnover must be accepted. The number of prospective employees will exceed resignations where the farmer's reputation

and credibility are adequate.

- The process of relationship development between employees and employer moves from ACCEPTANCE to FAMILIARITY. At this stage, the worker either goes or stays and works WITH you not FOR you.
- Those who stay, continue to develop in their sense of belonging and their personal interest in the work. They come to regard the farm as THEIR home and their testimony attracts others. This is not, however, a process of competing with other employer's by increasing fringe benefits.
- The farmer becomes a parental figure who extends to employees a better quality of life.
- Farming companies should not rotate their farm managers once they are established. These men should be trained to be what has been described above and sensitive to the needs, fears and concerns of those for whom he is responsible. Management by Objectives principles are clearly involved in this description. These have been described by Taylor (1974) in simplicity as,

  "Tell me what you expect of me
  Give me a chance to perform
  Tell me how I'm doing
  Help me when I need it
  Reward me accordingly"

  Management by Objectives' basic concept is that management and a subordinate set of goals, or objectives, by discussion and mutual agreement on achieving, for example, a further step towards higher productivity by an agreed date. On that date there will be a further discussion on progress made and difficulties encountered with management providing counselling and assistance if needed. Thereafter the process is repeated until the ultimate goal is attained.

- Involve and consult indunas (in this context, Black supervisors) at all times in selecting further indunas and in any other decision making. Without particpation, people tend to become disinterested and do a job without concern for the outcome.

- Establishment of, *inter alia*, a shop, sports clubs, schools, churches and clinics - the development of the infra-structure of a community - are a progression of this sociological development and not *vice versa*. Through consultation, and perhaps guidance by the farmer or manager, workers request these amenities and discuss how they themselves will assist in their provision. Never foist anything on employees, even one's own idea of a well designed village.

- Indunas should be trained to be sensitive to others under them and in the basic principles of Management by Objectives in the same way as senior farm managers are trained.

- Migrant female labour, even on a weekly basis, leads to serious social problems and this form of labour should be avoided or kept minimal.

- Blacks must not lose their identity as Blacks through education and association with Whites.

Horton reported further, that on his relatively small farm where community is at a high stage of development, labour overhead costs are considerably below the mean for Natal. This is despite the disadvantages noted in Section 2.2 of being located between Pietermaritzburg and Durban.

3 ERGONOMICS AND SAFETY

Without specialised logging machinery, the ergonomic layout of controls and seat positions is acceptable. However, agricultural tractors modified to skidders, forwarders, limber-buckers and harvesters have their controls awkwardly positioned, at times even behind the driver, and provide poor visibility of the work. (Hughes, 1982)

Various literature give check-lists and detailed specifications for ergonomic design of logging equipment (Hansson & Pettersson, 1980; Zerbe, 1980). Through such publications, reaction of responsible manufacturers and the demands by enlightened buyers aid in affecting improvements to the oergonomic design of forestry machinery.

Gustafsson & Lipton (1979) describe how the efforts of Skogsarbeten have improved the quality of safety clothing in Sweden. Points noted from their report are that protective clothing is often not worn because it is uncomfortable and an encumbrance. Helmets should have a total mass below 300 grams, should have a heat reflecting finish, a chin strap and adjutable ventilation. Ear muffs and visor should be attached to the helmet. The material and design of safety leggings is detailed and their use is mandatory in Sweden. Strict specifications for boots are given also. No mention is made of the specially designed gloves worn by most chainsawyers.

Employment of the felling technique for the conventional chainsaw system for wattle and *E. grandis* and the work site layout suggested will assist in decreasing the current accident rate. Training is also most important.

Injuries from hatchets or limbing axes are frequent. These accidents occur principally because the labourers were not taught to stand on the opposite side of the tree from the branch they are removing. Dangers or excessive daily exposure to chainsaw usage were discussed in Section 4.9.3. A summary of desirable chainsaw features has been given (de Laborde, 1980, Appendix I)

For several years, the writer has met and corresponded with the South African National Occupational Safety Association. It is hoped that their involvement in forestry will increase employers' awareness of the requisites for the provision of safety.

APPENDIX E

EXAMPLE OF A TEAL ANALYSIS OF HARVESTING AND TRANSPORT

In this Appendix, TEAL is used to analyse the integrated system in *E. grandis*. Similar parameters are taken as given in Section 6.7.2 using the fifth timber extraction and transport system, *viz* preceding the skidder by highleading. However, the three-wheel loader is replaced by manual stacking of timber at roadside.

Mean lead distances for highleads, skidders and lorries are 60 metres, 150 metres and 25 kilometres, respectively. It is assumed that debarked and debranched stems are left to dry infield before extraction. The target daily output is 250 tons of timber.

Specific details are as follows:

Plantation measurements:

Tree diameter at breast height overbark	16,5cm
Tree height	22,0m
Stems per hectare	1150 stems
Timber density	1,47m^3/t
Crosscut pole length	2,44m

Labour costs:

Harvesting: as stated in printout.

Transport:

Labour	2,86/day
Conductor	3,00/day
Driver	6,00/day
Supervisor	6,40/day
senior supervisor,salary	800,00/mth
fixed costs	100,00/mth
Highlead, variable cost	5,71/h
fixed cost	415,00/mth
Skidder, variable cost	4,73/h
fixed cost	120.00/mth
Lorry, variable cost	0,50/km
fixed cost	232,73/mth
Crane, variable cost	5,00/h
fixed cost	540,00/mth

Several points in the analysis require comment. In Section 6.7.1 it was stated that it is difficult to attain the required daily output where chainsawyers are felling large quantities of timber daily as in this system. Hence, Production Details, Section 2 of TEAL, shows a close matching of the optimum output to that which was required (250,351 tons). However, this is coincidental as is shown under the 'At maximum daily task rate' column where there is a drop from three to two teams with the increased output, but the output is optimised at 220,309 tons per day. This is 30 tons less than required.

As the chainsawyer who fells has a daily output of approximately 110 tons (TEAL, Section 1) it is possible for the output to be 110/2 = 55 tons above or below the required level.

The total cost for harvesting is R2,76 per ton, but the timber extraction and transport cost is R4,28 per ton. This is the inverse of the cost distribution for *E Grandis* shown in Table 1.1. The principle source of this cost is in transport R2,12 per ton. The lead distance chosen of 25 kilometres is close to the figure of the Economics Divison, South African Timber Growers' Association (1982) which shows that the average lead distance of the growers monitored was 26 kilometres for lorries of all types.

T E A L: ********** SAMPLE ANALYSIS ********** 12 - 1 - 84

****
* E. GRANDIS *
****

MEAN TREE DIMENSIONS

Breast-height diameter:	16.5 cm	Height:	22.0 m	Bark thickness:	5.0 mm
Bark mass:	.0000 t	Timber volume:	.196 m3	Timber mass:	.134 t

Number of 2.44 m poles: 7.3 poles

ESTIMATED YIELDS PER HECTARE AT 1150. STEMS PER HECTARE

Bark mass:	.0 t	Timber volume:	226. m3	Timber mass:	154. t
Poles:	8361. poles				

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INTEGRATED HARVESTING SYSTEM
****

COST DATA SUPPLIED

Wage rates for tasked workers

	At normal daily task rate (R)	At maximum daily task rate (R)
Labourer, payment category 2	1.38	1.40
Chainsawyer, payment category 2	.13	.14
Conductor, payment category 2	.05	.05
Marker, payment category 3	3.00	3.00

Daily wages, other costs (as described below) and fixed costs per worker per day

	Daily wage (R)	Other costs (R)
Labourer	see above	.83
Chainsawyer	see above	.83
Conductor	see above	.83

Marker	see above	.83
Supervisor	6.40	.83
Clerk	3.10	.83
Senior supervisor	7.50	.83
Infield chainsaw mechanic	5.00	.83

	Fixed costs (R)
Fixed costs per worker per day	1.44

PRODUCTION DETAILS

Prescribed activities for labourers and chainsawyer(s):

Labourers: debranch, stack brush and debark

Chainsawyers: one sawyer fells uphill and, ifno labourers, debranches. Two sawyers crosscut after extraction.

1. DAILY TASKS IN STATED OUTPUT CATEGORIES

		At normal daily task rate	At maximum daily task rate
		(Trees)	(Trees)
Trees:	labourer	25.	33.
	chainsawyer 1	625.	825.
	chainsawyer 2	312.	412.
		(Tons)	(Tons)
Bark mass:	labourer	.000	.000
	chainsawyer 1	.000	.000
	chainsawyer 2	0.	0.
		(Cubic metres)	(Cubic metres)
Timber volume:	labourer	4.907	6.477
	chainsawyer 1	122.672	161.927
	chainsawyer 2	61.238	80.865
		(Tons)	(Tons)
Dry timber mass:	labourer	3.338	4.406
	chainsawyer 1	83.450	110.154
	chainsawyer 2	41.658	55.010
		(Poles)	(Poles)
Poles:	labourer	182.	240.
	chainsawyer 1	4544.	5998.
	chainsawyer 2	2268.	2995.

2. REQUIRED DAILY OUTPUT WAS 1872 TREES, OPTIMUM DAILY OUTPUT IS AS FOLLOWS:

Trees	1875.	1650.
Bark mass (t)	.000	.000
Timber volume (m3)	368.015	323.854
Air-dried timber mass (t)	250.351	220.309
Number of poles	13632.	11996.

3. NUMBER OF WORKERS AND TEAMS

	(Workers)	(Workers)
Number of labourers per chainsawyer	25.0	25.0
Number of crosscut per felling saw	2.0	2.0
Total number of workers in each harvesting team	31.0	31.0
	(Teams)	(Teams)
Total number of teams	3	2
	(Workers)	(Workers)
Number of workers to product normal and maximum daily output rates:		
Labourers	75	50
Chainsawyers 1	3	2
Chainsawyers 2	6	4
Conductors	3	2
Markers	6	4
Labourer supervisor(s)	2	1
Chainsawyer supervisor(s)	1	0
Total number of supervisors	3	1
Clerk	0	0
Senior supervisor	1	1
Infield chainsaw mechanics	1	0
TOTAL	98.0	64.0

4. TOTAL MAN-DAYS FOR THE STATED CATEGORIES FOR LINE WORKERS

	(Man-days)	(Man-days)
Tree:	.052	.039
Ton bark:	.000	.000
Cubic metre timber:	.266	.198
Ton dried timber:	.391	.291
100 Poles:	.719	.533
Hectare	60.107	44.606

5. OUTPUT AND HECTARES PER MAN-DAY FOR ALL WORKERS DESCRIBED ABOVE

	(Trees)	(Trees)
Trees	19.133	25.781
	(Tons)	(Tons)
Bark	.000	.000
	(Cubic metres)	(Cubic metres)
Timber volume	3.755	5.060
	(Tons)	(Tons)
Timber mass	2.555	3.442
	(poles)	(poles)
Poles	139.105	187.444
	(Hectare)	(Hectare)
Hectare of plantation	.017	.022

6. CHAINSAWS AND CHAINSAW FUEL REQUIREMENTS

	(Chainsaws)	(Chainsaws)
Number of operating chainsaws required	9	6
Number of standby chainsaws required	4	3
TOTAL	13	9
	(Litres)	(Litres)
Daily fuel usage per chainsaw	12.5	16.5
Total daily chainsaw fuel usage	112.7	99.1

Litres chainsaw fuel usage per:	ton bark	.00
	cubic metre timber	.31
	ton dried timber	.45
	100 poles	.83
	hectare	69.10

STANDARD COSTS FOR LINE FUNCTIONS

Note:
Costs are for stated category of output and per hectare. Variable and semi-variable costs include all labour listed above and the cost of their hatchets. Fixed costs include overhead costs and other costs (eg, food, clothing, WCA, medical expenses, etc.)

	At normal daily task rate	At maximum daily task rate
	(R)	(R)

1. VARIABLE AND SEMI-VARIABLE COSTS FOR LABOUR

Tree	.19	.18
Ton bark	.00	.00
Cubic metre timber	.98	.90
Ton dried timber	1.44	1.32
100 poles	2.65	2.43
Hectare	221.47	203.04

2. FIXED COSTS FOR LABOUR

Tree	.08	.06
Ton bark	.00	.00
Cubic metre timber	.38	.28
Ton dried timber	.56	.42
100 poles	1.04	.77
Hectare	86.55	64.23

3. TOTAL LABOUR COSTS

Tree	.27	.23
Ton bark	.00	.00
Cubic metre timber	1.36	1.18
Ton dried timber	2.01	1.74
100 poles	3.68	3.20
Hectare:	308.02	267.27

4. CHAINSAW COSTS

	(R)
Tree	.10
Cubic metre timber	.50
Ton dried timber	.73
100 poles	1.34
Hectare	112.09

5. TOTAL PRIMARY HARVESTING COSTS INCLUDING HATCHET COSTS

Tree	.27	.23
Ton bark	.00	.00
Cubic metre timber	1.88	1.70
Ton dried timber	2.76	2.49
100 poles	5.07	4.58
Hectare	423.56	382.81

6. DAILY WAGE RATE FOR ALL TASKED WORKERS FOR NORMAL AND MAXIMUM OUTPUT LEVELS

Labourers	2.51	3.36
Chainsawyers	5.91	8.40
Conductors	2.27	3.00
Chainsawyer 2	5.90	8.39

7. DAILY COSTS

Chainsaw	20.31	26.80
Chainsawyer, conductor and chainsaw:		
collective variable and semi-variable costs	77.50	102.70
collective total costs	83.26	108.46
collective total costs for all teams	249.77	216.91
Total for primary harvesting (for all those costs supplied)	690.59	549.25

TIMBER EXTRACTION AND TRANSPORT SYSTEMS
****

In this analysis 1 timber extraction and transport systems are considered

5.00 days are worked per week, 480. minutes on weekdays and, 0. minutes Saturdays

INDIVIDUAL ANALYSIS OF EACH SYSTEM

TIMBER IS QUOTED IN TONS AND WAS GIVEN AS 43.0 POLES OR LOGS PER TON

SYSTEM 1

Required daily output is 280. tons or cubic metres was specified

PRODUCTION DETAILS

The five timber movements in the table below are given under the following heading and are, respectively:

Timber movement 1: Type 3 => 4-ton highlead

Timber movement 2: Type 6 => skidder

Timber movement 3: Type 1 => manual timber stacking or extraction to roadside

Timber movement 4: Type 27 => lorry loaded by mobile independent crane and gantry or tip offloaded

Timber movement 5: Type 32 => independent mobile crane mounted on a tractor

	Timber movements					
	1	2	3	4	5	Total/mean
Cycle time (standard or basic minutes as appropriate)	2.36	4.75	.17	90.09	25.04	
Unit daily output (only for setting daily tasks for labourers)	206.50	129.85	49.00	60.00	140.20	
Full output (t or m3 as specified:)						
weekday	413.00	389.54	343.00	360.00	400.01	
Saturday	.00	.00	.00	.00	.00	
weekly	2065.00	1947.69	1715.00	1800.00	2000.06	
monthly	8363.25	7888.15	6945.75	7290.00	8100.26	

annually	100359.00	94186.80	71442.00	69984.00	97203.12	
Efficiency factor						
(av. % machine availability X av. % target achieved)						
Originally specified	.72	.72	.85	.80	.80	.78
Altered to accommodate supply	.61	.65	.85	.87	.63	.72
Expected output corrected by the effiency rating						
(t or m3 as specified)						
weekday	250.35	250.35	250.35	250.35	250.35	
Saturday	.00	.00	.00	.00	.00	
weekly	1486.80	1395.36	1251.75	1152.00	1600.05	
monthly	6021.54	5651.21	5069.60	4665.60	6480.21	
annually	72258.48	67814.49	60835.20	55987.20	77762.49	
Number of machines or vehicles in each category corrected to accommodate the efficiency factor	2	3	0	4	2	
Numoer of loads per unit at:						
full rate: weekdays	118	75	2107	6	0	
Saturdays	0	0	0	0	0	
weekly	590	375	10535	30	0	
average expected rate: weekday	84.96	54.00	1794.18	4.80	.00	
Saturday	.00	.00	.00	.00	.00	
weekly	424.80	270.00	8970.90	24.00	.00	
monthly	1720.44	1093.50	36332.13	97.20	.00	
Average load per haul (t or m3 as specified)	1.75	1.70	.00	12.00	12.00	
Average kilometres each vehicle travels per day	.00	18.63	.00	240.00	.00	
Total average kilometres travelled per day	.00	55.89	.00	960.00	.00	1015.89
Fuel usage for each machine or vehicle:						
litres/hour	4.00	4.30	.00	12.00	4.00	69.10
litres/ton or cubic metre as specified	.09	.20	.00	1.53	.14	1.96
litres/weekday	11.25	16.66	.00	96.00	20.03	143.95
litres/100 kilometres	.00	.00	.00	40.00	.00	40.00
kilometres/litre	.00	.00	.00	2.50	.00	2.50
litres/average month	227.91	337.45	.00	1944.00	405.55	2914.91
Watch hours per machine or vehicle per month	80.46	96.50	102.94	129.03	.00	408.93
Kilometres per machine or vehicle per average month	.00	382.29	.00	4860.00	.00	5242.29
Total numoer of workers:						
labourers	10	24	6	0	0	40
conductors	0	0	0	0	0	0
operators or drivers	2	3	0	4	2	11
supervisors	.20	.20	.20	.20	.20	1.00
senior supervisors	.07	.07	.07	.07	.07	.33
Total of line workers	12.27	27.27	6.27	4.27	2.27	52.33

Tons or metre3, as specified, per man-day	20.41	9.18	39.95	58.69	110.48	4.78
Man-days per ton or metre3 as specified	.05	.11	.03	.02	.01	.21
COST ANALYSES (Output unit: one ton)						
Rand per ton						
variable and semi-variable costs for labour	.21	.44	.10	.12	.06	.93
total costs for labour	.28	.60	.13	.13	.07	1.21
total costs for machines or vehicles	.29	.36	.00	1.98	.43	3.06
total costs per above unit	.57	.96	.13	2.12	.50	4.28
Cents per ton-kilometre	.00	.00	.00	18.99	.00	
Daily costs						
variable and semi-variable costs for labour	52.54	111.03	24.12	29.30	15.64	232.61
total costs for labour	69.32	148.97	33.14	33.68	18.02	303.13
total costs for machines or vehicles	73.50	91.07	.00	495.99	106.67	767.22
total costs	142.82	240.04	33.14	529.67	124.69	1070.35
Monthly costs						
variable and semi-variable costs for labour	1063.86	2248.29	488.36	593.25	316.64	4710.40
total costs for labour	1403.72	3016.63	671.07	682.01	364.89	6138.33
total costs for machines or vehicles	1488.41	1844.08	.00	10043.73	2160.00	15536.22
total costs	2892.13	4860.72	671.07	10725.74	2524.89	21674.55
Annual costs						
variable and semi-variable costs for labour	12766.36	26979.43	5860.30	7119.04	3799.66	56524.77
total costs for labour	16844.63	36199.58	8052.89	8184.11	4378.73	73659.96
total costs for machines or vehicles	17860.90	22129.02	.00	120524.76	25920.00	186434.68
total costs	34705.54	58328.60	8052.89	128708.87	30298.73	260094.64

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DATA IGNORED - IN CONTROL MODE

@BREAK,P S06PR1

APPENDIX F

EXAMPLES OF DISTRIBUTIONS OF ERROR RESIDUALS, EXPRESSED AS A PROBIT, PLOTTED AGAINST THE DEPENDENT VARIABLE

One principal selection criterion in the final development of the regression models in Chapter 5 is the satisfactory random, *viz* homoscedastic, distribution of error residuals plotted against the variables. Typical patterns have been given (Draper & Smith, 1981, p. 145; Gujarati, 1978, p.201).

In the figures below, examples are given of these distributions with the error residuals expressed as a probit. Figure 1 shows a homoscedastic distribution stated as being a "satisfactory residuals plot" (Draper & Smith, 1981, p. 145) except for the lowest point, marked with an arrow, which demonstrates a possible outlier.

Figure 2 shows a distribution where the pattern expands to the right and Figure 3 a pattern that is 'U' shaped and also expands to the right. These characteristics indicate that a transformation of the dependent variables is required (Draper & Smith, 1981, p. 147).

Figure 1

A distribution of error residuals expressed as a probit that is homoscedastic with exception to a possible outlier which is marked with an arrow

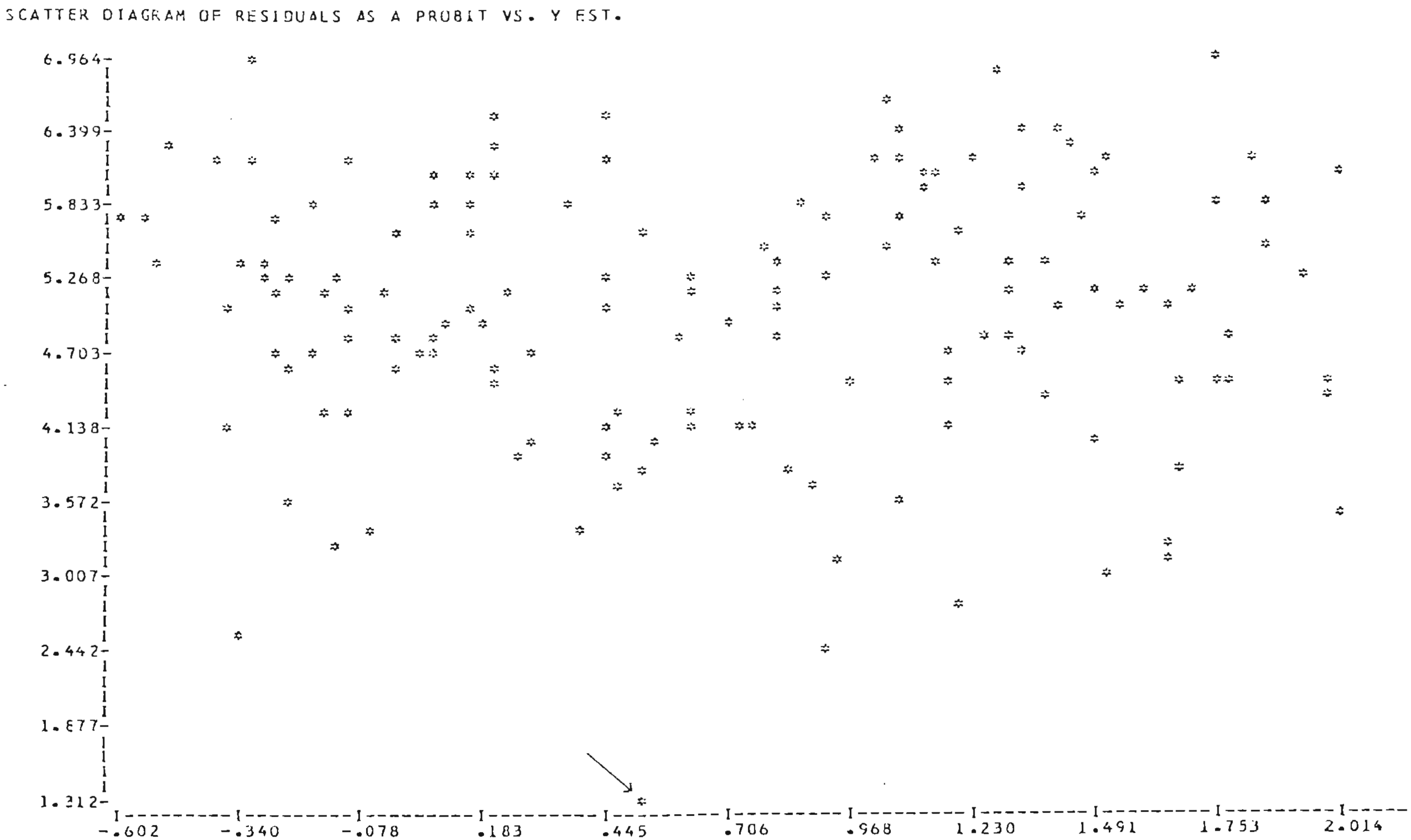


Figure 2

A distribution of error residuals expressed as a probit giving a pattern that expands to the right

SCATTER DIAGRAM OF RESIDUALS AS A PROBIT VS. Y EST.

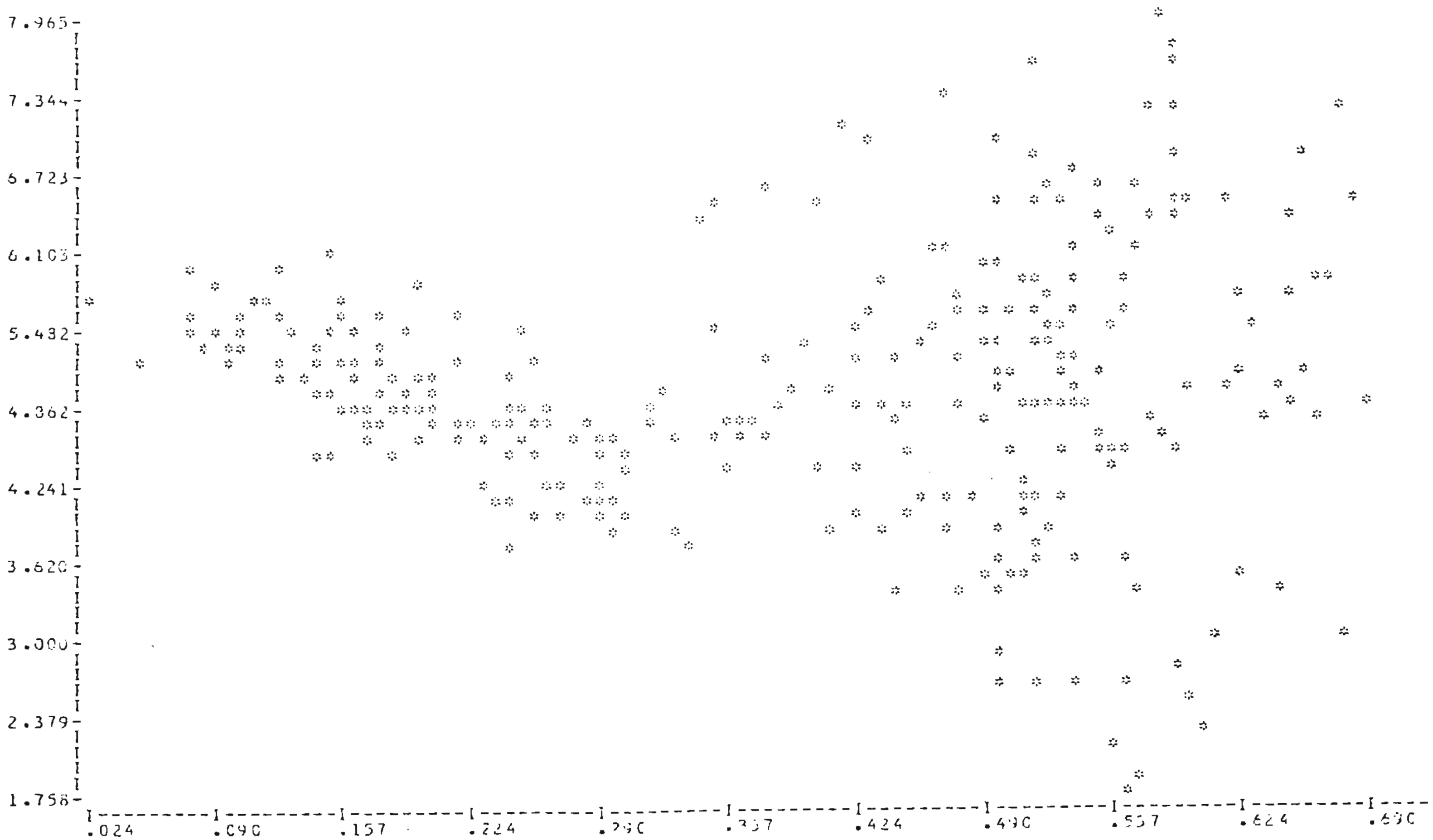
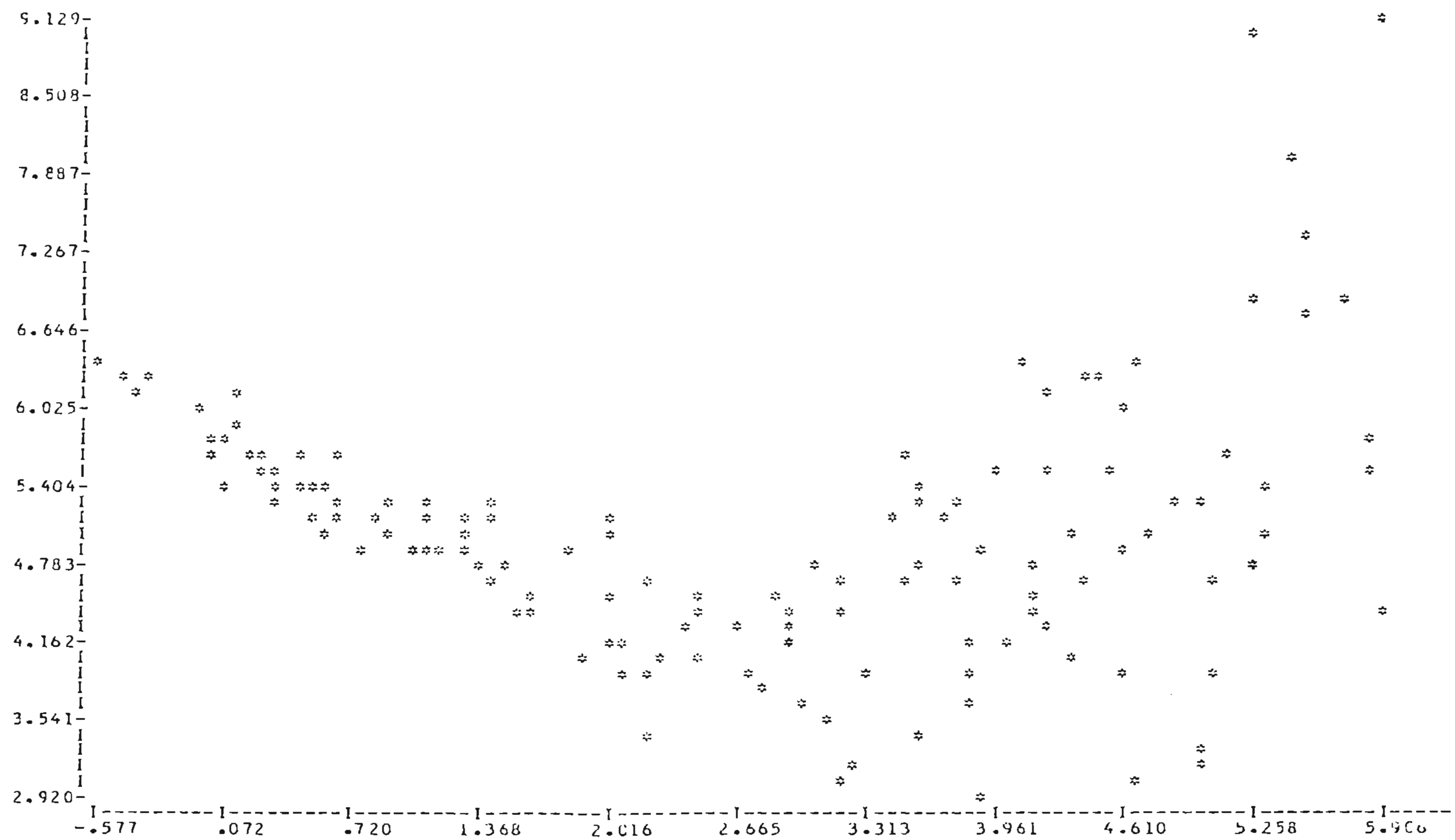


Figure 3

A distribution of error residuals expressed as a probit giving pattern that is 'U' shaped and expands to the right

SCATTER DIAGRAM OF RESIDUALS AS A PROBIT VS. Y EST.



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