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CHOICE OF TECHNOLOGY IN LESS INDUSTRIALIZED COUNTRIES WITH PARTICULAR REFERENCE TO FORESTRY AND SAWMILLING

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PREFACE

I got interested in questions regarding choice of technology in less industrialized countries more than 10 years back, when working as forest economist in Kenya's Ministry of Natural Resources, Forest Department. Since then, this interest has just increased.

While working on the topics discussed in this study, I have received help and support from various sources. The people at Sao Hill Sawmill in Tanzania has provided data and assistance during my stays at the project. Several persons have commented on previous drafts of the study: Prof. I. Adelman (Ch. 3), Prof. J. Eid (Ch. 3 - Ch. 6), Prof. O. Hofstad (Ch. 1, 2, 8), Dr. A. Lunnan (Ch. 4 - Ch. 8), Prof. W. McKillop (Summary), Prof. L. Nagoda (Ch. 8), Senior Lecturer H. Omnes (Ch. 5 - Ch. 7), Senior Consultant A. Seim (Ch. 8), Prof. R. Skaar (Ch. 5 - Ch. 7), Prof. J. Strand (Ch. 3), Prof. A. Svendsrud (all chapters), Prof. E. Thorbecke (Ch. 3), Prof. F. Wenstøp (Ch. 4).

Grethe Delbeck has typed and retyped the manuscript, with assistance of Bjørg Wold.

My family - Kari, Dag Birger and Runar Johannes - has endured a busy and, sometime, absentminded husband and father.

The Norwegian Agency for International Development (NORAD) and the Agricultural University of Norway have provided financial support.

To these persons and institutions: My best thanks!

B.S.

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ABSTRACT

An overview is given of existing works regarding choice of technology in less industrialized countries (LIC), with special emphasis on forestry and forest industry projects. Some important theoretical aspects regarding the concept of technology and its role in economic development in LIC are discussed. Different methods for analysing socio-economic consequences of technological choice at the project level in LIC are discussed, and a multi-criteria simulation model is proposed. This model is used in an actual project in Tanzania to evaluate the appropriateness of the technological choice in the project, and to increase the empirical evidence concerning consequences of technological alternatives in LIC in general and in the forest sector in particular. Three operations in the project are analysed: skidding of logs from softwood (Pinus patula) thinnings and clearfellings, and sawmilling of softwood (Pinus patula). It is found that in all three cases the labour intensive technologies are highly compatible with the more modern, capital intensive alternatives considered, both regarding cost efficiency as well as other important development criteria like employment, working conditions, distributional effects, integration, independency, ecological effects, and risks. Finally, it is discussed how to arrive at appropriate technological choices in future development projects, with special reference to the forest sector.

Keywords: Choice of technology, appropriate technology, socio-economic analysis, economics, project evaluation, natural resources, forestry, sawmilling, skidding, logging.

ABBREVIATIONS

The following abbreviations are used in the study:

cu. m	=	cubic meter
cu. m (r)	=	- " - round volume
cu. m (s)	=	- " - of sawnwood
d.b.h.	=	diameter at breast height
h	=	hour
ha	=	hectare
IC	=	industrialized countries
km^2	=	square kilometer (= 100 ha)
kW	=	kilowatt
LIC	=	less industrialized countries
m^3	=	cubic meter
NOK	=	Norwegian kroner (regarding exchange rates see Appendix 2)
SEK	=	Swedish kroner (regarding exchange rates see Appendix 2)
shs	=	Tanzanian shs (regarding exchange rates see Appendix 2)
o.b.	=	over bark
u.b.	=	under bark

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SUMMARY

1. One important issue facing the governments of the less industrialized countries (LIC) is that of technological choice. The question of how existing natural resources, labour, capital and skills can best be combined to overcome problems of unemployment and underemployment and provide a stable base for future increase in the standard of living, is a complex, but crucial one.

In 1980, 790-1,100 millions of people were living in absolute poverty - i.e. below certain level of basic needs. Under various assumptions regarding economic growth, basic needs and population growth, the corresponding estimates for the year 2000 are 400-1,080 millions of people. If full employment is the goal, it is estimated that 86 out of every 100 productive jobs needed worldwide to absorb both the existing under- and unemployed and the increase in the labour force up to the year 2000, will have to be created in LIC. This means an annual rate of growth of productive jobs of 3.9% between now and the end of the century.

This annual growth estimate is an average for all LIC. Countries like Zimbabwe, Kenya and Tanzania for example have a projected annual labour force growth rate for the period 1980-2000 of respectively 4.5%, 4.2% and 3.5%. These, and similar countries, must have a considerably higher growth rate than the above-mentioned 3.9% p.a. in order to reduce underemployment by the year 2000.

The need for productive jobs has to be seen in relation to the investment costs per employee and available investment resources. Studies done by the World Bank, ILO, and others indicate that in LIC the present investment costs per employee are in the range of (in 1980 US $):

Medium/large scale manufacturing . .	6,000 - 40,000 US $
Small scale manufacturing	1,500 - 6,000 US $
Informal sector manufacturing . . .	0.1 - 1,500 US $

The gross domestic saving rate per new employee gives an indication of the investment opportunities available for a country. This rate is today below US $ 7,000 for most LIC. For example was it in 1979 for Botswana, Kenya, Malawi, Tanzania and Mozambique in the order of respectively 5,900 US $, 3,700 US $, 2,400 US $, 1,500 US $ and 900 US $ per year. This means that the investments in medium and large scale manufacturing cannot make a significant contribution to reduction of the present underemployment in most LIC.

Employments and savings are closely related to technology. Simplified, the choice of technology determines the direct employment and the labour and capital productivity, which strongly influence the profits and labour income. These factors then, determine the demand for goods and services as well as savings, indirectly influencing the investment behaviour and employment. The technological choice also influences other important development criteria than economic growth and employment, for example working conditions, dependency/independency, distributional and ecological effects, and flexibility.

The question of choice of technology in LIC has been widely discussed during the last decades. Most of the works in this field are of a general character, analysing the macroeconomic effects of various levels of capital intensities. The actual choice of technology, however, is done at the micro (project) level. During the last decade one may observe a growing awareness that fruitful discussion of the technological choice requires factual knowledge at the micro-level about the range of techniques available and their performance in terms of different development criteria such as profit and income generation, employment, labour productivity, dependency, etc.

Most of the existing works regarding technological choice on micro-level are, however, difficult to draw conclusions from, because the studies are few, and the methods of analysis

differ much. It is, therefore, in my opinion, important to discuss how analysis of the technological choice on micro-level in LIC should be done, i.e. what methodology to use and what factors to emphasize, and to use the method arrived at to provide increased empirical knowledge about the effects of the technological choice on project level.

Very few studies exist regarding choice of technology in forestry and forest industry projects in LIC. There are, however, several reasons why this question might be of particular interest in the forestry and forest industry sectors of most LIC. First, there seem to exist in these two sectors a range of technologies with different labour intensities, scale factors, product qualities and other characteristics which are broader than the narrow band of choices of which many decision makers seem to be aware, and which seem compatible both from a financial and a national economic point of view. Secondly, the relatively high income elasticity of demand for forest products, particularly at low-income levels and the pronounced linkage effects of forest industries with other sectors of the economy, give the two sectors high potential for contributing to the satisfaction of basic human needs and to economic growth. Thirdly, the forests and forest industries have a considerable potential regarding the saving of foreign exchange through import substitution, as well as export potential. Fourthly, the two sectors are based on renewable resources, and are closely linked with agriculture, the prevention of soil erosion, the protection of water catchment areas, and vital ecological factors in general.

This study has the following main objectives:

(i) Present an overview of existing works regarding the technological choice at the micro-level in LIC, with special emphasis on forestry and forest industry projects.

(ii) Discuss some important theoretical aspects regarding the concept of technology and its role in economic development in LIC.

(iii) Discuss possible methods, and arrive at a suitable method for analysing the socio-economic consequences of the technological choice at the project level in LIC.

(iv) Analyse the technological choice in one actual project (Sao Hill Sawmill, Tanzania) in order to:

- demonstrate how the methodology from part (iii) can be used in a given socio-economic context.

- evaluate the appropriateness of the technological choice in this project.

- increase the empirical evidence concerning consequences of technological alternatives in LIC in general, and in the forest sector (i.e. forestry and forest industries) in particular, thus contributing empirically to the discussion of the technological options available for LIC.

(v) Discuss how to arrive at appropriate technological choices in future development projects, with special reference to the forest sector.

Most work has been devoted to part (iii) and part (iv). Regarding part (i) a large amount of literature exists, and I have just focused on aspects of particular relevance to this study. In part (ii) an attempt has been made to synthesize existing knowledge and to point to vital inter-relations between factors involved in the technological choice in LIC.

The objectives of development vary from country to country and over time, depending upon the social and political situation.

Appropriateness, or optimality of any kind, have meaning only when related to objectives, and a necessary condition for discussing optimal or appropriate technology is that development objectives are directly specified, or can be derived indirectly.

Another necessary condition in this context is that the Government of the LIC in question looks upon the choice of technology at the project level as a steering parameter in its development strategy. If it should be of the opinion that other means (fiscal-, credit-, price-, wage policy, etc.) are efficient enough and more convenient to use than influencing directly the choice of technology at the project level, the question about appropriate or optimal technology is irrelevant. In this study it is assumed that the choice of technology at the project level is one (out of several other) interesting steering parameters which the Government will use.

The study concentrates on analysing the consequences of technological alternatives at the micro-level, assuming they can be implemented, and does not discuss institutional, political or other national or international factors which, in many cases, are strong forces in hindering appropriate technological choices. One reason for this approach is that such analyses would have to draw heavily on fields like political science and sociology. Another reason is that before going into such studies, it is important to have estimates of the potential gain of the possible technological alternatives in question, assuming they can be implemented - i.e. to map the total realistic set of alternative possibilities.

2. Ch. 2 gives a review of literature regarding choice of technology in LIC. A great number of works exist on this topic, but their coverage of forestry and forest industries is rather sparse. The chapter, therefore, concentrates on reviewing empirical studies related to forestry and forest industries, particularly studies where alternative

technologies are compared. In order to give a comprehensive view of the topic, a considerable part of the presentation is also devoted to major works of a more general character.

3. Ch. 3 aims at defining the concept of technology, and describing some important aspects between the technological choice at the project level and macroeconomic development planning. After reviewing various definitions, it is concluded that in this study, if nothing else is stated, technology is defined as the knowledge, skills and procedures for providing goods and services. As such, both the hardware (machines, tools, etc.) and the corresponding software (management, infrastructural services, experiences, etc.) are included in the concept of technology.

   The main purpose of Ch. 3.2.2 is to illustrate the importance of the technological choice in LIC for the growth in annual supply of goods and services by using a simple neoclassical growth model, and to discuss the strength and weakness of this kind of models in discussions of development in such countries. The model shows how a very high rate of capital accumulation (and savings) could be replaced by a relatively modest change in technological progress. For example it is shown that, under certain not unreasonable assumptions for Tanzania, an average increase in technological progress of 1.5% p.a. would have the same effect on the growth of the net national product per capita as a change in savings from 5% to 20% of the net national product. Another example, comparing the effects of alternative technological choices at the project level, shows that under certain conditions outlined in Ch. 3.2.2.2, a labour intensive technological path alternative gives a 6.4% p.a. higher growth in net national product per capita than a technology corresponding to the capital intensity actually chosen in the present Sao Hill Sawmill Project analysed in Ch 8. The neoclassical economic model used for these analyses has many weak points as discussed in Ch. 3.2.2.3 (for example important economic factors are

lacking, the objective function is too simple, risks are not included); but the model illustrates, in my opinion, how important the technological choice is for the growth of the material living standard per capita in a country like Tanzania.

4. Ch. 4 presents an overview of main methods for socio-economic project analysis, and gives a proposal for a method suitable for choosing between technological alternatives on project level in LIC. Two main categories of methods are analysed: simulation (scenario) and optimization methods. The latter category is divided in two subgroups: single criterion and multi-criteria methods.

   The methods differ in particular regarding one aspect-complexity. The complexity increases in at least three directions: when going from simulation to optimization; when going from one-criterion to multi-criteria (multi-objective) methods; when going from deterministic to stochastic methods.

   With the term "complexity" it is meant factors like data input requirement, resources requirement (personnel, technical calculation means, time, financial resources), understanding by the decision maker(s), and, thus, the decision maker's confidence in the results.

   In deciding which method to use, given a choice between technological alternatives, the factors mentioned above are important. In general one has to consider the costs and benefits of going from one method to a more complex one for the particular problem being analysed. Among the most important <u>costs</u> elements are:

   - data collection
   - technical expertise
   - technical equipment (EDP capacities, etc.)

- degree of understanding and involvement from the decision-makers, and from interest groups being influenced by the technological choice.

The benefit to consider will be the potential improvement of the decisions. For example, one will have to consider:

- Are conflicting interests a significant part of the problem?
- Are subjective preferences a significant part of the problem?
- Do market prices adequately reflect the value of the resources used and created in the project?
- Is the dynamic perspective (i.e. time) important?
- Do the decision makers have the necessary understanding of the method?

These cost and benefit factors depend on the development objectives which are thought valid, and the structure of the problem (i.e. what factors are affected by the technological choice, their inter-relationships and how exactly they can be quantified). It is, therefore, not easy in general to recommend one of the methods, as each project has to be considered separately. However, in my experience, it is in most development projects not possible to quantify exactly enough the relationships between the various factors involved for applying the more sophisticated mathematical methods described in Ch. 4.2.2.1.2 and Ch. 4.2.2.2.1. In most cases one will have a limited set of technological alternatives to choose among. Often there will be more than one criterion to consider, and difficult to aggregate the criteria into one single criterion. Conflicting interests will usually be involved, and the resources available (technological expertise, equipment, degree of understanding and involvement among the decision makers, time and financial resources) are in most cases rather limited.

All this points to the fact that, in the terminology of Ch. 4.2, it may be wise to use a multi-criteria simulation approach.

To illustrate this approach an example of a set of criteria is presented in Ch. 4.3.2 for choosing technology on project level in a nation X, and it is discussed how the criteria might be made operational. The criteria are not chosen by chance, but are supposed to reflect major development objectives in Tanzania, as discussed in Ch. 5.1.1. However, the criteria are supposed to be of interest also for other less industrialized countries, although the relative importance of the criteria will vary from country to country as well as over time. The criteria are:

- Production efficiency from a macroeconomic point of view (economic efficiency)
- Employment
- Working conditions
- Distributional effects
- Integration
- Independency
- Ecological effects
- Risks (flexibility, uncertainty, irreversibility)
- Other relevant factors

5. Ch. 5 gives some background information for the analysis to be presented in Ch. 6 - Ch. 8 to increase the readers' possibility of judging the relevance of the empirical studies for other areas. The analyses are based on the assumptions made in Chs. 5.2, 6.2, 7.2 and 8.2. If not otherwise stated, all market prices quoted refer to the 1977 price level in Tanzania. The technological alternatives are evaluated according to the above-mentioned criteria.

6. In Ch. 6 three methods for skidding of logs from thinnings in softwood (Pinus patula) plantations at Sao Hill are analysed: The most capital intensive method, Alternative A, is using agricultural tractor with 2-drum winch (Ford 6600-2). The second method, Alternative B, is using sledge-skidding with oxen; and the third method, Alternative C, is to pull the logs out manually by using skidding sulkies.

Table 6.15 presents the ranking of the three alternatives on each of the criteria discussed above. It is seen that except for the criteria "Indirect employment" and "Technical skill formation," alternative A is inferior to B and C for all criteria used. In particular the differences are high regarding economic efficiency (total annual costs of alternative A are 3.9 and 4.7 times higher than respectively alternatives B and C), and use of foreign exchange (alternative A uses 3.9-4.2 more foreign exchange than the other two alternatives). The investment costs per employee (manyear per year) are:

Alternative A	65,000 shs	(or 7,700 US $)
Alternative B	4,300 "	(" 510 ")
Alternative C	2,700 "	(" 320 ")

As the importance of the indirect effects depends upon certain quite strict assumptions, and the technical skill - criteria mentioned above in my opinion are of less importance here compared to particular the economic efficiency, it is concluded that alternatives B and C are preferable to alternative A.

Alternative C is superior or equal to alternative B for all criteria except "Working conditions", "Technical skill formation", and "Machine overcapacity." A decision maker who emphasizes increased employment of un/semi-skilled labour will therefore most likely choose alternative C. However, it should be noted that except for employment effects, alternatives B and C are approximately equal regarding the

criteria analysed here. The assumption in Ch. 6.2.3 of one helper per ox-driver could be discussed. If no helper is assumed, the cost efficiency of alternative B will improve by about 2.10 shs/cu.m.o.b. or about 30% of total costs, making it considerably more cost efficient than alternative C.

One should be careful in drawing conclusions from this study for projects having other physical, technical and socio-economic characteristics than the Sao Hill Sawmill Project. For example, the road costs are quite decisive regarding choice of thinning method. The low road costs at Sao Hill favour particularly alternative C. Also, the easy terrain conditions at Sao Hill favours alternatives B and C as alternative A is less sensitive to logging uphill compared to the other two methods.

7. In Ch. 7 three alternative methods for skidding of logs from Pinus patula clearfellings at Sao Hill are analysed. The most capital intensive one, alternative A, is using forwarder (Rottne Blondin 750). The second method, alternative B, is use of agricultural tractor (Ford 6600-2 with double drum winch), and the third method, alternative C, is using sledge skidding with oxen. Smooth terrain with maximum slope about 15% is assumed. Mean dbh, volume per log, and extraction volume per ha are respectively 31.0 cm, 0.25 cu.m and 560 cu.m per ha. The log size distribution is as stated in Appendix 7.

Table 7.13 shows the ranking of the three alternatives according to each of the criteria discussed above. It is seen that except for the criteria "Indirect employment" and "Technical skill formation", alternative C is superior to alternatives A and B in a Pareto-optimal sense (i.e. equal or better for all criteria used).

The difference between alternative C and the other two alternatives is particularly great regarding economic efficiency and employment. For the most probable assumptions (shadow prices 0.7, 1.3 and 1.6 of respectively un/semi-skilled labour, skilled labour and import), zero price increases, and 9% p.a. calculation rate of interest, it is seen that the net discounted costs will be 3.59 mill. shs using forwarders,1.54 mill. shs using agricultural tractor, and 0.63 mill. shs using oxen.

Table 7.12 shows that alternative C gives about 3 times higher direct employment than alternative A, and about 50% higher employment than alternative B. Regarding employment of unskilled and semiskilled personnel, alternative C gives about 30% higher employment than alternative B. The high employment of skilled personnel in alternative C compared to alternative B, results from the ox-drivers being classified as skilled personnel. The investment costs per employee (manyear per year) are:

Alternative A	348,000 shs	(or 41,300 US $)
Alternative B	68,000 "	(" 8,100 ")
Alternative C	5,200 "	(" 620 ")

Based upon this it is concluded that alternative C is the best alternative, unless technical skill formation is given a very high weight.

As already discussed for thinnings, one should be careful in drawing conclusions from this study for projects having other physical, technical and socio-economic characterisitics. For example is alternative C favoured by the relatively low road construction costs and the easy terrain at Sao Hill, making it easy to avoid, among other things, skidding uphill. Also, some factors which could be important are not included in the analyses, for example that alternatives A and B most likely have lower loading costs at roadside than alternative C because of easier piling of logs, and that whole stem skidding is not considered.

8. In Ch. 8 three alternative technologies for softwood sawnwood production are compared. Alternative A and alternative B represent one centrally located circular mill with annual production 14,000 cu.m(s) on one shift, of which about 2,500 cu.m(s) are from thinnings. Alternative A is identical with the original Sao Hill Sawmill, which started production in 1976. Alternative B is a modified version of alternative A having a more optimal location and lower construction and logging costs than alternative A (cf. Ch. 8.2.3). Alternative C consists of five smaller circular sawmills closer to the forest, each with a one-shift production of about 2,800 cu.m(s) per year. In alternative C it is assumed that the five sawmills have a common central unit for sorting, drying, trimming, dipping, impregnation and sales/marketing of the sawnwood, for repair and maintenance of the logging and sawing equipment, and for administration.

Alternatives A and B each consist of one double slabber, one circular split saw, two circular resaws and one circular double edger. For the bigger logs there is an additional circular saw which can be operated as a separate unit or in combination with the resaws. Each of alternative C consists of two circular saws - a slabber and a resaw. Alternatives A and B are based on electricity from installed diesel generators, whereas alternative C takes the power directly from a 164 HP (SAE) diesel motor, one for each sawmill.

Table 8.24 presents the ranking of the three alternatives of technology on each of the criteria discussed above. It is seen that alternative C is equal or superior to alternatives A and B for all criteria considered. In particular it is seen that the economic and employment factors strongly favour alternative C. At 9% rate of interest, most probable shadow prices (0.7, 1.3 and 1.6 for respectively un/semiskilled labour, skilled labour and import) and zero relative price changes, the discounted present costs are:

Alternative A 60.9 mill. shs

Alternative B 52.6 " "
Alternative C 40.6 " "

With these assumptions alternative A and alternative B are respectively 50% and 30% more expensive than alternative C from a national economic point of view. These relative cost differences are fairly constant, but decrease slightly with increased price of labour and energy because alternative C is more labour intensive and demands some more diesel and oil than the two other alternatives. The relative cost differences increase with increasing prices of investments, imports and other domestic resources (exclusive of labour and diesel/oil) and with increasing rate of interests.

The above mentioned cost differences for alternatives A and B relative to alternative C correspond to respectively 3.17 and 1.97 mill. shs. per year or about 226 and 140 shs. per cu.m of sawnwood produced, during the project's assumed life-time of 10 years and assuming 9% p.a. rate of interest.

The main reason for the relatively large difference between the alternatives is that alternatives A and B are more capital intensive and demand more import and domestic resources than alternative C. The initial investment amounts (i.e. investments at year zero) are 26.4 mill. shs., 22.8 mill. shs. and 14.3 mill. shs. for alternatives A, B and C respectively.

These differences are mainly caused by higher investment costs in alternatives A and B of logging equipment, sawmill machinery (including green chain and power supply), and buildings.

From Table 8.23 it is seen that alternative C has about 11% higher direct total employment effect than the other two alternatives. The employment of skilled personnel is about equal in the three alternatives, but for un/semiskilled personnel alternative C gives about 17% higher employment than

alternatives A and B. The investment costs per employee (manyear per year) are:

Alternative A	118,000 shs	(or 14,000 US $)
Alternative B	101,000 "	(" 11,900 ")
Alternative C	57,000 "	(" 6,800 ")

Based upon this it is concluded that alternative C represents the best technological choice, under the assumptions made.

If the skidding operations in alternative C were assumed to be done by using oxen instead of agricultural tractors, the analyses in Ch. 7 show that the preferability of sawmill alternative C relative to alternative A would be even higher than shown above.

Table 8.24 also shows that alternative B is superior to alternative A in a Pareto-optimal sense.

One should be careful in drawing general conclusions from this study. Three factors particularly favour alternative C at Sao Hill. First, that the timber supply areas were relatively widely scattered. At higher timber supply concentrations near the bigger sawmill, alternatives A and B are likely to be relatively more attractive than shown in this analysis. Secondly, no electricity is yet available at Sao Hill, which means that all three sawmill alternatives have to use diesel or steam for power supply. If public electricity were available at prices below diesel or steam, the costs of alternatives A and B would probably have been lowered relative to the costs of alternative C. Thirdly, alternative C results in lower costs regarding social infrastructure than alternatives A and B, because alternative C is more decentralized and more of the workers can live in their existing homes.

For projects having physical and socio-economic conditions similar to the Sao Hill project, however, the result of this study ought to be of interest. Finally, this study also shows that labour intensive technologies exist which are highly compatible with modern capital intensive methods both from a financial and a socio-economic point of view.

9. Ch. 9 aims at discussing more generally the content of the previous chapters in relation to the study objectives specified above.

Many different methods have been used for analysing technological choice, and it is hard to compare the results from different studies. Only a few of the existing studies compare alternative choices of technology. This is the case particularly regarding forestry and forest industry studies. When alternatives are compared, most often only one or two criteria are considered: profitability (or cost efficiency) from a business economic point of view, and employment.

It is worth noticing that except for one study on the use of powersaw instead of two-man raker saw, these analyses of technology in forestry and forest industry projects all indicate that the labour intensive technologies are preferable to the more capital intensive alternatives analysed.

Although burdened with severe simplifications compared to reality, the neoclassical growth model applied in Ch. 3.2.2 illustrates the importance of the technological choice in LIC. In my opinion, the differences regarding contribution to economic growth per capita between the three technological alternatives in sawmilling that are analysed, are striking, not least when knowing that alternative C probably not is the optimal solution (cf. Ch. 9.5.1), and that alternative A - the technology actually chosen - is recognized as being one of the most successful forest industry projects in Tanzania.

The neoclassical growth model does not give results other than the cost efficiency analysis in Ch. 8.4.1, but the strength of the model is that it focuses on one variable important in most

LIC, the growth in consumption per capita. However, such a model would not, in most cases, be sufficient for choosing technology on the project level, because other development criteria than economic efficiency, for example those described in Ch. 8.4, would not then be considered.

The appraisal method proposed in Ch. 4.3 proved to be operational in the case studies in Ch. 6 - Ch. 8 and capable of distinguishing between, and of ranking the technological alternatives analysed according to the pre-established criteria. None of the other methods discussed in Ch. 4.2 would, in my opinion, have made more correct technological choices with the given criteria, and the other methods would be considerably more resource demanding.

It is a considerable strength of the proposed method, that it allows for starting the analysis at a relatively aggregated level and then proceeding towards more detailness according to the need and wants of the decision makers. For example, the analysis could in theory be expanded to integrate most of the criteria originally treated separately by the economic efficiency criterion, if the decision makers would accept increased costs and personal involvement regarding stating their preferences.

One of the most severe problems in practice is to define the realistic set of technological alternatives. In most projects this set is not obvious, and special care should be devoted to this stage of the analysis.

Assuming the development criteria used in Ch. 6 - Ch. 8 are relevant for Tanzania, the analyses generally suggest that the actual choices of technology that were made in the initial phase of the Sao Hill Sawmill Project seem to be:

(i) Close to optimal when choosing the use of sulkies in the thinning operations.

(ii) Far from optimal in the skidding from clearfellings, choosing the Volvo TC 860 forwarders.

(iii) Far from optimal when choosing one centrally located sawmill (alternative A in Ch. 8) instead of 5 decentralized mills with a common central unit (alternative C in Ch. 8).

The differences between the technologies actually chosen and the optimal ones of the alternatives analyzed in Ch. 7 and Ch. 8 are so significant that the conclusions above can hardly be questioned, although the analyses are based on many assumptions burdened with considerable risks. Also, several factors mentioned in Ch. 9.5.1, suggest that the differences between the optimal choices and the technologies actually chosen are greater than estimated in this study.

The development in relative prices since 1977 in Tanzania presented in Appendix 2, shows that the labour costs have increased considerably less than the other main production costs at Sao Hill Sawmill, and that particularly petrol, diesel and the capital costs have increased strongly. This implies that the conclusions above regarding the priorities in 1977 between the technological alternatives analysed in Ch. 6 - Ch. 8, were even stronger in 1982 and 1986, i.e. the labour intensive alternatives were even more favourable in 1982 and 1986 than in 1977 compared to the capital intensive technologies considered.

The Sao Hill Sawmill Project is considered by NORAD as well as Tanzanian authorities to be a successful industry project. The analyses in Ch. 3.2.2.2 and Ch. 8 indicate that if the choice of technology in other projects in Tanzania is as far from optimum as in that project, the social opportunity cost, regarding economic growth per capita as well as regarding other important development criteria, could be of a considerable magnitude.

One main reason for the results in Ch. 6 - Ch. 8 favouring labour intensive technologies is the low labour costs in Tanzania relative to the capital costs, in particular when considering the shadow prices on labour and foreign exchange. This effect is shown in Fig. 3.1. Another reason of a more general character could be that transport operations are essential in all of the three analyses. Generally, the transport costs tend to be high in LIC among other things because of poor roads, difficulties with spares, repair and maintenance of vehicles, etc. Technologies which lower the transport costs, could, all other factors equal, have a comparative advantage. This could particularly be the case in short distance transport with low speed for all alternative technologies, as in skidding of logs.

It is important to evaluate the effect on employment of different technologies, particularly on employment of unskilled and semiskilled workers. In this study all labour intensive technological alternatives give employment to significantly more workers classified as unskilled and semiskilled, compared to the capital intensive alternatives.

Previous studies have pointed to the importance of including the working capital in the analyses of technological choice at the project level, because the labour intensive technologies most often would demand a higher use of working capital. The analyses in Ch. 6 - Ch. 8 support this hypothesis. However, in all three analyses the working capital costs are less than 10% of total costs, and do not influence the overall ranking of the technological alternatives.

Except for the greater use of energy in the sawmilling operations, the analyses show that the labour intensive alternatives used the same amount or less of "none-labour" and "none-capital" production inputs (i.e. inputs which are not direct labour or capital) compared to the capital intensive methods.

Much of the literature on choice of technology pays considerable attention to surplus generation and the ratio of surplus generated per unit of investment. Surplus is most often defined as the difference between net value added and wages, and is important to the economy as far as it is reinvested. Factors like type of ownership (foreign versus domestic companies), possibilities of enforcing savings through taxation, differences in propensities to consume between workers and capital owners, etc., are in general factors to consider here. In the analyses in Ch. 6 - Ch. 8 no premium is given to investment relative to consumption, i.e. it is assumed that the rate of savings in Tanzania is as wanted by the Government. However, even if this assumption were relaxed and it were assumed that most of the wages will be consumed, it can be seen from Ch. 6 - Ch. 8 that the labour intensive alternatives, because of lower total costs, will have a significantly higher surplus generation as measured by difference in total production costs, compared to the capital intensive alternatives. In addition there is the difference in surplus generated by any savings of wages, assuming the marginal propensity to consume to be less than one. As such, the analyses in Ch. 6 - Ch. 8 show that labour intensive alternatives exist which give higher contribution to economic growth than the more capital intensive technologies analysed.

The differences regarding income distribution between the technological alternatives analysed in Ch. 6 - Ch. 8 are striking. The labour intensive alternatives give higher income to unskilled and semiskilled workers and use more resources provided in the Iringa region, and Tanzania, than the other alternatives.

As discussed in Ch. 2 neoclassical analysis of choice of technology is based on the existence of a wide range of technologies of varying labour and capital intensities. Critics have denied that such choices exist for LIC. The analyses in Ch. 6 - Ch. 8 support the neoclassical view for the skidding and sawmilling operations in Tanzania at the

present state of development, particularly when considering that different combinations of skidding equipment and sawmilling methods can be used.

The analyses in Ch. 6 - Ch. 8 underline the importance of, and connections between, the choice of type of output and the choice of technology. For example, if tree length skidding were assumed instead of log skidding, both the use of sulkies and oxen would be nearly impossible.

The quality of the products produced by the technologies analysed in Ch. 6 - Ch. 8 was the same and independent of their capital intensity. This could be a general characteristic of forestry and forest industry operations because of their bulky and intermediate type of products compared to several other lines of production. However, further empirical studies need to be carried out before generalizations are made.

The results in Ch. 7 - Ch. 8 do not support the neoclassical view that relative prices determine the choice of technology. This is not surprising because the technology in the project analysed (as in most other Government-based projects in Tanzania) was chosen in an economic environment which was far from the neoclassical assumptions of perfect competition. In fact, the results in Ch. 7 - Ch. 8 support the hypothesis reported in Ch. 2.2.1, that when price competition is not the rule, the goals of the "engineering man" is likely to override the arguments of the "economic man."

All studies in Ch. 6 - Ch. 8 show that the labour intensive alternatives have greater flexibility than the more capital intensive ones regarding breakdowns, lack of spare parts, foreign exchange savings, availability of service facilities, changes in outputs, etc. This might be only incidental, but could also be a general tendency, which should be studied more thoroughly.

The results in Ch. 6 - Ch. 8 show that large changes in the relative prices of labour and investment would be necessary to change the priority arrived at with the given criteria. However one should be careful in generalizing the results in Ch. 6 - Ch. 8 to other LIC, because both the socio-economic and technological environment may vary considerably among countries. Only more empirical studies, from different countries, would make it possible to reject - or not reject - any hypothesis of the generality of the results in the present study.

In Ch. 7.6 proposals are presented for getting appropriate choices of technology in development projects, with particular reference to forestry based projects.

10. The question of technological determinism mentioned by several authors is raised in Ch. 10: The situation in LIC may be technologically determined, not because there are no alternative technologies to choose from, but because of the complex social, political, and economic links between the selection mechanisms and the technologies chosen. It is argued in this study that this question is actually a hypothesis which can be rejected, or not rejected, only by empirical studies and actual operations. Thus, research in this field should not only be occupied with mapping the technical and socio-economic performance of alternative technologies, but also with analysis of which factors (political, social, economic) are decisive in the actual choices of technology. This would provide a better understanding of the possibilities of arriving at more rational choices. It would also be a challenging interdisciplinary task for disciplines like engineering, economics, political science, sociology, social anthropology and psychology.

The choice of technology should be viewed as a dynamic process, changing over time according to changes in the technical, socio-economic, and political structure it operates

within, and at the same time influences. Thus, as development is gradually achieved by means of appropriate technology, the meaning of what is "appropriate," will change because of this development.

Technology cannot be viewed in isolation from the society it is intended to benefit, since it is just one segment of the total environmental, technical, social and political structure in which societies function. All social processes are complex, and the choice of technology alone cannot solve the development problems of third world countries. However, as hopefully indicated by this study, there are for these countries considerable benefits to be gained by choosing the appropriate technology at the project level.

1 INTRODUCTION

1.1 Background

One important issue facing the governments of the less industrialized countries (LIC) is that of technological choice. The question of how existing natural resources, labour, capital and skills can best be combined to overcome problems of unemployment and provide a stable base for future increase in the standard of living, is a complex, but crucial one.

Most of the LIC labour force of about one thousand million people are employed in activities where labour productivity is very low (ILO 1976, HOPKINS 1980). The actual number of people classified as un- or underemployed depends largely upon what is meant by unemployment and underemployment. These concepts are difficult to define properly (STEWART 1978:32-58, HOPKINS 1980). Most often the concepts of underemployment and basic needs are used: Those who cannot satisfy their basic human needs are defined as underemployed[1]. Estimates of underemployment will, therefore, depend on what is defined as basic human needs. Here, various approaches are used (GUPTA et al. 1979, OECD 1979, HOPKINS 1980).

HOPKINS (op.cit.) summarizes the efforts made so far, stating that in 1980 790 - 1,100 millions of people were living in absolute poverty - i.e. below certain basic-need poverty lines. Under various assumptions regarding economic growth, basic needs and population growth, the corresponding estimates for the year 2000 are 400 - 1,080 millions of people. If full employment is the goal, 86 out of every 100 productive jobs needed to absorb both the existing under- and unemployed and the increase in the labour force up to the year 2000, will have to be created in LIC. This means an annual rate of growth of productive jobs of 3.9 % between now and the end of the century.

This annual growth estimate is an average for all LIC. Countries like for example Zimbabwe, Kenya and Tanzania have a projected annual labour force growth rate for the period 1980-2000 of respectively 4.5 %, 4.2 % and 3.5 % (HANSEN 1984). These, and similar countries, must have a considerably higher growth rate than the above mentioned 3.9 % p.a. in order to reduce the underemployment by the year 2000.

The need for productive jobs has to be seen in connection with the investment costs per employee and the available investment resources.

Studies done by the World Bank, ILO, and others indicate that the present investment costs per employee are in the range of (HANSEN 1984):

Medium/large scale	manufacturing	(1980 US $)	6,000 - 40,000
Small scale	"	(" ")	1,500 - 6,000
Informal sector	"	(" ")	0.1 - 1,500

The gross domestic saving rate per new employee gives an indication of the investment opportunities available for a country[2]. This rate is today below US $ 7,000 for most LIC. For example was it in 1979 for Botswana, Kenya, Malawi, Tanzania and Mozambique in the order of respectively 5,900 US $, 3,700 US $, 2,400 US $, 1,500 US $ and 900 US $ per year (HANSEN 1984:74). This means that the investments in medium and large scale manufacturing necessarily not can make a significant contribution to reduction of the present underemployment in most LIC.

Employment and savings are closely related to technology. Simplified, the choice of technology determines the direct employment and the labour and capital productivity, which strongly influence the profits and labour income. These factors then, determine the demand for goods and services as well as savings, indirectly influencing the investment behaviour and employment. The technological choice also influences other important development criteria than economic growth and employment, for example working conditions, dependency/independency, distributional and ecological effects, and flexibility (cf. Ch. 3.2 and Ch. 4.3.2).

The question of choice of technology in LIC has been widely discussed during the last decades. Most of the works in this field are of a general character, analysing the macro-economic effects of various levels of capital intensities. The actual choice of techno-

logy, however, is done on the micro (project) level. The last decade one may observe a growing awareness that fruitful discussion of the technological choice requires factual knowledge on micro-level about the range of techniques available and their performance in terms of different development criteria, as profit and income generation, employment, labour productivity, dependency, etc. A review of some of the literature is presented in Ch. 2.

Most of the existing works regarding the technological choice on micro-level are, however, difficult to draw conclusions from, because (a) empirical studies are few, in particular studies where alternative technologies are analysed, and (b) the methods of analysis differ much. It is, therefore, in my opinion, important to discuss how analysis of the technological choice on micro-level in LIC should be done, i.e. what methodology to use and what factors to emphasize, and to use the method arrived at to provide increased empirical knowledge about the effects of the technological choice on project level.

Very few studies exist regarding choice of technology in forestry and forest industry projects in LIC. There are, however, several reasons why this question might be of particular interest in the forestry and forest industry sectors of most LIC (WESTOBY 1962, SOLBERG 1981). First, there exist in these two sectors a range of technologies with different labour intensities, scale factors, product qualities and other characteristics which are broader than the narrow band of choices of which many decision makers seem to be aware, and which seem compatible both from a financial and a national economic point of view. Secondly, the relatively high income elasticity of demand for forest products, particularly at low-income levels and the pronounced linkage effects of forest industries with other setors of the economy, give the two sectors high potential for contributing to the satisfaction of basic human needs and to economic growth. Thirdly, the forests and forest industries have a considerable potential regarding the saving of foreign exchange through import substitution, as well as export potential. Fourthly, the two sectors are based on renewable resources, and are closely linked with agriculture, the prevention of soil erosion, the protection of water catchment areas, and vital ecological problems more in general.

1.2 Objectives of the study

This study has the following main objectives:

(i) Present an overview of existing works regarding the technological choice on micro (project) level in LIC, with special emphasize on forestry and forest industry projects.

(ii) Discuss some important theoretical aspects regarding the concept of technology and its role in economic development in LIC.

(iii) Disscuss possible methods, and arrive at a suitable method for analysing the socio-economic consequences of the technological choice on project level in LIC.

(iv) Analyse the technological choice in one actual project (Sao Hill Sawmill, Tanzania) in order to:

- exemplify how the methodology from part (iii) can be used in a given socio-economic context
- evaluate the appropriateness of the technological choice in this project
- increase the empirical evidence concerning consequences of technological alternatives in LIC in general, and in the forest sector (i.e. forestry and forest industries) in particular, thus contributing empirically to the discussion of the technological options available for LIC.

(v) Discuss how to arrive at appropriate technological choices in future development projects, with special reference to the forest sector.

Most work has been devoted to part (iii) and part (iv). Regarding part (i) a large amount of none-empirical studies exists, and I have just focused on aspects of particular relevance to this study. In part (ii) an attempt has been made to synthesize existing knowledge and to point at vital interrelations between factors involved in the technological choice in LIC.

The major target groups of this work are:

- Administrators/policy makers/politicians involved in questions related to technological choice in LIC
- Consultants involved in projects in LIC, donor agencies, and capital owners interested in investing in LIC
- Researchers and others interested in the topic.

1.3 Main assumptions and limitations

The study considers the situation in third world countries by focusing on the following question: Given that a certain product, or range of products, is to be produced and that there technically are more than one alternative available - to what extent is it possible to decide which of these technological alternatives are most appropriate for the society as a whole?

By technology, I mean the knowledge, skills and procedures for providing goods and services (cf. Ch. 3.1).

The study concentrates on the problem regarding choice of technology at the project (micro) level. It is assumed that the production output, as well as the available technological alternatives, are exogenously given. It should, however, be emphasized that the project concept may also include the alterntives disclosed by the following two questions: (a) Can a new, more appropriate technology be developed to produce the wanted output? (b) Can output A be substituted by other products whose production and use are more attractive for the society than A from an overall point of view? The point is that (a) and (b) in principle just increase the number of technological alternatives to be analyzed.

The objectives of development vary from country to country and over time, depending upon the social and political situation. Appropriateness, or optimality of any kind have meaning only when related to objectives, and a necessary condition for discussing optimal or appropriate tecnology is that development objectives are directly specified, or can be derived indirectly.

Another necessary condition in this context is that the Government of the LIC in question looks upon the choice of technology on project level as a steering parameter in its development strategy. If it should be of the opinion that other means (fiscal-, credit-, price-, wage policy, etc.) are efficient enough and more convenient to use than influencing directly the choice of technology on project level, the question about appropriate or optimal technology is irrelevant. In this study it is assumed that the choice of technology on project level is one (out of several other) interesting steering parameters which the Government will use.

As pointed out by ROBINSON (1965) there is no direct way of comparing different production techniques between two situations which represent different time periods, different states of knowledge, differing degrees of competition, etc. This problem is not discussed in the present study. Here, I have taken the more pragmatic view, based on SUTCLIFFE (1971:145-146), that it is when drawing conclusions from retrospective empirical studies that the problem of measurement of capital becomes an acute one. When the problem is to choose among a given set of technological alternatives in the same country, at the same time with similar economic and social conditions, the problem of capital measurement is more of theoretical than practical interest.

This study concentrates on analysing the consequences of technological alternatives on micro-level, assuming they can be implemented, and does not discuss institutional, political or other national or international factors which, in many cases, are strong forces in hindering appropriate technological choices. One reason for this approach is that such analyses would have to draw heavily on fields like for example political science and sociology. Another reason is that before going into such studies, it is important to have estimates of the potential gain of the possible technological alternatives in question, assuming they can be implemented - i.e. to map the total realistic set of alternative possibilities[4].

In line with this, the question of explaining technological change - why certain technologies are implemented and new ones developed - is beyond the scope of this study. For detailed discussions of

these aspects of technology, the readers are referred to SCHUMPETER (1934, 1939, 1961), SALTER (1966), ELSTER (1983), and FRANSMAN & KING (1984).

It may be argued that analyses of choice of technology in LIC should include a discussion of development theories and the concept of development. This discussion has been left out, partly because of the existence of a considerable amount of literature on the topic[5], and partly because it is, in my opinion, not necessary for the study, given the above mentioned assumptions regarding specification of objectives and government attitude towards the technological choice as a steering parameter.

A final limitation of the study is my own background, knowledge, and attitudes. These points limit the study in at least two ways: First, how the factors considered are treated; and secondly, what factors are omitted from the discussion.

NOTES TO CHAPTER 1

[1]Open unemployment is a very different phenomenon in LIC from that in industrialized countries. In the latter it includes all those for whom the system simply fails to provide work, whereas in LIC many of the unemployed have chosen to be unemployed. To the extent they have made this choice, they are often not the worst off in their society:

> "Open unemployment hardly exist in developing countries, with the exception of those fortunate enough to be able to wait until a suitable job turns up. Hence the unemployed in developing countries are greatly outnumbered by those who cannot satisfy their basic needs (which may not even be the case with all the unemployed). Those who are really desperate are forced to work in some manner, often for long hours and meagre rewards. Such people suffer from lack of access to assets and services, have low or non-existent levels of education and are generally concentrated in the rural areas. These are what we call the underemployed. In order to make an estimate of their numbers we have assumed that all those workers whose families are in absolute poverty must be, by definition, underemployed" (HOPKINS 1980:571).

[2]Development aid and foreign loans increase the investment potential, but for most LIC in the long run, the domestic savings will be the most important factor here.

[3]SEN (1975) gives an interesting explanation why micro-level analysis has been, in his opinion, a negleted field of research in technological economics. It is worth while considering the following statement (op.cit. p. viii):

> "The emphasis on aggregate effective demand on intersectoral interdependencies had an important effect on the development of both economic theory and practice, but the simplification of technological complexities occuring in such aggregative analysis - macro as well as sectoral - also had certain drawbacks. For the developing countries in particular, a shift in emphasis to the study of technological "details" is long overdue. For example, a study of Indian planning experience reveals a repeated lack of precise technological information in oversimplified sectoral planning models, contributing to the remarkable gap between expectations and achievements.
>
> A persistent problem has been the fundamental dichotomy as regards information: while the central body knows a great deal about planning objectives and over-all balances, it knows rather little about technological details, and while the operating units are familiar with the technological details, they do not know a great deal about over-all balances.
>
> Faced with this problem, planning strategies have evolved typically on one side or the other of the informational dividing line. Those focusing on aggregative or sectoral planning models have concentrated on over-all balances while making do with rather crude technological information. Those focusing on, say, project evaluation and cost-benefit analysis have concentrated

> on the technological "details" - broadly defined - and tended to gloss over the inter-dependence - or general equilibrium - aspects of planning. That each type of strategy is essentially incomplete is clear enough, but without using a fully fledged iterative model capable of encompassing both aspects, it has been a matter of judgement which part of the information base to concentrate on, and which to leave to crude guesswork. It is fair to say that there has been some switch in recent years from the sectoral balance focus to the technological details focus, partly connected with the real world development already discussed".

[4]The term "realistic" introduces subjective elements, but that is, in my opinion, hard to avoid.

[5]An overview of existing work in this field is given in HETTNE (1982).

2 PREVIOUS WORKS ON CHOICE OF TECHNOLOGY IN LIC - A SELECTION

2.1 Introduction

This chapter gives a review of literature regarding choice of technology in LIC. A great number of works exist on this topic, and surveys are presented in bibliographies like JENKINS (1975), CARR (1976), and JERVAN et al. (1986). These bibliographies, however, are not very detailed and the coverage of forestry and forest industries is rather sparse. In this chapter, therefore, I have concentrated on reviewing empirical studies related to forestry and forest industries, particularly studies where alternative technologies are compared. In order to give a comprehensive view of the topic, a considerable part of the presentation is also devoted to major works of a more general character.

Except for the section on forestry and forest industries, which aims at covering most of the existing studies in this field, it has been necessary to be very selective. This has been done with the aim of covering the main arguments used by various authors regarding the technological choice in LIC.

2.2 Works outside the forest sector

2.2.1 More general works

JOHANSEN (1967) gives an overview of main development lines in economic growth theory, describing major differences and similarities between classical growth theory represented by Ricardo, Harrod-Domar models based on HARROD (1948) and (DOMAR 1957), and neoclassical growth theory represented by SOLOW (1956). In all these models technology is treated as an exogenous factor - i.e. determined outside the model. In the classical, and Harrod-Domar models the factor ratio between labour and capital (i.e. the capital intensity) is assumed constant. In neoclassical theory this ratio is endogenously determined based on assumptions of full substitutability between labour and capital.[1]

JOHANSEN (1963) shows in a neoclassical model, that if assuming that the saving rate depends on the technological choice in a way that all wages are consumed, and only profit is saved, then the long run production will be maximized by initially choosing a more capital intensive production than when savings are assumed independent of the technological choice. JOHANSEN (op.cit.) argues that implicit in this result it is assumed for example that wages are independent of capital intensity (i.e. wages are equal in the "modern" and the labour intensive sectors of the economy) and that the government cannot use fiscal or other means to ensure an optimal saving rate.[2]

The neoclassical treatment of technology has been criticized for several reasons. Based on SUTCLIFFE (1971:140-197), STEWART (1978:26-31, 46-49) and BHAGAVAN (1979:37-55), the critics may be summarized like this.

a. The neoclassical models usually pick up only two characteristics regarding technological choice: The relative prices of labour and capital, and the investments (savings) generated by the economic surplus. Thus, important aspects are not included like (some of these are closely interrelated):

   - Differentation between labour skills requirements of the various technological alternatives. Usually, in LIC, less unskilled labour will be required when capital increases.

   - Scale of input and capacity utilization.

   - Type of production inputs required - for example the need for imported goods and services.

   - Infrastructural requirements.

   - Service and maintenance.

   - Indirect effects (including effects on domestic innovative capacity).

   - Flexibility and risks.

b. The neoclassical assumption of "let the factor endowment speak" may be politically impossible in practice. For example may the sort of wages required to get undistorted factor prices reflecting their marginal productivity give an impossibly low consumption level for parts of the labour force.

c. The assumption of continous production functions with full substitutability between labour and capital is highly unrealistic. Usually, three main arguments are put forward here: (i) There are theoretical problems involved regarding the measurement and aggregation of technology of various types and vintages. (ii) The ceteres paribus assumption made that except for labour and capital, the technologies are similar, is in most cases unrealistic. Various vintages will have various characteristics for example regarding use of energy, imported goods, quality of output, etc. (iii) In most cases the technology available does not cover the whole specter of labour and capital in the isoquant curves (cf. Figure 3.1) - i.e. the production functions are not continous, not to say twice differentiable.

d. Capacity utilization varies across industries in the same sector. For example will an increase in shift work reduce the capital intensity. Likewise, low capacity utilization due to for example unexperienced technical and administrative know-how raises labour productivity more than capital productivity.

e. Assumptions of perfect competition in factor and product markets are unrealistic.

Point c above are crucial for the many policy recommendations given by economists recommending to change factor prices in LIC to solve the question of technological choice. For example KALDOR (1965) and AMIN (1969) deny the existence of any choice. The significance of this question is illustrated by STEWART (1975 a:1-3). Suppose the economy produces a single good. Suppose that it has limited investment resources, as shown by $O\bar{k}$ in Figure 2.1, and that it has labour supplies $O\bar{L}$. For full employment of labour and full use of its investment resources the appropriate technique is represented by f in the figure. The investment per man is shown by the slope of the line Of, which may be defined as the capital or investment intensity of the technique. If there is a wide range of efficient techniques for producing the good in question, as shown by the isoquant TT in the figure, then the existence of appropriate technique f is assured. The question at issue is then whether to adopt technique f thereby ensuring current full employment, or whether by using a more capital intensive technique, say r, more savings may be generated and subsequently a faster growth in investible resources and output and employment. Practically, the question at issue is how to alter factor prices and other determinants of technique selection in such a way that the appropriate technique, be it r or f, will in fact be selected. But suppose the isoquant TT exists only in the economists' imagination and that only a single efficient technique exists, shown by the ray Oq. Changing factor prices and

other incentives to secure the adoption of technique f will then be pointless, since being the only available technique q must be chosen. The debate between f and r is equally pointless, and unemployment $u\bar{L}$ will occur, acording to STEWART (op.cit.).

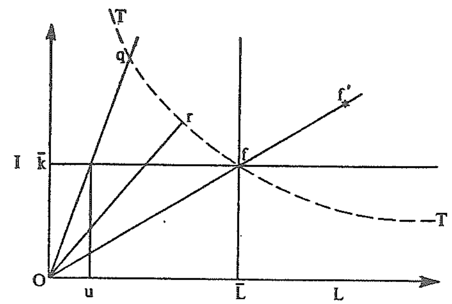


Figure 2.1. Illustration of the importance of assuming full substitutability between capital and labour. (From: STEWART 1975 a:2).

SEN (1968) discusses the problem of choice of technique in a labour surplus economy. The work is based on the assumptions that an extra weight has to be attached to the investible surplus generated - i.e. it is assumed that the saving rate is inoptimal. At the end he also presents some case studies regarding choice of alternative techniques for cotton-weaving and cotton-spinning in India.

COOPER (1982) uses a rather sophisticated neoclassical model, based on SEN (1968), to investigate the optimal choice of technology in the capital good sector assuming (a) this sector makes machines for the consumption sector and for the investment sector (i.e. machines to make machines for the consumption sector); (b) the criterion of choice is to maximize output of machines for the consumer-goods sector; (c) this happens in a planned economy with abundant labour supply and limited investible surplus, and where at any real wage rate a certain amount of labour can be employed in the capital-good sector. The main result of the analysis is that the real wage does not influence the optimal choice at all - it is influenced only by the <u>technical</u> conditions of production.

STEWART & JAMES (1982:3-4) critizize this model, first because it assumes that the workers in the sector making machines to make machines do so unassisted by machines. This is highly unrealistic, and the nature of machines that these workers need, could affect the conclusions. Secondly, the model assumes a given wage rate which does not vary with technique. Thirdly, and most important, it is argued, the model ignores the time aspect, by assuming instantaneous adoption and not taking into account that using a more capital intensive technique in the capital sector is essentially a way of extending the time period of production.

In recent years the neoclassical economic tradition of assuming full substitutability between capital and labour both ex post and ex ante, has been followed by the more realistic approach of assuming full substitutability of the production factors ex ante, but having ex post no substitutability[1]. Such models, originally introduced by JOHANSEN (1959) and further elaborated in JOHANSEN (1972), have yet, however, not been used to any extent in analyses of choice of technology in LIC.

HIRSCHMAN (1958) advocates using capital intensive production methods in LIC, especially in "machine-paced" (as opposite of "operator-paced") industries. His main arguments for this is that the labour force in these countries is unstable, inexperienced and less disiplined, and managerial skill very scarce. This leads to the hypothesis (the "Hirschman hypothesis") that the greater the degree of capital intensity in industry is, the smaller is the labour productivity differential between IC and LIC.

This hypothesis has been tested empirically. BHALLA (1976) gives an overview of existing works in this field, and concludes that in the present state of knowledge there is no evidence in favour of the argument that low-cost technologies are necessarily management- and supervision-intensive. However, the influence of economic, cultural, and other factors is emphasized as an area where further empirical research is highly needed.

DOSSER (1962) makes a critical review of different main investment criteria proposed for LIC. The following criteria are examined:

- Capital-output ratio rule
- The social marginal productivity method, as defined by KAHN (1951)
- The marginal per capita re-investment quotient, as defined by GALENSON & LEIBENSTEIN (1955)
- Marginal growth contribution, as defined by ECKSTEIN (1959)
- Sen's "time series" criterion, as defined by SEN (1957)

The main conclusion of DOSSER (op.cit.) is that these criteria relate to particular, and different, kinds of economies both in IC and LIC. In addition, he argues that other factors not covered by these criteria, might be very important. These factors are classified as follows (each of which is discussed quite in detail):

(i) Political inhibitions or political consequences surrounding some lines of investment.

(ii) The strategy of obtaining foreign or international capital.

(iii) The greater need for, and difficulty of, coordination of investment decisions.

(iv) The greater need for, and difficulty of, forecasting future demand.

MARSDEN (1970) argues that technology is an important variable in development strategy and that the government has a vital role to play in influencing investment decisions, directly and indirectly, giving an optimal utilization of available resoures. He gives the following main reasons why the direct transfer of technologies from IC to LIC may be inappropriate:

- Capital is dearer and labour cheaper in LIC.
- Large-scale production may be inefficient in the conditions prevailing in some LIC.
- Advanced technologies may reduce both employment and real incomes in certain circumstances.

For selecting "progressive technologies" he proposes the following guidelines:

- Wide disparities in capital intensity per worker in different sectors should be avoided.

- A technology should suit the economic and social environment in which it is employed.

- New technologies should stimulate output in indigenous industries and be capable of being reproduced locally.

- The productivity of capital should be maximized and the social cost of production minimized.

SUTCLIFFE (1971:140-197) discusses various aspects of technology and industrialization, of which I will mention here:

- The theory of intertemporal welfare economics postulates that a rational government, if it has control over the kind of investment which is undertaken, will maximize the present value of future streams of consumption, discounted at an appropriate social rate of discount which may not be constant for all periods in the future. In practice, however, governments or planners will lack sufficient reliable information for this. In addition, their decisions are most often dominated by less abstract objectives - for example to reduce the present unemployment or to affect a certain distribution of income.

- Increased employment is in itself not an argument for labour intensive projects in LIC. Even if in the short term the major objective of economic policy were to maximize employment, with no efficiency constraint, the adoption of the most labour intensive techniques might still not be the best way to achieve it. It would be appropriate policy only for the immediate maximization of employment. If the time horizon is anything longer than instantaneous, then the possibility arises that more capital intensive, though not the most capital intensive, techniques can most efficiently reduce unemployment. This could be made through increasing the surplus which is reinvested to provide further employment in other enterprises; alternatively it could result from the effect of greater linkages to other new potential industries, or by raising the wage levels of those who are in employment, increasing demand for new manufactured goods, and so increasing the incentive to invest.

- To avoid confusion it is important to differentiate between the choice of technology for a specific production process and the choice of technology for the economy as a whole. For example is neoclassical growth theory almost solely concerned with higher dimension problems of the ratio of capital to labour for the economy as a whole.

- There are many industries in which all the available techniques are labour intensive by the standards of the industrial sector as a whole; there are others where even the most labour intensive of available techniques is highly capital intensive compared with the rest of industry. This fact underlines the importance of realizing that the relationship between the employment of capital and labour in the industrial sector is not merely one of choosing different techniques to produce the same output, but also one of selecting the composition of output itself. The advantages claimed for a high degree of capital intensity might be obtainable from using the most capital intensive techniques in the most labour intensive industries. On the other hand, many industries which are labour intensive, such as machine tools, are intensive in the use of a particular kind of highly skilled labour. These complications present problems which are not solvable by simple formulas.

- Within nearly all construction activities there is a wide range of possible techniques. This is the situation also for many industries which supply materials for construction - e.g. the production of wood and cork products, bricks and tiles. The labour intensive methods in these sectors also tend to use large amounts of unskilled rather than technically skilled labour. The flexibility of these sectors is important because they account for large proportion of total industrial output, and in particular for a high proportion of gross fixed capital formation, in many LIC.

- In most LIC there is a clear distinction in the cost of capital between foreign investors and indigenous investors. The former most often raise capital for new investment out of retained earnings or in the capital markets of IC. Most indigenous investors in LIC are forced to raise capital locally - to higher costs than foreign investors. Thus, in assessing investment patterns in LIC, the type of investors must be taken into account. Capital intensive investments in capital-scarce countries may, from the point of view of the foreign private investor, be completely rational.

WELLS (1975) reports in a study from Indonesia that the managers' choice of technology appears to be influenced by two objective functions, which in low-wage countries are generally conflicting. The first objective, that of "the economic man", is to minimize costs. This leads to a relatively labour intensive production process. The second objective, that of the "engineering man", tends to lead toward more sophisticated, capital intensive technology. Where price competition is the rule the objectives of the "economic man" is reported to seem to override those of the "engineering man". However, when the firm has a monopolistic advantage, there is less pressure on the firm to minimize costs in order to survive, and the goals of "engineering man" are allowed to move the firm to a level of technology that is more advanced than that which the "economic man" would prefer.

DICKSON (1974) analyses some of the social relations associated with contemporary technology in both LIC and IC. He argues that any interpretation of the process of technological development which sees this process as being independent of political considerations, is an ideological distortion. His main thesis is that technology plays an important political role in society, a role intimately related to the distribution of power and the exercise of social control. Technology and social patterns reinforce each other in both a material and an ideological fashion.

ILO (1976) discusses technological choice and innovation for LIC and argues (op.cit.:141-143):

"Discussion of technology's role within the developing world has been subject to considerable controversy. The issues and the interrelationships involved are certainly complex. But the task of the policy maker has not been made easier by the tendency for the advice rendered to him on this topic to be polarised into two, widely divergent schools of thought.

On the one hand, the protagonists of the latest, advanced technology have argued that:

- modern techniques are the most efficient; their adoption will allow the development gap to be closed more quickly
- modern technology provides economies of scale which result in capital saving (i.e. lower capital/output coefficients) and larger surpluses at the enterprise level; if invested, these surpluses will increase the future rate of growth of output
- modern technology is necessary to achieve high quality standards, particularly for international markets
- modern technology often economises on scarce managerial and technical skills and reduces material wastage
- in most sectors there is little practical choice available; the so-called technological spectrum between traditional and modern techniques is really a vacuum
- reliance on obsolete, labour intensive technologies would condemn the developing countries to technological backwardness and stagnation
- any employment problems that might ensue from concentration on modern technology are best handled by income transfer (social security, subsidies, free services) to those affected or by special employment-creating programmes in one or two selected sectors where greater technological flexibility is said to exist (e.g. public works).

On the other hand, the advocates of labour intensive technologies claim that:

- a technology's characteristics cannot be separated from the socio-economic environment in which it has to operate; technical efficiency should not be confused with economic efficiency
- most modern technology originates in the highly industrialized economies whose needs and circumstances are currently very different from those prevailing in LIC in terms of factor (land, labour, capital, entrepreneurship) endowment, size of markets and enterprises, consumer incomes and tastes, skill levels, structure of distribution, transport facilities, etc.
- the most desirable technologies for LIC are therefore those which require little capital per worker (i.e. labour intensive), can be used efficiently on a small scale, are easily serviced and repaired, do no require high levels of education or training to operate and utilize locally available materials
- a much wider range of technologies with these characteristics exists than is believed by the central planners; they are not readily available because price distortions and other biases encourage the suppliers of technology (research institutions, machinery manufacturers, multinationals) to concentrate on the initially easier transfer of current "off-the-shelf" technology designed for the major markets of the industrialized countries
- where the requisite labour intensive, capital saving technologies do not exist, it would be worth while to devote increased resources to the development and adaption of suitable indigenous technologies; given appropriate incentives and institutional arrangements, the benefits ought to outweight greatly the costs (economic, social and political) of the present dependence upon alien technologies
- technology should be treated as a strategic variable in development strategy in which the policy maker guides the investors' choice between alternatives (new or existing), either directly by central planning decisions or indirectly through policy instruments affecting the "price signals" faced by private entrepreneurs; otherwise, there is little prospect of combining growth with equity
- the high and increasing capital intensity of advanced technology, plus the severe constraints on the investment funds available, would mean that only a very small proportion of the labour force would benefit from this kind of technological progress; the majority would be condemned indefinitely to stagnation, underemployment and reliance on "trickle-down" or charity for any future growth in their incomes".

It is recommended (op.cit.:147-155) to:

- make further evaluations of alternative technologies in various sectors
- develop technological research in LIC
- improve the international coordination in this field
- establish consultative groups on appropriate technology
- establish an international appropriate technology unit
- influence research and development by multinational enterprises.

MCROBIE (1976) discusses how to mobilize the knowledge on low-cost technology and to communicate it to potential users in a practical form, envisaging this as a three stage process: First is the task of diagnosting and understanding the need for technology, the level of which this need can be identified, and the kind of technology we should be concerned with. Second is the problem of securing the knowledge itself (sources, methods and organization). Third is the question of communication; how to get the knowledge into the minds of planners and administrators and into the hands of those who can turn it into action?

SINGER (1977) gives a wide discussion of how technology can be related to the fundamental objective of satisfying basic human needs. Among other things, he underlines that it is pointless to set up intentions for a more appropriate technology unless trained and motivated personnel are available to make them work, and that the success will heavily depend upon the full cooperation of the scientific community, of advisory panels of leading citizens, of management and workers in the productive sectors and, in short, of the community as a whole. The importance of the educational system, both formal and informal, which creates an attitude of interest in technological problems and an understanding of its vital role in national development, is stressed. Special and explicit attention to policies on technology and the development of technological institutions should be given in the national development plans for LIC. It is argued that the very exercise of doing this would bring home to planners the need for consistency in the development planning and the choice of technology, and prevent inconsistent decisions.

WHITE (1978) gives a systematic gathering and analysis of the evidence regarding to what degree there exist appropriate factor proportions for LIC. By "appropriate" he means factor proportions that are roughly in line with the overal factor availabilities in an economy. The main question analysed is whether there exist economic efficient alternatives to the modern capital intensive technology of the rich industrial nations, or whether fixed factor proportions (i.e. current Western technology) describes the only efficient technology available for LIC. In his opinion the evidence summarized suggests strongly that greater labour intensity in LIC manufacturing is feasible and would be efficient. A view that LIC are currently condemned to high capital labour ratios, because there are no efficient alternatives, is not consistent with the evidence. The evidence also suggests that incentives matters. Appropriate factor prices are important to the discovery and profitable use of appropriate factor proportions and appropriate products. Effective competition in product markets can also provide an important push here, particularly by leaving less scope for pure engineering thinking to dominate efficient factor use. However, it is emphasized op.cit. that large gaps still remain in our knowledge of appropriate factor use. The existing studies based on econometric investigations of factor substitution using production functions, are not convincing (cf. below). It is argued that what is mostly needed is more microeconomic studies - i.e. studies of individual manufacturing processes or products. Published evidence is reported op.cit. to exist for only a dozen products and processes regarding factor substitutability. Although these studies are said to provide powerful demonstrations of the feasibility of labour intensive methods, more convincing than the CES-production function econometric studies, it is emphasized op.cit. that these micro studies have limitations leaving among others the following questions unanswered:

(a) Does the economies of scale favour capital intensive processes? Only two of the studies reported op.cit. have investigated this, and they find (BOON 1975 for metal machinery and STEWART 1975 b for cement block manufacture) that there are appreciable economies of scale and that capital intensive methods are necessary to capture these economies. On this matter WHITE (1978:35) states:

"Why economies of scale favor capital intensive processes is unclear; this just seems to be a fact of technological nature for the particular processes investigated. To what extent can this be generalized? Most of the investigators of product technology do not mention it, and this may well be a phenomenon restricted in significance to only some of the processes that go into manufacturing a product, like metal finishing, and flow processes involving liquids, pipes, and containers, like petroleum refining and chemical production. The importance of setting-up costs for a production run or of the surface area and volume relationship of containers dominates here. For other manufacturing processes, scale effects seem likely to be much less important. Clearly, though, much more needs to be known about the relationship between scale and factor substitutability".

(b) Are capital intensive processes necessary to ensure high quality? STEWART (1975 b) argues that this is the case for cement blocks. WHITE (1978:36) says on this matter:

"Stewart argues that this is the case for cement blocks. This echoes the earlier arguments noted above that, particularly in metal-finishing processes, machines can substitute for skilled labour and foreman supervision in ensuring a high, uniform quality standard. Other process studies either claim that quality needs not be affected by technique or neglect to mention the problem. Again, we need to know more in this area".

(c) What about the other inputs in the production process than capital and labour? On this matter, WHITE (1978:36) states:

"A few studies do account for the differential efficiency in the utilization of raw materials by different techniques. But it is difficult to tell if this is a serious problem generally. Further, how valid is the argument that mechanization is an efficient substitute for management supervisory skills? Unfortunately, there is only one piece of quantitative evidence on this point. CLAGUE (1970) has shown that the overall efficiency of peruvian industries increased as capital intensity increased; machine-paced processes seem to offer less latitude for labor inefficiency. The engineering and process studies have not thus far been able to quantify this, and so it must remain, with the exception of Clague's study, largely an open question. But PACK (1976) reminds us that high levels of mechanization will require skills necessary to repair the complex modern machinery, and these are usually as scarce in LDCs as the management skills that the machines are supposed to replace. The repair skills to handle simpler machinery, however, usually are in greater supply. Pack argues that good management is also needed in order to recognize the possibilities for labor-capital substitution and to do the necessary innovations to adapt equipment rather than just accept completely the sales pitch of the traveling capital-goods salesman from the United States, Europe, or Japan".

WHITE (1978) also discusses the causes of inappropriate factor proportions, and offers the following five explanations why efficient labour intensive technological alternatives are not chosen in practice:

(a) The relative prices of capital and labour are frequently badly out of line with their true social worth:

"A wide variety of government policies have made capital artificially cheap in capital-short economies, while labor has been made artificially expensive in many of these same economies. Capital is made cheaper through government-subsidized low-interest loans, favourable exchange rates or low tariffs for imported capital goods, tax holidays on new investments, and accelerated depreciation on capital goods. Labour in urban manufacturing has been made more expensive through minimum wage legislation, mandated fringe benefits, restrictions on the ability to lay off workers, and government-encouraged union pressures. These labor provisions are most likely to be enforced in the government sector, in large firms, and in MNCs. As we argued earlier, they are a major factor in encouraging high urban unemployment. Real urban wages are frequently two or more times rural wages. --- Generally, the pattern reported is rising real wages in manufacturing in most LDCs, while capital remains cheap or becomes cheaper. The rising real wages in LDC manufacturing sometimes receives two defences; both should be put to rest. First, it is argued that wages should rise with the increases in productivity in manufacturing. Besides mixing cause with effect, this argument is wholly inappropriate for an economy with widespread un- and underemployment. As long as there is substitutability, greater capital shallowing should be encouraged through low wages; only when labor grows scarce should real wages rise in line with rising productivity. Second, it is argued that in a world of monopolistic MNCs which escape LDC taxes through internal transfer pricing vis-a-vis the parent company, high wages may be the only way that the LDC can capture some of the profits. But the obvious solution to this is to improve government taxation and customs procedures and to reduce the MNC's monopoly power by introducing more competition (via imports, if necessary) into the domestic economy in which MNC sells, or by opening up for wider bidding the extraction and export concessions that the MNC has. Using wages to try to capture those profits is a distinctly inferior and potentially quite harmful policy. The cheap-capital and high-wages policies have laudable goals - to encourage investment and to raise worker incomes - but their inevitable result is to encourage entrepreneurs to substitute away from labor and toward capital intensive processes" (op.cit.:48-49).

(b) Entrepreneurs, and especially engineers, have a strong tendency to think in terms of developed-country mechanized technology as the ideal regardles of factor prices:

"The confusion between high labor productivity and efficiency enters here. If markets are noncompetitive, entrepreneurs seem willing to sacrifice some of their potential monopoly profits in order to achieve this goal of mechanization. WELLS (1975) has labeled this the phenomenon of "engineering man". This appears to be a widely held notion. But there has been only one attempt formally to test the proposition. WHITE (1976) found that greater competition in Pakistani product markets forces industrialists to adopt more labor-intensive methods relative to the U.S. "ideal"; industrialists in less competitive markets were freer to pursue their engineering goals" (WHITE 1978:49).

(c) Information about labour intensive methods is frequently difficult to obtain. Search is costly. The firm may be familiar with the capital intensive processes and the absence of competition may reduce the incentive to search.

(d) Government policies are inappropriate, beyond the labour and capital pricing policies:

"Badly conceived, capital-intensive public projects are a waste of resources and surely do not provide a good example to the private sector. The mystique of high productivity and modernity pervades the public sector as much as it does the private sector. Other poor policies include a frequent negative attitude toward the import of used machinery and used vehicles, sometimes taking the form of outright bans. This is based on the belief that used machines are inferior and private entrepreneurs are mistaken in their purchases or that used machinery may be an easier vehicle for smuggling (through overinvoicing to smuggle funds out of the country or underinvocing to reduce tariff duties, since the customs officials may be less familiar with the true value of the machinery). As argued above, such policies are sacrificing potential major improvements in labor-capital ratios. And the unwillingness to tax or otherwise discourage the consumption of capital intensive consumer goods and the unwillingness of many governments to encourage the development of export markets for manufactured goods further push their economies toward capital intensive methods" (op.cit.:50).

He also takes up the argument in favour of capital intensive methods that they would raise the income share of capital owners who are supposed to have higher rates of savings and reinvestment than workers, thus increasing the pace of industrialization, and argues (op.cit.:25):

"This kind of argument, of course, presupposes that government taxation of labor incomes for savings purposes is not feasible. But ignoring this, what do we know about saving rates.
The evidence reviewed by MIKESELL & ZINSER (1973) does indicate that saving out of labor income is very low; the marginal propensity to save rises with income, and the saving rate out of profits is high. But OSHIMA (1971) argues that added income to low-wage workers might reduce the dissaving of many. If we turn to the saving rates of firms of different capital intensities, RANIS (1962) provides evidence that medium-size (less capital intensive) firms have higher savings and reinvestment rates per unit of output than do large firms. APPAVADHANULU (1974) argues that small firms in India have higher saving rates than large firms.
The evidence thus is somewhat mixed. And given the possibility of government taxation as a form of saving, the income distribution, saving, and reinvestment argument appears to be a weak reed on which the case for capital intensity might rest".

Regarding research and development (R & D) in LIC, WHITE (1978:51-52) argues:

"Although plenty of opportunities for more appropriate factor proportions exist in LDCs, the range of choice is far from complete, and in many instances a serious need exists to develop new processes and products for LDCs that will be more labor-intensive and, of course, that will increase the overall productivity of all factors generally. This is technological progress, with research and development as the main generating agent. Unfortunately, technological progress and R & D are only imperfectly understood in the developed countries, and the data there are still poor and spotty. Much less is known about this area in LDCs.

Most investigations of R & D in developed countries involve tests of the Schumpeterian hypotheses that large absolute size and market power are necessary to encourage R & D. The evidence from these tests is definitely mixed. But in LDCs the data are so scanty that writers on the subject are generally content if they can just quantify R & D expenditures; there have been only a few empirical tests of hypotheses. The LDCs perform only 2 % of all R & D conducted in the non-communist world, and LDC manufacturing firms appear to spend only 0.1 - 0.2 % of their sales on R & D. In contrast, manufacturing firms in the United States on average spend 2 % of sales from their own finances on R & D. KATZ (1973), in one of the few detailed studies of LDC R & D, found that the R & D expenditures as a percentage of sales of Argentine firms in nine industries were only a fifth of the relative amounts spend by domestic U.S. firms in the same industries.

The reasons for the low levels of spending are many: low levels of income; shortages of trained personnel; the small sizes of firms in LDCs; the ready availability of developed country technology and the low risks involved in transfering it intact rather than trying to adapt it; the absence of competitive pressures to innovate; and the practise of MNCs, if they do any R & D relevant to LDCs, to do it mostly in their home countries".

WHITE (1978:58) also emphasizes the connection between management and the use of labour intensive management:

"If the connection between good management and appropriate factor proportions is as crucial as much of the evidence suggests (with good management meaning that entrepreneurs can recognize and utilize the opportunities for appropriate factor proportions and also that supervisory skills may be able to substitute for mechanization in the maintenance of quality standards), then appropriate management-training institutes may be as (or more) important as appropriate R & D institutes for discovering and applying efficient labor-intensive methods".

Based on the choice of technology of 400 firms in light manufacturing in Thailand over the period 1962-1974, LECRAW (1979) investigates what makes the firms in an industry to choose one technology rather than another. The analysis relaxes the usual neoclassical assumptions of profit maximizing behaviour, risk neutrality, and perfect information. It is concluded that risk, information costs, management, competitive pressure, and projected profits had a significant impact on the choice of technology. In particular it is stressed that a substantial amount of non-optimizing behaviour regarding the choice of technology occurred when competition was limited.

STEWART (1978) gives a detailed discussion of the role of technology in the economic development of LIC. The following summarizes some of the author's conclusions relevant to the present study:

* Much of the dualistic pattern of development in LIC can be attributed to the fact that modern technology has characteristics suited to IC, not to LIC.
* Empirical case studies show that in many cases there is a significant range of efficient labour intensive technological alternatives.
* The nature of the market served and the type of product required are of critical significance in determining the choice of technology. Many of the selection mechanisms of technology are in one way or another the outcome of the economic system and of the technology already in use, for example the income distribution and the control of resources of different types of decision makers.
* A system based on advanced-country technology tends to generate high incomes among those employed with the technology. The technology in use partly determines the relative advantage of different types of technique in new investments. Relative prices and availability of resources are to a considerable degree determined by the existing technology. The effective pursuit of an alternative appropriate technology

would threaten interests in IC as well as those interests in LIC that are currently benefitting from the use of advanced technology. The alliance of interests between advanced countries and the advanced technology sector in LIC presents a formidable obstacle to any significant change in LIC.

* Promotion of a local capital-goods industry in LIC and greater emphasis on trade between thirld-world countries are likely to make a move to an alternative development path easier for LIC. Most important is to develop local technical innovation directed towards local needs.
* Given the close connection between selection mechanisms and the technology in use, it is likely to prove extremely difficult to follow an alternative path.

FRANSMAN & KING (1984) emphasizes the question of how imported technology is assimilated and changed to suit local circumstances, and how technological improvements of various kinds are brought about in LIC. The focus is on technological capability, and this aspect is examined both from a theoretical and empirical point of view.

SKARSTEIN & WANGWE (1986:54-84) discusses the problems of choice of technology, technology transfer and policy, and the relationship to the problem of implementation of the industrial strategy in Tanzania. It is argued that the industrial strategy stipulates the priority industrial activities into which investments should be allocated in order to achieve specified national goals, and that the type of technology chosen and the policy adopted towards technology is important in enhancing the realization of the national development goals.

Looking into the practice of choice of technology in Tanzania the authors find that the source of external finance, the technical managerial skills constraint, and specifications of product quality (based on the inherited consumption technology) have largely determined the types of technologies imported into industry in Tanzania. The types of technologies which have been imported on the basis of these criteria have in their opinion not facilitated the implementation of the industrial strategy in achieving the national goals.

Skarstein and Wangwe proceed to suggest the following criteria for choice of technology which will lead to the selection of technologies which are consistent with the industrial strategy and the national goals:

- (i) degree of utilization of local material resources;
- (ii) degree of utilization of local human resources;
- (iii) the extent to which technologies contribute to training and learning by doing in a way which contributes to creating technical and managerial skills over time;
- (iv) the extent to which a technology creates demand for the products of the domestic capital goods sector;
- (v) the generation of surplus and capital accumulation;
- (vi) the extent to which a technology is likely to minimize X-inefficiency at the operational stage;
- (vii) the implications on the utilization and generation of foreign exchange;
- (viii) the degree to which an imported technology is transferable so that the stock of local technology can be augmented in the process.

In their opinion, these criteria should be used in determining the choice of technology so that the implementation of the industrial strategy is facilitated and the national goals are enhanced. In particular it is emphasized that the structural change and self-reliance objectives will be enhanced by the type of policy that will be adopted towards technology.

2.2.2 Case studies on project level

JEQUIER (1976) and IBRD (1976) give a quite detailed study of the question of "appropriate" technology in LIC. In addition to a more general discussion, several case studies are presented. BHALLA (1975) also gives a collection of case studies regarding technological choice in LIC. Among the lessons from these studies, I will mention:

- The importance of intermediate material (production input) costs in affecting the capital-labour substitution, should be recognized.

- Working capital requirements are often not considered in existing micro-analysis of the technological choice. Empirical studies suggests that, in general, the working capital required by labour intensive methods is larger than that needed for their capital intensive counterparts.
- In discussions of the technological choice in LIC, not only the factor substitution between labour and capital is important, but also the substitution between different types of labour skill required. For example regarding supervision, it might be that more capital intensive machines calls for workers with a high level of technical ability to manage machines, whereas more labour intensive production requires ability to organize a large number of workers. It might well be that the type of supervision needed for labour intensive methods (skills needed for organizing workers) is more readily available and cheaper in developing countries than the type of supervision needed for capital intensive methods. Very few studies exist, if any, dealing specifically with the effects of these factors on technological choice at the level of the firm or the industry.
- There may be a close connection between labour intensity and product characteristics.
- The question of choice of technology is closely related to the question of choice of products. If product characteristics (quality, size, product mix, etc.) may differ, the number of technological alternatives will, in most cases, increase substantially. An important aspect here is that the production process may be regarded as a chain in which the technological choice at one stage determines the choice at other stages. A detailed disaggregation of production into number of tasks is recommended. For some tasks very little scope will exist for substituting labour for capital, whereas for others a range of efficient possibilities may exist.
- Risk and uncertainty, related to the organization and structures of markets as well as the reliability of the technological alternatives, are important issues regarding the technological choice, and seem to constitute one of the least explored areas in empirical research.

BYERLEE et al. (1983) brings evidence to the debate on employment-output conflicts using data from a detailed nationwide survey of major economic sectors in Sierra Leone. The evidence is examined both from the demand and supply side. On the demand side, an important finding is the evidence of a favourable demand outlook for products of labour intensive small-scale sectors both through increasing consumer incomes and import substitution. It is also shown that the demand for labour intensive commodities would be favoured by more equitable incomes. On the supply side, it is shown that distortions in wage rates and interest rates are largely confined to the large-scale sector, and that small-scale sectors pay higher duties on imported goods and equipment, and at the same time lack the tariff protection of competitive products, enjoyed by the large-scale sectors. A wide range of production techniques with varying capital and labour intensities were being used in many subsectors of the economy, and the more labour intensive techniques were also more efficient users of capital in all subsectors - i.e. the employment-output conflict did not exist. It was found that changes in factor prices would affect the optimal mix of technologies particularly in the agricultural sectors. It is concluded that the study provides solid empirical support for a rural mobilization strategy emphasizing smallscale sectors and labour intensive technologies to promote both output and employment, and that such strategy requires government action to correct factor-price distortions (which favour the large-scale sectors) and fundamental improvements in institutions to support the small-scale sectors.

2.3 Works related to forestry and forest industries

2.3.1 More general works

STREHLKE (1974) summarizes a number of important basic principles which should be respected regarding working and living conditions of forest workers in LIC. It is concluded that effort must be made to overcome the present problems in this field and to make life worthwhile for those many millions without whose mobilization real progress will never come.

BRUNIG (1974) gives a thorough discussion of the tangya system versus shifting cultivation. No economic analysis are made of actual cost-studies. It is concluded that no fixed answer exists on what system to chose; the decisions will vary with the local, natural and economic situation.

RUKUBA (1974) discusses in more general terms the scope and limitations of technological changes in forestry in Uganda. He concludes that the introduction of machines is only justified if, having worked out costs and benefits, the economic profitability is higher of this alterantive than using labour which may be in supply at low alternative costs. He also emphasizes that employment should be given high priority in forestry development plans, and concludes (op.cit.:268-269):

"The nature of work in forestry and forest industries is such that the use of machines and equipment to replace manual labour is necessary to optimize productivity.

Most developing countries like Uganda, have sought, accepted and applied some technological changes in forestry and forest industries and will continue to do so, provided those changes are beneficial and compatible with socio-economic conditions in those countries. Simple and inexpensive techniques and equipment will often be introduced to start with until local expertise and other facilities are build up to cope with more sophisticated ideas and machines.

There are many constraints to the introduction of technological changes in developing countries, including the lack of general education and specialists, availability of cheap labour which makes it uneconomic to introduce mechanization, and shortage of foreign exchange necessary to import new skills, machines and equipment from developed countries where these originates".

SUNDBERG (1974) attempts to identify experiences from the history of European forestry useful for LIC in their efforts to modernize and expand their forestry. He states that this is not an easy task. Conditions in LIC are heterogenous, and it is easy to resort to trivial generalities applicable anywhere, but of little practical use. Among others the following recommendations are given op.cit.:

- International collaboration regarding transfer of technology from IC to LIC should require increased support by the former. However, machine firms should market their machines in LIC only where satisfactory service is or can be made available and regard this as a moral obligation of the seller rather than the responsibility of the user, because the users in LIC are often seriously handicapped when it comes to buying spare parts. Likewise, the machine firms should resist the temptation to exploit technical assistance programmes as easy market outlets.

- Transfer of knowhow requires not only knowledgable donors, but also a fertile seedbed at the receiving end - trained staff with competance and skill to implement the techniques in the new environment, to identify the necessary modifications and to supervise and improve the techniques. Analytic methodologies for exploration of a given work situation should be used. Education and training of staff in the art of analyzing technological alternatives and in evaluating their costs and benefits should be improved, together with strengthening the administrative, managerial and entrepreneurial structure.

- The forestry system must be less inward-looking and the foresters must advocate their case in terms and languages understandable for politicians, planners, and the general public.

- Technology in one sector of an economy cannot be viewed in isolation - it must be related to the general state of technological development in the country or the area.

- Often in LIC, machines could favourably be put on two-shift operation, but the duration of each shift to some four to five hours.

- A well developed and maintained forest road network is of fundamental importance in the forests. Where unemployment persists, manual road construction should be considered.

- LIC should and must mechanize, but it should be made with great caution.

FAO (1982 a) reports from a seminar on appropriate technology in forestry in India: Some of the papers are mainly of a general character, but also some empirically oriented studies are presented. STREHLKE (1982) discusses how training for using intermediate technologies should be done. FRYKMAN (1982) presents a check list for important issues to consider regarding ergonomics and safety aspects in the choice of technology. MASLEKAR (1982) describes charcoal production using portable metal kiln in Nagpur, India. BASU (1982) sums up experiences from a study in Northern India to assess the social profile, economic status and attitudes towards logging training among forest workers in Northern India. SKARNER (1982) gives a presentation of various basic logging tools manufactured in India. MINGZHANG (1982) describes some low-cost equipment used in Southern China and corresponding costs and average performances. SOWANI (1982) reports how regional income and employment from forestry in Nagpur has been increased many times by changes of traditional management practices - here replacing mixed miscellaneous forests by teak plantations. In addition FAO (1982 a) gives an interesting review of the present degree of mechanization in the various countries of South-East Asia. However, no analyses regarding socio-economic impacts of alternative choice of technologies are presented.

FAO (1982 b) is a handbook for forest operations dealing with the manufacture and utilization of tools and equipment to improve productivity in labour intensive forestry operations. The aim of the publication is to make forest work easier, to promote self-reliance at the community level, and to decrease dependency of foreign currency. No comparison of alternative technologies is presented.

2.3.2 Logging and log road transport

CHANDRA (1978) reports from a study from North-India that work output could be doubled, and energy input halfed when using crosscut saws in timber felling.

MICSKI & STRIDSBERG (1981) reports of a comparison between using two-men raker saw and power chain saw in Pinus patula plantations at Sao Hill, Tanzania. This is one of the few studies in forestry where alternative methods are studied at the same time under similar physical and socio-economic environments. The main conclusion of the study is that using power chain saw in 15 years old plantations of Pinus patula in 1980 cost about 8.80 shs per cu.m o.b. whereas using two-men raker saw cost about 15 shs per cu.m o.b. at 1980-market prices in Tanzania. Using shadow prices of 2.0 and 0.75 for respectively foreign exchange and wages, the costs became 17.10 shs per cu.m o.b. for the power chain saw and 29.00 shs per cu.m for the raker saw.

There are two main reasons for this result: First, that the productivity per man using power saws is more than 5 times higher than using the raker saw; secondly that the investments and spare parts costs as well as their import content assumed in the study are not very different for the two methods.

There are for me some uncertainties regarding the calculation method used (for example how interest costs, working capital, days out of production because of accidents, and stocks of spare parts are accounted for). However, the cost difference between the two methods is so great, that adjustments of these factors could hardly influence the result significantly for the conditions in Tanzania in 1980.

MIGUNGA & DYKSTRA (1983) also compared crosscut saws with power chain saws in cutting Pinus patula plantations in Tanzannia, and found nearly the same costs for the two methods at prevailing market prices. They also note that crosscut saws are more widely available and familiar to the workers, and that the foreign exchange component is low compared to chain saws.

KANTOLA & VIRTANEN (1986) gives a detailed description of tree felling and conversion clearing of forest plantation, with emphasis on simple equipment. No comparative analyses of alternative technologies are presented.

SKAAR (1973) presents results from a pilot study of timber skidding from a softwood thinning using a locally made skidding cart. Partly based on this study, a locally made logging sulky was tested in Tanzania (FOSSER 1974). A study on the use of sulkies was done in Norway in 1976 (FOSSER 1976), and the most comprehensive study yet of this method was done at Sao Hill, Tanzania and reported by OLE-MEILUDIE & OMNES (1979) (cf. below and Ch. 6.2.4 for main results of this study). SKAAR (1981) gives an outline of these studies.

FERGUS et al. (1977:142-150) presents a short appraisal of some logging and log transport alternatives at Sao Hill Sawmill. The continued use of 2-man cross-cut saws and axes in the cutting operations are recommended (no cost analysis of alternatives is presented). In the terrain transport of thinnings the use of skidding sulkies (as described in Ch. 6.2.4 of this report) is recommended. In skidding of clearfellings three alternatives are appraised (Volvo TC 860 forwarder, Ford County and Ford 6600-4 agricultural tractor - cf. Ch. 7 of this report), giving the following costs at 1977 market prices:

Volvo TC 860 Forwarder	21.000	shs	per	cu.m	o.b.
Ford County	14.50	"	"	"	"
Ford 6600-4	9.50	"	"	"	"

In the log road transport three alternatives are appraised (Volvo TC forwarder with trailer, Scania LB 81 with a 1-axle piggy-back trailer, and MB-Track tractor), giving the following costs at 1977-market prices (for a one-way distance of about 25km):

Volvo TC 860	30.000	shs	per	cu.m	o.b.
Scania 81	15.00	"	"	"	"
MB-Track	18.00	"	"	"	"

It is estimated op.cit. that the MB-Track system at Sao Hill Sawmill would employ about 6 times as many workers as a system based

on Scania 81. No further appraisal of these or other logging and log transport alternatives is presented.

HEDING & OLE-MEILUDIE (1979) reports of a pilot study on ox-skidding in conifer thinnings. 26 loads were timed for ox-chain skidding and 56 loads for ox-sledge skidding in a 16 years old *Pinus patula* plantation in Tanzania. In both alternatives a pair of oxen and a two-man crew were used. In spite of the few observations the results show clearly that the skidding-sledge represents a major improvement compared to chain skidding. The maximum loadsize was increased from 0.24 m^3 o.b. to 0.45 m^3 o.b. The skidding speed was increased from 1.8 km per hour to 3.6 km per hour and the production increased from 1.3 m^3 o.b. to 2.2 m^3 o.b. per working hour at 100 m skidding distance. The productivity and skidding costs at market 1979 prices were compared to alternative methods giving the following results for 20 m, 100 m and 200 m skidding distances:

Method	Productivity, m3/h			Cost, shs/m3		
	20	100	200	20	100	200
Sulky	1.7	0.8	0.5	2.64	5.61	8.97
Ox-chain	3.3	1.3	0.7	2.52	6.40	11.90
Ox-sledge	4.7	2.2	1.3	1.91	4.27	6.90
Tractor	5.0	4.6	4.0	16.10	17.50	20.13

Only 16 % of the total cost per hour for tractor skidding was labour cost and machine cost covered 84 %. On the other hand - only 7 % of the total cost in ox-sledge-skidding was capital cost (depreciation, interest and repair of sledge) whereas 93 % was hiring rates for the pair of oxen and the labour charges. Also, approximately 84 % of the tractor costs were foreign currency whereas only 7 % of the ox-sledge costs had to be covered by foreign exchange.

It should be noted that road costs are not included in the above estimates, and that the actual costs of using oxen are not estimated, but only the costs of hired oxen are used. The study gives no other socio-economic appraisal of the various methods than mentioned above.

OTAVO-RODRIGUEZ (1986) reports of an ox-skidding study from Chile in 1983. The study provides general information about the use of oxen in forestry operations, and skidding productivity estimates. These estimates correspond fairly well to estimates given in SOLBERG & SKAAR (1986) for Malawi (cf. below); the main reasons for the differences between the two studies seem to be size of the oxen used, and different delay times and explanatory variables used in the productivity regression analysis. OTAVO-RODRIGUEZ (op.cit.) reports that the costs of skidding with agricultural tractor was about 0.86 US $ per cu.m o.b. compared to 0.14 - 0.20 US $ per cu.m o.b. for ox-skidding (depending on terrain slope and whether one considers thinnings or clearfelling), assuming 40 m average skidding distance. The study does not include road costs, and no other criteria than costs at prevailing (1983) market prices are used for comparison.

SOLBERG & SKAAR (1986) gives description and productivity estimates of oxen skidding of logs in softwood thinnings and clearfelling in Malawi. The oxen skidding was in 1983 from 3.5 to 8.6 times chaper than agricultural tractor skidding both from business and national economic point of view. The investment costs per created workplace were from 2.1 to 8.9 times higher for agricultural tractor skidding compared to oxen skidding. Also regarding other vital development criteria like independency, working conditions, flexibility and uncertainty, oxen skidding was found to be superior to using agricultural tractor. The authors recommend to introduce this skidding method in other East-African countries and to start research to improve the implements and work organisation of oxen skidding, together with improvements of animal training, feeding, caretaking and breeding. The authors also recommend that main socio-economic obstacles in implementing oxen skidding should be analyzed.

OLE-MEILUDIE & DYKSTRA (1982) analyses the technical and financial feasibility of using farm tractors to replace conventional logging machines as terrain transport equipment in clearfellings. Two types of tractors were tested: a Ford 6600 rear-wheel drive tractor and a County 1164 four-wheel drive tractor. Each tractor was studied in three terrain-transport modes: log-length skidding, tree-length skidding and grounded winching on steeper slopes. The study was limited to *Pinus patula* stands at rotation age 26-28 years on gentle to moderately steep slopes. Assuming 100 m skidding

distance the following productivity and costs (at 1980-market prices) are reported op.cit.:

Skidding machine	Productivity, m3/workplace hour	Skidding cost, shs/m3
Timberjack skidder	14.9	10.52
Clark Ranger skidder	9.6	13.68
Ford 6600 farm tractor	8.3	10.53
County 1164 farm tractor	9.3	13.43

It is concluded that farm tractors may well be a suitable choice as log-skidding equipment in most, if not all, forest projects in Tanzania. Road costs are not considered in the above estimates, and no socio-economic appraisal is given except the financial cost estimates mentioned above.

LAARMAN, VIRTANEN & JURVELIUS (1981) evaluates various types of forestry logging equipments (technical choices) in the Philippines. The following techniques are studied:

- Tree felling and crosscutting in virgin dipterocarp timber (comparing large power chain saw, small power chain saw and two-men crosscut saw).
- Terrain transport of logs (comparing crawler tractor, four-wheel skidder, farm tractor, and water buffalo).
- Debarking (comparing jungle knives - bolos - and debarking spuds).
- Log loading (comparing manual loading and mechanical wheel loader).
- Underbush clearing (comparing bolos, brush hooks, and motorized clearing saw).
- Tree planting (comparing wooden dibbles and oval-blade planting hoes).
- Thinnings in man-made tree plantations (comparing small power chain saw and bow saws).
- Pruning (comparing bolos with pruning saws).
- Small-log crosscutting (comparing bolos, axes, and bow saws).

The field work was conducted in a 7 months study during 1976 and early 1977.

The work is based on quite detailed time studies of the various operations. Two main criteria are used: Cost (at 1977 market prices in the Philippines) and employment. In addition, one chapter is devoted to a general discussion of occupational safety, training of workers, local tool manufacture and socalled indirect and none-economic factors.

The study provides a considerable amount of information. Most of the labour intensive methods are found cost compatible with the capital intensive methods under the prevailing (1977) market prices. It is emphasized that one important factor regarding labour intensive equipment is to improve the working technique and improve the quality and the maintenance of the equipment. In the general discussion experiences are given regarding attitudes and prestige factors, labour management and overhead, questions of scale, organization and coordination. For example, the following excerpts (op.cit.:83-85) illustrates, in my opinion, realistic obstacles which are often easy to forget in theoretical outlines of the question of technological choice:

> "Whether in the forestry sector or elsewhere, labour intensive methods often sum up against psychological resistance. Planners, government officials, and industrialists may reject all but the latest and most sophisticated technologies. Technological sophistication is equated with progress and development, not considering the social consequence on employment. The most modern capital-intensive methods may be selected even when careful cost studies show labour-intensive methods to be more economically rational. Mechanization is glorified for its prestige value and because "engineering man" tends to prevail over "economic man".
>
> Entrepreneurs and workers face genuine psychological hurdles when taking a step downward on the technological ladder. For instance, the project encountered some difficulties in arranging for manual falling and crosscutting in large timber. Since the two-man crosscut saw was generally discarded some years ago, workers who have already used chain saws ridiculed the manual method as "primitive". The workers cooperated in the work study, but treated it as a joke and were taunted by their companions.
>
> Likewise, the operator of the chain saw in the thinning study looked down contemptuously upon the bow saws. The bolo crew in the clearing study inquired if they could not use chain saws, instead.

> Thus a machine mentality is already pervasive among those of the timber concessionaires. It may be difficult if not impossible to arrest the one-way change in mental attitude. This implies that the labour-intensive methods discussed in this report cannot be thrust upon workers presently well acquainted with more capital-intensive techniques. Rather, the labour-intensive methods will be acceptable only to workers at a lower level of experience, such as new work-force entrants, casuals, part-time farmers, and so forth.
>
> But in the same way that an experienced faller venerates the chain saw, a worker, who has nothing more than an old and decrepit axe admires the bow saw. Because the existing hand tool technologies are so impoverished, the workers on the very bottom of the technological spectrum look up to the new hand tools and accessoires. A sturdy hand tool of good design and with bright red or orange paint can be as attractive and stimulating as a new chain saw to these men. A worker's mental disposition towards the improved labour-intensive methods is therefore a matter of whether he is presently "above" or "below" that level of sophistication.
>
> The acceptability or rejection of labour-intensive methods is determined not only by the workers, but even more by the employers. The decision-maker may explicitly or implicitly attempts to reduce the "headache" of workers' absences, sickness, and turnover by minimizing his labour requirements. The amount of overhead connected with work-related accidents, subsidization of housing, workers recruitment, workers transportation, possible legal embattlements in the case of workers' death or serious injury, etc., is proportional to the size of the labour force. Unlike machines, workers have personality conflicts, require hospitalization, get drunk, and develop feelings and motivations that affect their dispositions towards work. Individuality and free volition reflects a fault no more serious than being born human, but these same qualities are the bane of prodution control".

Regarding management and organization it is stated (op.cit.:87):

> "In fact, the presence or absence of competent management and organization perhaps more than anything else will determine the practicality of the labour-intensive methods. Some of the talents required are the ability to think in terms of unit costs rather than gross production rates, and to conceptualize and implement "mixed methods" and "parallel systems". Examples of mixed methods and parallel systems include (1) carabao skidding and manual carrying to transport small logs from the stump site to a bunching point, from where machine skidders take them the longer distance to the road; (2) labour-intensive methods to fall and cross-cut small trees combined with power chain saws for large trees; (3) manual loading of small logs in parallel with mechanical loading of large logs; and (4) mechanical tree planting on easy terrain integrated with manual tree planting on difficult terrain".

The only draw-backs I can find with this study are the following:

(a) Cost efficiency from a national economic point of view using shadow prices are not done; (b) it is not clear to what degree working capital is included, and the interest rate used is not specified; (c) the alternatives should have been evaluated more explicitly regarding other important, but difficult quantifiable variables, like for example those mentioned in Ch. 4.3.2 of the present study; (d) road costs (and hence estimates of optimal road spacing) are not included in the analysis of transport technological alternatives.

It is worth noting that ILO now is following up this study in actual implementations in Phillipine forestry projects.

Among the policies and strategies for implementation given op.cit. some of the most important ones are:

- Working groups (in Phillipines) should be set up to promote training and introduction of tools and working methods, to investigate incentives for employment, and to monitor development.
- More case-studies of technological alternatives should be done.
- Vocational training at the level of foremen and workers should be emphasized.
- Forestry hand tools production should be promoted by the Government.
- Employment rotation might be used to employ a larger number of workers on a part-time basis rather than fewer on full-time work in cases where workers need to work on their own land to produce agricultural crops for food as well as being employed for cash wage.
- Guidelines on mechanization should be worked out distinguishing between labour-displacing mechanization and labour-augmenting mechanization.
- A wider and more in-depth review of existing laws and regulations should be undertaken to avoid unwanted bias against the use of labour intensive methods. As examples are mentioned: (a) The present requirements for potential concessionairy to have more than minimum quantities of capital available before being allowed to bid for forestry concessions, discriminating against the kind of small-scale entrepreneur who ordinarily does not have large amounts at his disposal; (b) increased

possibilities for subcontracting (e.g. in log loading and terrain transport, thinning of plantations), which would enable the use of more labour intensive methods by small contractors.

2.3.3 Pitsawing and forest industries

Probably the first published estimates in Tanzania of productivity, costs and benefits of pitsawing are presented in FERGUS et al. (1977:Appendix 5). The study is based on a very limited sample from sawing *Pinus patula* logs in plantations at Sao Hill and Mbeya, Tanzania, but the results are reported op.cit. to be judged as realistic by pitsawyers and other professionals being familiar to pitsawing in Tanzania. Based on actual measurements, the following sawnwood recovery percentages are reported as realistic:

Low	Average	High estimate
35 %	40 %	55 %

Based on the performed time studies the following productivities per 2-man crew are reported, assuming 8 working hours per day, 250 working days per year and 40 % sawnwood recovery percentage:

Low	Average	High	
0.13	0.18	0.28	cu.m(s) per day
30	45	65	cu.m(s) per year

Regarding sawing quality it was considerable differences between the three groups of sawyers observed (op.cit.:200). The worst group had a maximumm/minimum variation of 3-4 mm on width and 2-3 mm on thickness (i.e. maximum thickness/width subtracted minimum thickness/width of the same sawnwood piece). This group was fairly new in the business. The best group worked with an accuracy of 1.5 mm as maximum/minimum variation. The center-line deviation was reported to be quite small.

No direct appraisal between pitsawing and alternative methods are presented. However, (op.cit.:106) the investment costs per generated workplace are compared - giving 200 shs per workplace for the pitsawing studied and 86,000 shs per workplace for the Sao Hill Sawmill (the mill described as alternative A in Ch. 8 of the present report). The total production costs (not including the logging costs, which were estimated to about 122 shs per cu.m(s)) at the Sao Hill Sawmill, were estimated to 596 shs per cu.m(s), of which about 161 shs per cu.m(s) is import and 107 shs per cu.m(s) is wages and salaries (op.cit.:114). The total pitsawing costs (including logging) amounted to 436 shs per cu.m(s), of which 310 shs is salaries and 2 shs is import, the rest being stumpage paid to the Forest Department (op.cit.:203).

The earning of the pitsawyers amounted to approximately 28 shs per 8 hours working day. For comparison, the corresponding earnings for a saw operator at Sao Hill Sawmill in 1977 was about 22 shs and for casual labour about 14 shs.

One should be careful when comparing these two types of making sawnwood (the physical strain is considerably harder to pitsawing, the sawnwood quality differs, the terrain transport factors are difficult to compare, ecological effects are different, etc.). However, it is in my opinion worth reflecting on the high economic and financial efficiency of the traditional method of pitsawing, covering well the local demand regarding quality and price, compared to the modern technological choice represented by the Sao Hill Sawmill.

KIJOTI & WHITE (1981) reports of a study of pitsawing of *Grevillea robusta* in the Pare Mountains of Tanzania. The main results of the study were:

- the pitsawyers studied showed little inclination towards steady, regular work
- better maintenance of tools would have improved both volume of output and accuracy of sawing
- average productivity was measured to 0.09 cu.m(s) per 2-man working crew per 8-hour working day (*Grevillea robusta* is a hardwood and takes longer time for sawing than softwood like *Pinus patula* referred to above)
- the average cost of pitsawing was 897 shs per cu.m(s), and each pitsawyer earned approximately 40 shs per 8-hour working day compared to the minimum salary of unskilled labour of approximately 14 shs per day
- accuracy of plank dimensions was reasonable, and higher in thickness than in width

- average sawnwood recovery was measured to 42 %
- in mountain rain forest hand sawing is ecologically less destructive than mechanical methods.

SOLBERG & WAMAGUNDA (1975) presents a study of Kenya's sawmilling sector, covering a sample of about 58 sawmills and 75 % of the country s total sawnwood production in 1972/73. They divide the sample in 6 size groups according to annual one-shift production capacity:

Size group 1:	Mills producing	less than	500	cu.m(s)	per year
" " 2:	" "	" "	500-1,000	"	" "
" " 3:	" "	" "	1,000-1,500	"	" "
" " 4:	" "	" "	1,500-2,500	"	" "
" " 5:	" "	" "	2,500-4,000	"	" "
" " 6:	" "	more "	4,000	"	" "

Regarding capital intensity they conclude (op.cit.:46-47):

(a) The smaller sawmills (i.e. the mills in size group 1, 2 and 3) compared to the mills in size group 5 and 6 seem to have the following advantages:

- Considerable lower fixed capital per employee, the mills in size group 1 and 2 having as an average a 35 % lower figure here than the mills in size group 5 and 6.
- Higher gross value added per 10,000 shs of fixed capital assets, the mills in size group 1, 2 and 3 having as an average a 21 % higher value added than the mills in size group 5 and 6.
- Slightly higher profit in % of fixed capital assets. The mills in size group 1 are significantly above the other mills, and the mills in size group 6 are clearly below the average, whereas the mills in the other size groups are more or less equal in this respect.
- Easier management, because of fewer employees and less sophisticated equipment. It is interesting to observe the data regarding time out of production: The smaller mills have clearly longer time out of production (the mills in size group 1 and 2 are as an average approximately 100 % longer time out of production than the mills in size group 5 and 6). The smaller mills, because of their cheaper machinery, can much easier afford machinery breakdown. Another interesting point is the low time out of production (0.9 days per month) for the mills in size group 4. This could indicate that the mills in this size group represents an optimum regarding machinery utilization.

(b) The bigger mills (i.e. the mills in size group 5 and 6), compared to the smaller mills in the study, seem to have the following advantages:

- Higher labour productivity measured as gross value added per employee, the mills in size group 1, 2 and 3 having as an average 22 % lower labour productivity than the mills in size group 5 and 6.

- Higher sawing quality - in particular for mills in size group 6.

- Most likely higher sawntimber recovery percentage. However, this is not always true because some of the smaller mills cover a market which made possible utilization of shorts and offcuts and which most of the bigger mills could utilize only as fuelwood.

(c) If employment and social profitability are given first priority, then smaller mills (i.e. the mills producing in 1 shift 500-1,000 cu.m(s) per year) should be established. If labour productivity, accurate sawing (i.e. high quality timber) and high sawntimber recovery percentage are given first priority, then larger mills (i.e. mills producing in one shift more than 2,500 cu.m(s) per year) should be put up. Sawmills aimed primarily at exporting should therefore, not be less than producing approximately 2,500 cu.m(s) per year. On the other hand could sawmills producing mainly for their local demand, favourably be in the size of 500-1,500 cu.m(s) as annual capacity.

FREEMAN & SOLBERG (1978) presents a multivariate statistical analysis of the data in SOLBERG & WAMAGUNDA (1975). The same picture emerges. Regarding economies of scale it is noteworthy that the largest mills have lower productivity measured as net value added per employee, than the other mills. This is explained by referring to relatively more reprocessing and reselling of timber by the smaller mills, as well as factors like management effectiveness and higher capital intensity in the larger mills.

Regarding sawmilling and integrated processes FERGUS et al. (1977) gives no detailed analysis of technological alternatives, but the following aspects mentioned op.cit.:66-67 are in my opinion, of interest:

- Manual sorting and loading on trolleys, using rails for transport, combined with manual stacking, could be financially more efficient in Tanzania than using load-trucks, and at the same time giving 60 % higher employment.

- An alternative to the present Sao Hill Sawmill could be 10 smaller sawmills based on the double circular sawbench with 2 sawblades on one axle and one bench for each sawblade. These mills should be located in the forest along the roads. The sawnwood must be transported to a central plant with the necessary equipment for anti-blue stain treatment, seasoning, trimming, sorting and sale. These mills should each have a production capacity of about 3,000 m^3 o.b. of logs per year. The investment is estimated to about 3.0 mill. shs. In addition comes equipment for logging and road transport of logs and sawnwood. The total production costs of this method are estimated to about 500 shs per cu.m(s), which is considerably lower than the present sawmill s production costs in 1977 (about 716 shs per cu.m(s) - cf. op.cit.:114). The employment of this alternative is estimated to about the double of that of the present sawmill. No detailed analysis of the alternative is done.

LAARMAN (1982) examines how inputs of sawmill labour and fixed capital vary by sawmill scale in the Phillipines. The policy context is using sawmill scale as an instrument of employment generation. Higher labour-output ratios are found for small than for large sawmills. However, in the large sawmills the labour-output ratio increased considerably when accounting for the labour content of kiln-drying and integrated sawnwood remanufacturing. Because the sum of wage costs plus capital rentals is greatly overshadowed by expenditures for roundwood, the trade-off between labour absorption and allocation efficiency is highly sensitive to only small variations in roundwood costs and roundwood conversion rates.

ROOS (1983) compares three methods of generating electricity for power supply of two sawmills in Tanzania producing annually respectively 20,000 m^3 of pine (Pinus patula) sawnwood and about 4,500 m^3 of Mninga (Ptereocarpus angolensis) sawnwood, the mills needing respectively a power supply of 600 kW and 150 kW. The three electricity producing methods are: Using diesel generators, steam engine, and steam turbine. For the smallest mill the following costs are presented (in 1982-prices, assuming 10 years write-off time for the steam based machinery and 5 years for the diesel generators, 10 % p.a. real term rate of interest):

	Diesel	Steam engine	Steam turbine
Investment costs (SEK)	220,000	900,000	1,800,000
Maintenance (SEK/year)	5,000	9,000	18,000
Fuel (SEK 3.255/l) (SEK/year)	763,000		
Total costs (SEK/kwh)	0.84	0.16	0.31

It is stated that the costs per kwh would be the same for the bigger sawmill, needing 600 kW, because the investment costs are directly proportional to the power quantity. However, the investment amount for a steam engine would then be 3.6 mill. SEK. It is not stated whether labour and building costs are included in the calculation, and no economic evaluation is done. No alternative use for the sawmill residues is assumed. In practice this cost is negative because of disposal costs. The probably most critical operation factor is stated to be the water availability. It is stressed that as well the water quantity as the quality should be carefully studied at an early stage of investment planning.

SKARSTEIN & WANGWE (1986:149-168) examines the viability of the Southern Paper Mill (SPM) in Tanzania having a production capacity of 60,000 tonnes per year. The financial return of the SPM is found to be very low, and it is concluded (op.cit.:264):

"(1) The problem of economies of scale combined with a high share of foreign currency in capital as well as manufacturing costs necessitates that the project will be sucessful on the export market. However, as we attempt to show, only the excessive investment cost per tonne of installed capacity (estimated at 4,867 US $ per tonne in 1982) make exports impossible at competitive prices without substantial government subsidies. The project will therefore, most probably, represent a heavy financial burden on the Tanzanian Government in any case.

(2) The size and the complexity of the project exceed Tanzanian managerial and technical capabilities at the present stage of development. This in turn has necessitated substantial foreign technical and managerial assistance which has increased the costs of the project.

(3) Large-scale projects require a more developed infrastructure than smaller ones. The high infrastructural costs associated with the establishment of the SPM represent an additional financial burden for Tanzaia.

(4) And finally, the size of the project has necessitated a combination of funds from various financiers. This has in turn caused delays in the implementation of the project and problems and conflicts within the project organization".

GRAN (1984) analyses the Sao Hill Sawmill project in a political science context, trying to answer the question: What decision processes produced the actual choice of project and its internal structure? The findings focus on the conflict and competition between decision making models (of which the dominant one is called

the profit model), the production and reproduction of the competing models, and the consequences of them in the form of industrial organization. An attempt is made to show that decision models are systematically related to institution. In the case of Sao Hill Sawmill it is argued op.cit. that institutions in private and public setors in Norway systematically supported different decision-making models, and that the data suggest that this simple typology of institutions is significant for understanding the discrepancies between models for planning and organizing wood industry in Tanzania. Further, it is suggested op.cit. that dominant decision models reflect dominant class interests, and that the change of models basically depends on change of dominant class and political regime.

NOTES CHAPTER 2

[1]Cf. Ch. 3.2.1.

[2]JOHANSEN (1963, 1967) are based on previous works by a.o. GALENSON & LEIBENSTEIN (1955), DOBB (1960) and SEN (1957) regarding the debate whether capital intensity may be justified even in a labour-abundant economy because of the consequences for savings and the subsequent growth. These studies are not made particularly for analyzing problems regarding choice of technology in LIC, but for analyzing optimal savings/investment strategies more in general.

This is also the case for two other studies of considerable interest for understanding effects of the technological choice on project level - i.e. SALTER (1966) and JOHANSEN (1972). SALTER (op.cit.) gives a basic analysis of the relationships between movements of productivity, prices, costs and investment in industries experiencing a continous flow of new techniques. The basic idea is that techniques of production (and then productivity) change through time for two main reasons: improving technical knowledge and changing factor prices. The new best-practice technique (i.e. the technique which employs the most recent technical advances and is economically appropriate to current factor prices at a given date) has the following effects: First, the output of the industry is expanded until price falls to equality with the total costs of plants employing the new technique. Secondly, some of the older existing plants are scrapped or replaced until the operating costs of the oldest plant (or plants) equal the new level of price and the total costs of the new best practice technique (including a profit margin). A flow of new best-practice techniques leads to a series of such equilibria (which combine both short- and long-run elements) and so traces out the path over time of output, costs, prices, and productivity.

One may say that SALTER op.cit. concentrates on explaining the main economic causes and consequences of technological change. As such he goes beyond the scope of the present study, which primarily aims at discussing how to arrive at the best choice of technology in a project context in LIC - i.e. the new best-practice technique. However, the work of Salter is, in my opinion, valuable as a frame for the more limited problem discussed in this study.

JOHANSEN (1972) analyzes the concept of production functions, aiming at getting more realistic integration between micro- and macro-economic prodution functions. His concept of "ex ante" and "ex post" substitution possibilities (cf. Ch. 3.2) are closely related to the "new best-practice technique" and "average practice technique" used by SALTER (op.cit.).

PART II SOME THEORETICAL CONSIDERATIONS

3 TECHNOLOGY

This chapter aims at (i) defining the concept of technology, and (ii) describing some important aspects between the technological choice on project level and macroeconomic development planning.

3.1 Definition of technology

Technology is a concept which is defined in different ways by different users. The purpose of this chapter is to present some definitions given by authors working with analysis of questions of technology, and to present my own definition of the concept, as I shall use it in Ch. 4 and onwards.

ANON (1966) defines technology in the following way: "Technology is systematic knowledge and action, usually of industrial processes but applicable to any recurrent activity. Technology is closely related to science and to engineering. Science deals with man s understanding of the real world about him - the inherent properties of space, matter, energy and their interactions. Engineering is the application of objective knowledge to the creation of plans, design, and means for achieving desired objectives. Technology deals with the tools and techniques for carrying out the plans".

According to JANTSCH (1967:15), technology "means utilization of applied sciences, of natural, humanistic and social sciences".

DICKSON (1974:16-17) defines technology like this: "It is an abstract concept embracing both the tools and machines used by society and the relations between them implied by their use. Tools and machines mean objects selected or fabricated by man as a mean of changing the state of his material environment".

MERRILL (1968) defines technology as "the skills, knowledge and procedures for making, using and doing useful things".

STEWART (1978:1) applies approximately the same definition: "Technology is often identified with the hardware of production - knowledge about machines and processes. Here a much broader definition is adopted, extending to all the "skills, knowledge and procedures for making, using and doing useful things". Technology thus includes methods used in non-marketed activities as well as marketed ones. It includes the nature and specification of what is produced - the product design - as well as how it is produced. It encompasses managerial and marketing techniques as well as techniques directly involved in production. Technology extends to services - administration, education, banking and the law, for example - as well as to manufacturing and agriculture. A complete description of the technology in use in a country would include the organisation of productive units in terms of scale and ownership. Although much of the discussion will be in terms of technological development in the hardware of technology, the wider definition is of importance since there are relationships between the hardware and the software - between, for example, mechanical process and managerial techniques and infrastructural services - which help determine the choice made in both spheres".

MÜLLER (1980:20-26) defines technology as "comprising the four components (a) technique (the hardware of the production - machines, tools, etc.), (b) knowledge (accumulated experience, skill), (c) organization (management relations), (d) product (the result of the three other parts)".

KAMANN (1982:1) defines technology "in the anthropological sense, as the way people, or a group of inhabitants of a particular area, produce their goods and services in order to survive".

FREEMAN(1974:5) defines technology as "any set of standardized repeatable operations that regularly yield predetermined results".

STINCHCOMBE (1983:83) defines technology in the following way: "Virtually any set of activities carried on by social groups has an aspect of knowledge, skill and material means which determines (or is thought to determine) how much results of what kind are obtained from the activity. We call this aspect of a system of activities its technology. That is, the technology of a set of activities consists of those aspects of the pattern of activities that influence, or are thought to influence, the effectiveness or efficiency of the activities for achieving the ends for which they are carried out".

In this study, I shall, if nothing else is stated, by technology mean the knowledge, skills and procedures for providing goods and services. As such, I include both the hardware (machines, tools, etc.) and the corresponding software (management, infrastructural services, experiences, etc.) in the concept of technology. In contrast to some authors, e.g. ISHIKWA (1972) and STEWART (1978), I do not in this study differentiate between the concepts of "tehnology" and "technique". This I have done because it is hard to arrive at practical definitions distinguishing between these concepts.

3.2 Macroeconomic planning and choice of technology on project level - some aspects

3.2.1 Central concepts

3.2.1.1 Substitution between labour and capital

The concept of substitution between labour and capital is important for the effects of technological change in macroeconomic growth models. Based on JOHANSEN (1959) one may distinguish between four main groups of models:

a) Models having a fixed capital coefficient (i.e. a fixed proportion of the production input is capital), but no explicit treatment of the labour inputs. HARROD (1953) and DOMAR (1957) are examples here.

b) Models having fixed production coefficients both for capital stock and labour input. The input/output model of LEONTIEF (1953) is an example here.

c) Models having full substitutability between labour input and capital stock both ex ante (i.e. before the investment is done) and ex post (i.e. after the investment is done). HAAVELMO (1954, 1961), SOLOW (1956) and MEAD (1961) are examples of this. Here, perfect markets are assumed so that profit maximization producers substitute labour for capital according to given prices on these factors - i.e. it is assumed that producers are willing to and able of utilizing all of the existing capital and labour. This type of economic models I will refer to as neoclassical models. The adaption could be described as follows:

Assume that we have a profit maximization firm that takes prices as given both in its output and its factor markets. Let p be the price of the output of the firm, w the vector of factor prices, x the vector of production factors used, and f(x) the production function describing the output of the firm. Maximizing the firm's profit function

$$\pi = p \cdot f(x) - wx$$

gives the well known first order optimal condition:

$$\frac{\frac{\partial f(x)}{\partial x_i}}{\frac{\partial f(x)}{\partial x_j}} = \frac{w_i}{w_j} \qquad (3.1)$$

This expression tells that the technical rate of substitution (i.e. at what rate factor i can be substituted by factor j while maintaining a constant level of output) should equal the economic rate of substitution (i.e. the rate factor i can be substituted by factor j while maintaining constant costs).

This is illustrated in Figure 3.1 for the two-factor case labour (x_1) and capital (x_2). The curved line AB gives the production function $f(x_1, x_2)$ for a given output Y. The line cb is the production isocost (constant cost) line given by:

$$C = w_1 x_1 + w_2 x_2$$

or

$$x_2 = \frac{C}{w_2} - \frac{w_1}{w_2} x_1$$

where

C is a constant

w_1 and w_2 are factor prices of respectively labour and capital.

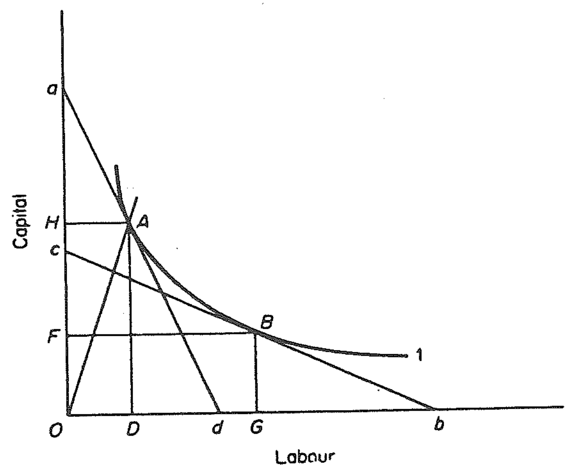


Figure 3.1. Illustration of the two-factor neoclassical approach to choice of technology.

If the labour costs (w_1) are high relative to the capital costs (w_2) as is the case in industrialized countries, the lowest isocost curve touching the isoquant AB would be the line ad giving the optimal point A. If the labour costs are low relative to the capital costs so that all isocost curves are parallel to the line cb ($\frac{w_1}{w_2} = \frac{Oc}{Ob}$), the optimal point will be B. This point gives a technology which implies the use of DG more labour and HF less capital than situation A.

d) Models which assume full substitutability between labour and capital ex ante and fixed proportions between them ex post. This type of production function was first proposed by JOHANSEN (1959). His proposal was based on the hypothesis that any increments in production can be obtained ex ante by different combinations of increments in labour and capital inputs, whereas any piece of capital which is already installed will (ex post) continue to be operated by a constant amount of labour throughout its life span. Thus one get a socalled "putty" situation ex ante and a "clay" situation ex post. This approach is discussed in depth in JOHANSEN (1972). A main point here regarding our discussion of the technological choice is that one gets fewer substitution possibilities with a "putty-clay" production function approach than with the neo-classical assumption of full substitutability[1].

3.2.1.2 Technological progress in economic theory - a brief overview

In the following the concepts of embodied and disembodied technological change, capital saving, labour saving and neutral technical changes are described. These concepts are important in macroeconomic analysis incorporating technology, and for understanding vital connections between micro- and macroeconomics regarding the choice of technology.

According to JOHANSEN (1972:145) embodied technological progress can be defined as favourable shifts in the ex ante production function which leave the efficiency of already established production units unaffected. This type of progress can only take place through the interaction of new tehnology.

Disembodied technological progress are changes which affects the models of operation of existing production units in such a way as to improve their performances (op.cit.:152). This type of technological progress takes place even in the lack of investments, and is the result of improved education, operational skill, social and technical infrastructure, etc.[2]

The classification of technological progress as to whether it is capital-saving, labour-saving or neutral owes its origins primarily to HICKS (1932) and HARROD (1948). Their criterion of classification differs, however. Harrod's classification of technical progress uses the concept of the capital-output ratio. Given the rate of profit, technical change is said to be capital-saving if it lowers the capital-output ratio, labour-saving if it raises the capital-output ratio, and neutral if it leaves the capital-output ratio unchanged.

Hick's classification of technical progress uses the concept of the marginal rate of substitution between factors, which is the rate at which one factor must be substituted for another leaving output unchanged. The marginal rate of substitution is given by the ratio of the marginal products of factors (cf. Eq. 3.1). Holding constant the ratio of labour to capital, technical progress is said to be capital-saving if it raises the marginal product of labour in greater proportion than the marginal product of capital; labour-saving if it raises the marginal product of capital in greater proportion than the marginal product of labour; and neutral if it leaves unchanged the ratio of marginal products. These definitions are illustrated in Figures 3.2, 3.3 and 3.4 respectively.

Technological progress on a production-function map is represented by shifts in the function towards the origin showing that the same output can be produced with fewer inputs, or that the same volume of inputs can produce a greater output. According to the shape of the new production function, either fewer of one or both factors will be required to produce the same output. In the case of neutral technological progress some of both factors can be dispensed with. In the case of non-neutral technologicl progress, if only one factor is saved the progress is said to be <u>absolutely</u> labour- or capital-saving. If fewer of both factors are required, the technological progress is said to be <u>relatively</u> labour- or capital-saving.

Consider first neutral technological progress (Figure 3.4). The ray from the origin, or expansion path, OZ, goes through the minimum-cost point of tangency between the production function YY and the factor-price ratio line KL. With neutral technological progress the production function shifts such that the new point of tangency at the same factor-price ratio lies on the same expansion path.This means that the ratio of marginal products is the same at the same capital to labour ratio, and equal proportionate amounts of the two factors are saved. The condition for neutral technological progress is simply that the new production function is parallel to the old.

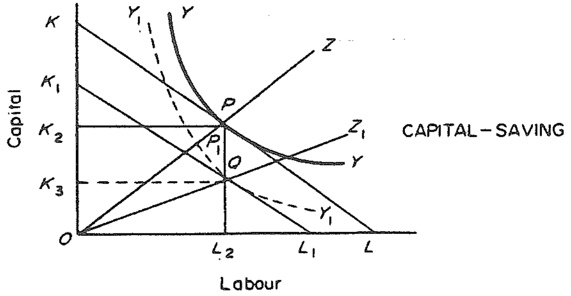


Figure 3.2. Capital-saving technological progress.

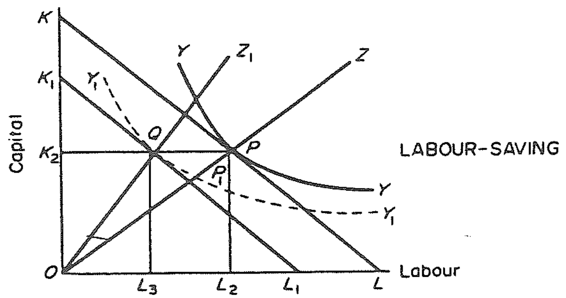


Figure 3.3. Labour-saving technological progress.

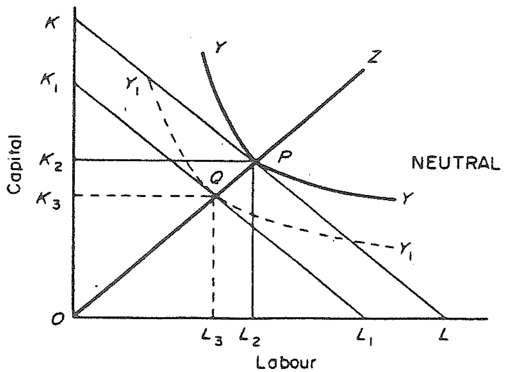


Figure 3.4. Neutral technological progress.

With labour-saving technological change (Figure 3.3) the ratio of the marginal product of capital to the marginal product of labour rises such as to shift the minimum-cost point of tangency from the old expansion path OZ to a new expansion path OZ_1. At P_1, where the new production function cuts the old expansion path, the ratio of the marginal product of labour to capital is lower that at P. P_1 is not an equilibrium point and it will pay producers to move to point Q, substituting capital for labour. The ratio of marginal products has not remained unchanged at a constant labour to capital ratio, and L_2L_3 labour is saved.

Capital-saving technological progress (Figure 3.2) may be similarily described. In this case the ratio of the marginal product of labour to the marginal product of capital increases and the shift in the production function is such that the minimum-cost point of tangency now lies to the right of the old expansion path. At P_1, where the new production function cuts the old expansion path, the ratio of the marginal product of labour to capital is higher than at P. Again, P_1 is not an equilibrium point and it will pay producers to move to point Q, substituting labour for capital. The ratio of marginal products has not remained unchanged at a constant labour to capital ratio, and in this case K_2K_3 capital is saved.

JOHANSEN (1972:152)considers the disembodied technological progress as composing of two components: (a) Capacity-increasing progress, which increases the capacity of a production unit while having the input coefficients unaffected; (b) input-saving progress, which reduces the input coefficients of a production unit without affecting its capacity.[3]

The combined production output effects of the various forms of technological progress and increase in current inputs (for the inputs i = 1,2), is summarized by Johansen (op.cit.:171) like in Eq. 3.2:

$$
\begin{aligned}
\dot{X} = {} & q_1 \dot{V}_1 + q_2 \dot{V}_2 && \text{(increase in current inputs)} \\
& + \frac{1 - q_1 m_1^+ - q_2 m_2^+}{m_3^+} I && \text{(new capital, including effects of embodied technological progress)} \\
& + \int\int_{G(q_1,q_2)} (1 - q_1\xi_1 - q_2\xi_2)\kappa(\xi_1,\xi_2) f(\xi_1,\xi_2)\, d\xi_1\, d\xi_2 && \text{(capacity-increasing disembodied technological progress)} \\
& \left.\begin{aligned} & + q_1 \int\int_{G(q_1,q_2)} \mu_1(\xi_1,\xi_2)\xi_1 f(\xi_1,\xi_2)\, d\xi_1\, d\xi_2 \\ & + q_2 \int\int_{G(q_1,q_2)} \mu_2(\xi_1,\xi_2)\xi_2 f(\xi_1,\xi_2)\, d\xi_1\, d\xi_2 \end{aligned}\right\} && \text{(input-saving disembodied technological progress)}
\end{aligned}
\tag{3.2}
$$

where:

X	is total output
t	is time
$\dot{X} = \frac{dX}{dt}$	is growth of total output X at time $t=0$
V_i	is available input of type i $(i=1,2)$
$\dot{V}_i = \frac{dV_i}{dt}$	is increased use of inputs at time $t=0$ $(i=1,2)$
q_i	is the (shadow) price of input of type i $(i=1,2)$
m_i^+	is the average input of type i per unit of output $(i=1,2)$
m_3^+	is the average capital coefficient of new capacity
I	is the increase of new capacity at time $t=0$
ξ_i	is input of type i per unit of output $(i=1,2)$
$\kappa(\xi_1,\xi_2)$	is the proportionate increase in existing production capacity units with input coefficients ξ_1 and ξ_2
$f(\xi_1,\xi_2)$	is the capacity distribution in the $\xi_1 \xi_2$ plane
$G(q_1,q_2)$	is the region of positive capacity
$\mu_i(\xi_1,\xi_2)$	is the savings of input $\underline{i}$ per unit used of input $\underline{i}$ due to input-saving disembodied technological progress $(i=1,2)$

3.2.2 Macroeconomic effects of the technological choice on micro level - an illustration based on a simple neo-classical growth model

The main purpose of this section is to illustrate the importance of the technological choice in LIC for the growth in annual supply of goods and services by using a simple neoclassical growth model, and to illustrate the strength and weakness of this kind of models in discussions of development in such countries.

3.2.2.1 The model

The model is taken from HAAVELMO (1961), and emphasizes one fundamental problem for the poor countries, namely whether the annual supply of goods and services per capita will rise or fall.

The following assumptions are made:

* The productivity power of the country we have in mind can be described by a macro production function

$$X = \phi(N, K, t) \tag{3.3}$$

where:

X is the net national product of the country at time t

ϕ is a function with continous first derivatives, and full substitutionability between labour and capital

N is a measure of available labour and of the number of consumer units at time t

K is a measure of the total physical amount of capital at time t

t is historic time

K and N are functions of t

* A fixed proportion of ϕ is saved every year and all savings are invested in fixed capital - i.e.

$$\dot{K} = \sigma\phi(N, K, t) \tag{3.4}$$

where $\dot{K} = \frac{dK}{dt}$ and

σ is the current saving ratio

* The current capital-output ratio is defined by:

$$c = \frac{K}{\phi(N, K, t)} \qquad (3.5)$$

* N and $\frac{dN}{dt} = \dot{N}$ are exogenously given

* All other factors influencing X are assumed constant.

From Eq. (3.3) we have that the annual growth of the net product per capita ($\dot{x}$) is

$$\dot{x} = \frac{d(\frac{X}{N})}{dt} = [\frac{\partial\phi}{\partial N} - \frac{1}{N}]\frac{\dot{N}}{N} + \frac{\partial\phi}{\partial K} \cdot \frac{\dot{K}}{N} + \frac{\partial\phi}{\partial t} \qquad (3.6)$$

The partial elasticities of production ε_N and ε_K and the partial annual rate of change due to gradual technological improvements are defined by:

$$\varepsilon_N = \frac{\frac{\partial\phi}{\phi}}{\frac{\partial N}{N}} \qquad (3.7)$$

$$\varepsilon_K = \frac{\frac{\partial\phi}{\phi}}{\frac{\partial K}{K}} \qquad (3.8)$$

$$\mu(N, K, t) = \frac{\frac{\partial\phi}{\partial t}}{\phi} \qquad (3.9)$$

(σ, c, ε_N, ε_K and μ are all functions of time).

Dividing by ϕ, Eqs. (3.6) - (3.9) give the relative growth of $\dot{x}$:

$$\frac{\dot{x}}{x} = (\varepsilon_N - 1)\frac{\dot{N}}{N} + \varepsilon_K \cdot \frac{\sigma}{c} + \mu \qquad (3.10)$$

3.2.2.2 Applications

Let us make the reasonable assumption that both ε_K and ε_N are positive and that $\varepsilon_K + \varepsilon_N \leq 1$ - i.e. increasing returns to scale are disregarded[4].

If we consider $\varepsilon_K, \varepsilon_N$, σ and c as exogenously given it is seen from Eq. (3.10) that the annual increase of the supply of goods and services per capita ($\frac{\dot{x}}{x}$) is directly influenced by μ. For example if μ is 2 % p.a. (i.e. $\mu = 0.02$) then $\frac{\dot{x}}{x}$ will increase with 2 % p.a. more than without any technological progress. The technological progress defined by μ is here the combined effects of disembodied and embodied technological progress.

It is noteworthy that this effect is independent of the growth rate of population. One consequence is illustrated by the following example, comparing effects of changes in c and changes in μ.
Let us assume:

* $\varepsilon_K = \varepsilon_N = 0.5$

* $\frac{\dot{N}}{N} = 3.4$ % p.a. (the present case of Tanzania - according to WORLD BANK 1984:258)

* $\sigma = 0$ (i.e. K is constant)

It is then seen from Eq. (3.10) that the rate of technological progress, μ, has to be only 1.7 % p.a. (half of $\frac{\dot{N}}{N}$) to keep output per capita stationary. If μ is zero, the annual supply of goods and services will decline by 1.7 %.

The importance of μ is perhaps even more striking if we compare effects of changes in μ with effets of changes in σ. Assuming c = 6 (and ε_K, ε_N, and $\frac{\dot{N}}{N}$ as stated above) it is seen from Eq. (3.10) that a change in μ from 0 to 1.5 % p.a. has the same effects upon $\frac{\dot{x}}{x}$ as a change in σ from 0.05 to 0.29 or from 0.10 to 0.34. The point is that under the assumed conditions, a very high rate of capital accumulation (and savings) could be replaced by a relatively modest 1.5 % p.a. increase in production due to technological progress.

In the above examples we have assumed that the future technological progress is a certain per cent per year as a combination of embodied and disembodied technological progress. In the context of appropriate technology, the above estimate assumes implicitly that such a technology would be introduced gradually by replacement of old capital, investment in new capital, and improvement of existing capital as shown in Eq. (3.2).

A way of illustrating the macroeconomic importance of embodied technological progress on micro level, is to use Eq. (3.10) for data from alternative sets of technologies in an actual project, assuming, in addition to the points mentioned in Ch. 3.2.2.1, that:

* The technology on macro-level can be immediately changed similarly to the technological alternatives in this project[5] (alternatively one may assume that previously over time one has followed different technological development paths resulting in macro-economic situations at time t reflecting the technological alternatives mentioned below).

* The technological alternatives are defined as described in Ch. 8 regarding use of the production factors labour, capital and other resources (alternatives A, B and C in Ch. 8 are defined as respectively alternatives 1, 2 and 3).

* The net product of alternative i is defined as:

  $L_i + S_i = L_i + (O_i - C_i)$, i=1,2,3

  where

  L_i is the labour costs of alternative i, i=1,2,3
  S_i is the net profit created by alternative i, i=1,2,3
  O_i is the gross sales for alternative i, i=1,2,3
  C_i is the total production costs of alternative i, i=1,2,3

* All of S_i (i=1,2,3) is invested and all of L_i (i=1,2,3) is consumed.

* The gross sales O_i (i=1,2,3) is similar for the three alternatives and equals the selling price per cu.m of sawnwood in 1977 (586 shs) multiplied by the annual production volume (14,000 cu.m) - i.e. 8,204 mill. shs.

* L_i and S_i (i=1,2,3) are as shown in the Tables 8.1, 8.3 and 8.14.

* The invested capital is as stated in the Tables 8.15, 8.16 and 8.17 - i.e. 26,483 mill. shs, 22,805 mill. shs, and 14.305 mill. shs for respectively alternative 1, 2 and 3.

Based on these assumptions the data in Ch. 8 give the following estimates for σ, c and $\frac{\sigma}{c}$:

	σ	c	$\frac{\sigma}{c}$
Technological alternative 1	0.15	14.6	0.0103
" " 2	0.37	9.2	0.0402
" " 3	0.53	3.8	0.1395

Assuming constant elasticities of scale (i.e. $\varepsilon_N + \varepsilon_K' = 1$), and the present population growth in Tanzania of 3.4 % p.a. equalling $\frac{\dot{N}}{N}$, Eq. (3.10) shows that the growth of the net national product per capita $(\frac{\dot{x}}{x})$ with the three technological alternatives will be:

$$\text{Alternative 1: } \frac{\dot{x}}{x} = \varepsilon_{K1}(-0.0237) + \mu_1$$
$$\text{" } 2: \frac{\dot{x}}{x} = \varepsilon_{K2} \cdot 0.062 + \mu_2 \qquad (3.11)$$
$$\text{" } 3: \frac{\dot{x}}{x} = \varepsilon_{K3} \cdot 0.1055 + \mu_3$$

If μ_i (i = 1, 2, 3) are assumed to be approximately equal[6], Eq. (3.11) shows that alternative 3 (the most labour intensive technology) has a considerably higher growth of the net national product per capita than the alternatives 2 and 3, the difference increasing with increasing ε_K. If ε_{Ki} (i = 1, 2, 3) are 0.5 and μ_i (i = 1, 2, 3) are similar, Eq. (3.11) shows that alternative 3 gives a growth of the net national product per capita of 6.4 % p.a. and 5.0 % p.a. higher than respectively alternatives 1 and 2.[7]

3.2.2.3 <u>Discussion</u>

Compared with reality the model used above is highly simplified. There are at least three major factors which ought to be mentioned in this connection: (i) Important economic factors lacking; (ii) more sophisticated objetives; (iii) risks.

First, one may here think of the variables describing the functioning of the economy. Only one sector is assumed, whereas in reality, the economy in most countries consists of sectors with quite different forward and backwards economic linkages, profit generation, economies of scale, etc. The model is totally "supply driven" - i.e. it is assumed that the increased production of goods and services are automatically demanded. Natural resources and environmental aspects are not included in the model. Population and employment growth are considered similar, and the labour force is treated as one homogenous unit whereas in reality it consists of persons with different skills, attitudes, work performances, etc. A vital point here is that in many poor countries the major part of the technological progress will perhaps be disembodied technological progress related to better education and higher skill of the labour force. Dependency and institutional factors both domestically and internationally are not considered in the model[8].

Secondly, the objective of maximizing the net national product per capita might be questioned. The content of the economic growth is not considered neither regarding which types of goods and services are produced nor the distribution aspects, e.g. income distribution, covering of basic needs, self reliance[9].

Thirdly, all factors included in the model are burdened with risks.

The model has, therefore, many weak points, and one should be careful in drawing too strong conclusions from it. However, if we assume that all other factors than those included in the model are kept constant, the model in my opinion, makes it possible to illustrate the importance for economic growth per capita - and hence for the material living standard per capita - of the factors μ and c and the technological choice on micro level[10].

3.2.3 <u>Some notes on macroeconomic planning</u>

If, for a country:

- the prevailing income distribution is acceptable
- there exist no externalities
- perfect competition prevails,

then the market prices will reflect marginal social costs and benefits, and an ordinary project analysis based on commercial profitability is sufficient for deciding the optimal technological choice (UNIDO 1972:25-26, BOHM 1974:86-92). In the two-factor case illustrated in Figure 3.1, the optimal technology will be point A.

In real life, however, we know that the above mentioned assumptions are not valid. Mainly because of that, most LIC have established a central economic development planning organization (hereafter referred to as CPO).

Economic development planning deals with many issues. Among the most important may be mentioned (KUYVENHOVEN 1980):

(a) The desired rate of growth of production and investment; the distribution of income among income groups and regions; the development of employment opportunities, in particular for unskilled workers; the identification of major bottlenecks such as the rate of saving; the availability of skilled labour, management and administrative capacity; the maximum balance-of-payments deficit, the provision of education and training opportunities.

(b) The desired economic structure by sector and region, i.e. which industries should be developed or expanded, by how much, and in which region; a directly related problem is the sectoral distribution of investment in infrastructure.

(c) The selection and location of investment projects and the choice of production technique, in particular, the degree of labour intensity.

(d) The time-horizon, affecting, among other things, the treatment of saving. For long planning horizons the determination of the optimal rate of saving is a fundamental problem to be solved; in the medium term, saving is often considered a given constraint on the development of national income.

Many of these questions are interrelated: The choice of a certain production technology has consequences for the distribution of income, employment creation and the rate of saving. The sectoral distribution of investment affects the rate of growth of production, which, in turn, partly depends on the rate of saving and the development of the balance of payments, but also on the number of projets eventually selected and implemented. The latter again depends on the administrative capacity to identify projects and the technical and managerial skill to execute them properly.

The complicated nature of development planning has led to different approaches to the kind of models to be applied for planning economic development. One approach is to accept fully the interdependence of a number of various problems and to use detailed, complex mathematical models to solve the problems simultaneously. Other approaches, while acknowledging interdependencies, have concentrated on ways of simplifying the complex questions in development planning by breaking them down into separate, though not independent, problems. In this context, TINBERGEN (1967) has proposed that several consecutive stages in development planning characterized by different degrees of aggregation, be distinguished, namely:

(a) A macro stage, in which the development of the main economic and financial aggregates is determined.

(b) A middle stage, in which the expansion of different industries and their regional distribution is considered; if the regional aspect is treated separately, this stage can be called the sectoral stage.

(c) A project stage, in which investment projects are selected and their location is determined.

Depending on the way the planning process is organized, results for a particular stage should be carefully checked against those of other stages. With top-down planning, the results of some of the preceding stages may have to be reconsidered in the light of the findings for later stages. As information is usually much more precise at the micro stages of planning, one has to allow for feedback into the more aggregate stages. Through iteration and reiteration the formulation of a plan can then gradually be improved.

There is a basic difference between the project stage and the other stages of planning. If a project is defined as the smallest technically independent unit of production, the other stages are characterized by different degrees of aggregation of the very units that are the subject matter of microeconomic analysis at the project stage.

At each stage of the planning process, special techniques are employed to analyse the problems of that stage. At the sectoral stage, in which the main problem is to determine which industries should be developed or expanded, and to what extent, interindustry (input - output) analyses are widely recognized as a powerful analytical planning technique. Over the years, a variety of economy-wide multisectoral models have been developed in which input-output relations usually play an important role. Increasing experience with such models has led to a growing similarity in their general framework, enabling routine applications on a fairly large scale (see TAYLOR 1975, CLARK 1975). Without such models, it seems hardly possible to estimate consistently changes in the composition of demand, in the sectoral distribution of production and investment, and in a country's trade pattern, i.e. avoiding shortages in some sectors and surpluses in others. Also, the use of an input-output framework offers a useful basis for discussion between

project or sectoral specialists and those concerned with macroeconomic analysis and planning (TAYLOR 1975:42).

At the same time, however, there is a growing awareness of the limitations of the results of empirical applications to developing countries, both with regard to the sectoral level itself as well as other levels of planning. Stability of the structural coefficients poses a first problem. Input-output, capital-output and labour coefficients are normally estimated on the basis of data from some recent period. The inevitable time-lag between the last period of observation and the period to which the planning exercise refers becomes a major cause for concern in countries where additions to existing industries and rapid changes in technology may easily affect the stability of input coefficients.

A second major problem concerns the homogenity of the sectors, which is closely related to the aggregation problem. Theoretically, the basis for aggregating commodities is similarity in input structure and output proportionality. When thousands of commodities are aggregated into a limited number of sectors, it is an empirical matter whether those requirements are reasonably met. Several empirical studies suggest, however, that at the usual level of aggregation in input-output analysis, heterogenity of sectors may be such that the variance in economic characteristics among commodities within one sector is larger than among the sectors.

Another set of problems arises when multisectoral models are specified as linear programming models. Following TAYLOR (1975:59-82), the structure of applied planning models of this kind can usually be characterized by three kinds of restrictions. First, there are the real limitations on economic growth caused by input-output imbalance and the lack of primary factors of production, and foreign exchange. A second type of constraint is meant to reflect important but not well-understood limitations on growth, which are partly non-economic (constraints on capacity to absorb changes, minimum consumption and employment requirements, trade protection etc.). Third, restrictions are included to avoid overspecialization in foreign trade and other forms of extreme behaviour implied by linear systems. Given the nature of the restrictions of the second and third type, the usefulness of such planning models lies primarily in their indication of broad areas of sectoral choice rather than in exact optimal solutions for the development of sectors.

Similar qualifications apply to the dual solution giving estimates of the shadow prices of resources. As a result of model specification, small changes in the primal may cause large and discontinuous changes in the dual. The dual of an optimizing model of this kind should, therefore, primarily be used to check the structure of the model and the nature of the primal solution. Any additional claim that the dual can be used to determine shadow prices for project appraisal seems too ambitious (BRUNO 1975).

These factors are emphasized by UNIDO (1972:130-131):

> "The most glaring difference between actul situations and the model is the enormous difference in complexity. Even in the simple model we have assumed away significant planning problems in taking the feasibility frontier as a given of the problem. And in actual situations, there is a future as well as a present to be provided for; foreign trade is beset by uncertainties and market imperfections; political constraints inhibit the Government's ability to achieve desirable and technically feasible patterns of development; the representation of technological possibilities is itself a complex task; a multiplicity of goods and services rather than simply "consumption" and "investment" must be reckoned with. When these complications are taken into account, the very delineation of the feasibility frontier, or even a small part of it, becomes a task so formidable that it has eluded planners all over the world. An indication of the difficulties is customarily elaborated in countries that have attempted to use formal planning as an aid to development. Planning commissions are quite satisfied with their efforts if they can produce a single plan that is internally consistent. And when this plan is debated in the Government or in the country at large, the debate revolved primarily around its feasibility rather than its optimality. In terms of our simple model, debate hinges on whether the plan lies inside the feasibility frontier or outside it, not on whether the segment of the feasibility frontier on which it lies is tangent to an equal-welfare curve --------.
>
> Nor does the state of economic research hold out much hope that the situation will improve much during the 1970's. The mathematical planning models that at an earlier time held out much promise appear now to suffer from defect that will take a long time to remedy. These defects, which can be grouped under six headings, will only be touched on here: (1) All mathematical planning models simplify the objectives of development inordinately. For lack of data on policy makers' judgements as well as for computational simplicity, even the most ambitious do not go beyond a model in which the sole objective is maximization

> of a discounted present value of aggregate consumption. (2) Again for lack of data, but this time data on consumers' demand functions rather than on policy makers' judgements, no scope for variation in consumption according to relative scarcities is permitted. Instead goods and services are assumed to be necessarily consumed in fixed proportions. (3) Next, the conventional and almost universal approach to technology is to assume that linear input-output systems adequately describe the productive interrelationships of the economy. Again, a combination of ignorance, lack of data - and computational requirements dictate the approach, since it is widely recognized that the assumption of a single linear technique that remains constant over time for each sector of the economy is a drastic oversimplification of the range of choice; a simplification, moreover, that precludes systematic investigation of one of the most important areas of government policy. (4) In addition, computational limitations imposed by even the largest of the present generation of computers force the model-builder to decide between detail in the number of distinct productive sectors he will include or detail in the number of time periods he will cover. Either way, the model suffers as a representation of reality. (5) Moving on to foreign trade, it appears fair to say that no planning model has tried to come to groups with the choices available to the economy in export policies. Again, data are woefully lacking, for industrial exports depend heavily on quality, marketing capabilities and relationships that are difficult to quantify, and raw material exports depend on world conditions that are highly uncertain. The usual convention is to assume that the future will resemble the past. Imports are more tractable, but unless the economy is highly disaggregated (which, as we have just noted, precludes systematic optimization with respect to present and future), it is nearly impossible to represent coherently the policy choices available with respect to import substitution. (6) Finally, and perhaps most importantly, ignorance of politicl realities - both lack of data and lack of attention - have led to generally to ommission of constraints on saving and foreign exchange availabilities, imposed by the Government's difficulties in controlling demand for consumer goods".

3.2.4 Conclusions

Based on the discussion in sections 3.2.2.2 and 3.2.3, and UNIDO (1972), BLITZER et al. (1975) and KUYVENHOVEN (1980) I will conclude this chapter as follows:

1. Macroeconomic planning models are valuable in LIC as they indicate the importance for economic growth of vital factors like technological progress, services and investments, and population growth. These models are also necessary for getting consistency between the various sectors to avoid shortages or surpluses on sector levels. This is of obvious value in determining the size and composition of public investments by sector and the framework in which project formulators and evaluators in each sector must work.

2. The basic decisions regarding choice of technology are taken at the micro (project) level. Project planning can be considered the most concrete stage of planning. The degree of detail and quality of the data usually enable a much more precise analysis to be made than is possible at the previous stages of planning. Thus, the appraisal of projects can be based on criteria that reflect the objectives of development policy, all relevant scarce factors, and take account of local technical and socio-economic conditions.

   When the number of projects appraised in this way takes up a significant part of the available resources, systematic project planning has two important implications for the sectoral stage: (a) it leads to a substantial improvement in the available information on sectoral coefficients and, hence, in the estimation of effects, in particular indirect or linkage effects; (b) it enables sectoral criteria of attractiveness, either based on partial analysis or derived from economy-wide multisectoral models, to be refined. As a result, the consistency between the outcome of planning exercises at the sectoral and project level can be improved.

3. It is the task of the country's CPO to clarify as good as possible the parameters which are common for all projects considered and independent of decisions taken with respect to individual projects. These parameters include in particular the relative weights on the relevant objectives of development, the social rate of discount, the shadow price of investment, the shadow wages and the shadow price of foreign exchange. The problem in computing such national parameters is the circularity that arises from the sensitivity of decisions about each project to the magnitude of national parameters, and the sensitivity of the appropriate magnitudes of national parameters to decisions about all the projects.

NOTES TO CHAPTER 3

[1]This does not mean that there necessarily in all cases is a great difference between these two types of production functions. For example in HERVIK (1977:24-28, 31-32) it is shown that for long term development analysis, a putty-clay Cobb-Douglas production function and a traditional (neo-classical) Cobb-Douglas function with full substitutability between capital and labour will give asymptotically the same result with respect to long term relative economic growth.

[2]As mentioned by JOHANSEN (1972:154) it may be costs (for example regarding education, organizational aspects and social infrastructure) involved in the proces of disembodied technological progress. However, this is not discussed further op.cit.

[3]Capacity-increasing progress cover the concept of neutral technological progress used by Hicks (cf. Figure 3.4), whereas input-saving progress covers both the labour-saving and capital-saving alternatives of Hicks described in Figures 3.2 and 3.3.

[4]This is also assumed in HAAVELMO (1961).

[5]This is of course a quite hypothetical situation, but it is meant to illustrate vital macroeconomic consequences of alternative choice of technologies at large, assuming these alternatives with respect to σ and c are as in the actual project.

[6]One may look upon μ_i (i = 1, 2, 3) as disembodied technological progress, and as such it may be questionable whether this factor is equal for the three alternatives. One may argue that the most capital intensive technology (alternative 1) has more sophisticated machinery and organization than alternative 3, and therefore should have a higher potential for disembodied technological progress. On the other side, one may argue that the more labour intensive alternative (alternative 3) gives increased skill to more people than alternative 1. Which of these arguments are strongest is hard to judge, and the assumptions of similarity might be justified.

[7]It may be argued that ε_{K3} is likely to be higher than ε_{K1} and ε_{K2} because alternative 3 is the most labour intensive technology of the three alternatives analysed. If this is correct, the estimated differences regarding economic growth per capita are low estimates.

[8]Cf. for example CARDOSO (1967), FRANK (1969), TODARO (1977).

[9]Cf. for example GALTUNG (1976), GALTUNG et al. (1980), GREEN (1978).

[10]It is possible to construct more realistic models, incorporating several of the aspects discussed above, as shown e.g. by SEN (1968), LOUCKS (1975) and HERVIK (1977). However, such models get easily very complicated and hard to obtain increased knowledge from.

4 SOCIO-ECONOMIC PROJECT ANALYSIS

This chapter aims at (a) describing some vital connections between macroeconomics and project analysis; (b) presenting an overview of main methods for socio-economic project analysis; and (c) arriving at a method suitable for choosing between technological alternatives on project level in LIC.

A considerable part is devoted to task (b), as little documentation exists on this topic at least in the context of this study.[1]

4.1 Connection between macroeconomics and project analysis

The decision-theoretical connection between project analysis and macroeconomics may be illustrated as shown in Figure 4.1, based on JOHANSEN (1977:55-60), using the following symbols:

(1) a: This symbol represents a possible policy for the Central Planning Organization (CPO) in terms of what the CPO can directly decide upon. The CPO will have at its disposal a set of policy instruments, such as tax rates, government expenditures, monetary and credit policy, some direct decisions about production etc. We may think of a as a (large) vector indicating the values assigned to all these instruments.

In this context of technological choice on project level, a symbolizes a possible technological alternative in a possible project.

(2) A: This is the set of all possible policies, i.e. a set such that any policy $a \in A$ is ruled out by one or more conditions constraining the range of possible policies. The constraints delimiting the set A may be institutional, political, physical, or of other origins.

(3) z: This respresents factors which influence the development of the economy, but which are beyond direct or indirect control of the CPO. We shall call them non-controlled exogenous factors (or only exogenous factors). Examples are weather conditions of importance for agriculture and fishery. For a relatively small country, however, many elements of the development on "world markets" may also be taken as non-controlled and exogenous, for example world market prices. In most practical cases one may think of z as a vector of variables.

(4) Z: This is the set of all possible states of the non-controlled exogenous factors, i.e. we have $z \in Z$.

(5) x: This represents a description of the state of the economy. In particular x includes a description of all those aspects of the state of the economy which are relevant to the preferences of the CPO. In aggregated terms it would be a list of figures for national product, consumption, indicators of income distribution and so on. In principle, the description has to be as detailed as required by the CPO in order to judge about the desirability of the state. If only quantitatively different situations are under consideration, we may think of x as a vector.

(6) X: This is the set of possible states of the economy, i.e. we must have $x \in X$. The set X is constrained by the set of possible policies A and the set of possible states of the exogenous factors Z in conjunction with the relationships described below under (7).

(7) x=f(a, z): This represents the working of the economic system or mechanism for which one is planning. The meaning is the following: The state of the economy x is a function of the policy a pursued by the CPO and the exogenous factors z. This means that to every pair (a, z) consisting of a possible policy a and the possible constellation of the exogenous elements z there corresponds one state or result x, and the form of this dependency is symbolized by f. This is a highly condensed, symbolic representation. In the most simple

quantitative case x, a and z are all vectors. The fact that we symbolize the functioning of the economy by x=f(a, z) does not mean that an explicit mathematical or numerical formula can actually be written down, but only that a unique x corresponds to every a, z.

(8) W(x): This represents the preference scale of the CPO. We might in general think of this as an ordering of the elements x of the set of possible states X. This ordering may not necessarily be representable by a function. However, for simplicity, and because this is likely to be sufficient for practical purposes, we shall assume that the preferences are representable by a function W(x), which to every x in X assigns a value in such a way that if two elements x′ and x″, both belonging to X, are equally desirable according to the preferences of the CPO, then W(x′)=W(x″), and if x′ is preferable to x″, then W(x′) > W(x″).

(9) X_z: In addition to the elements introduced above it will sometimes be useful to have a special symbol for the set of states x , which are possible when the exogenous elements z are given. Such a set will be symbolized by X_z. The full set of possible states X is then the union of all X_z for $z \in Z$.

All elements (a, A, z, Z, x, X, X_z) are functions of time - i.e. the time dimension is included in the size of the vectors describing the elements.

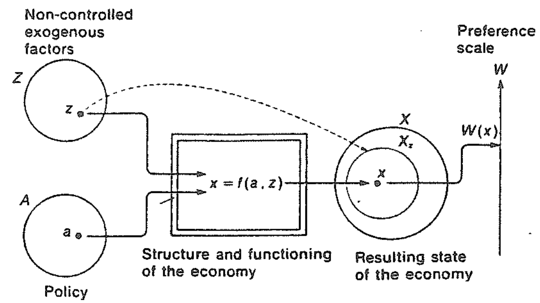


Figure 4.1: Illustration of vital relationships between project analysis and macro-economics. (Source: JOHANSEN 1977:55).

The relationships between these elements are indicated in Figure 4.1. The figure illustrates that the policy a is an element of the set of possible policies A, and the constellation of exogenous factors z is an element of the set Z of possible constellations of these factors. These two elements together act as inputs into the "model" or "structure of the economy" and produce a state of the economy x which is an element of the set X of possible states, or more specifically an element of the set X_z determined by the exogenous elements z as suggested by the dashed line.

The set X of possible states of the economy is generated by the policy a and the exogenous factors z over their possible sets A and Z. This means that any state x belonging to X can be produced by x=f(a, z) for some a belonging to A and some z belonging to Z, whereas any x not belonging to X cannot be achieved. Similarly any x belonging to X_z for some specified z can be produced by some $a \in A$ while z is kept fixed, whereas any x not belonging to X_z cannot be produced. Accordingly the sets X and X_z are not independent of, but determined by, the sets A and Z (or by z in the case of X_z) via the function f.

The elaboration of the best plan (read: the optimal technological choice) would then consist of the following steps:

1. Delimit the set of possible policies A (i.e. the set of possible technological alternatives).
2. Define the structure of the economy and its functioning, i.e. construct the model represented symbolically above by $x=f(a, z)$. This step includes the establishing of the list of exogenous factors influencing x.
3. Establish the preference function W(x).
4. Predict the exogenous elements z.
5. For the values of the exogenous factors predicted in step 4, search through the possible alternatives a in the set A so as to find the one (or one of those) which gives the highest value of the preference function W(x).

Symbolically the best alternative, determined by step 5, is a policy a^* which satisfies the following relation:

$$W(f(a^*, z)) = \max_{a \in A} W\big(f(a, z)\big) \text{ for given (forecasted) } z \qquad (4.1)$$

The corresponding state of the economy x^*, which we may call the <u>target</u> since it is the state aimed at by specifying the instruments at a^*, is given by

$$x^* = f(a^*, z) \text{ for given (forecasted) } z \qquad (4.2)$$

This target could evidently also be indicated by

$$W(x^*) = \max_{x \in X_z} W(x) \text{ for given (forecasted) } z \qquad (4.3)$$

This model is deterministic, and assumes, in addition, that conflicts between different interest groups are resolved in such a way that clearly defined W(x) exist. As mentioned in Ch. 4.3.1 this is often a strong simplification of reality.

4.2 <u>Overview of main methods for socio-economic project analysis</u>

The presentation in Ch. 3 indicates that the present macroeconomic models at best can include only some of the many important socio-economic consequences of technological choices in development projects, influencing W(x) in Figure 4.1. An important question is then, how to evaluate different technological alternatives in order to arrive at the optimal choice of technology - or may be more realistically - to avoid choosing a bad technology.

In theory the answer is simple: It is just to do a socio-economic project analysis. In reality this is not an obvious task. One severe problem is what type of appraisal method to use for estimating the effects f(a, z) and W(x) in Figure 4.1.

The many methods available for such analysis can be classified in several ways. For the purpose of this paper I have distinguished between two main categories: Simulation (scenario), and optimization methods. No detailed description of the methods is presented, as the idea is to get an overview of existing types of methods. The presentation does not pretend to be complete, but covers, in my opinion, the major relevant methods.

By the term "socio-economic project appraisal method" I mean a method which intends to include all social and economic factors which are assumed relevant in the actual analysis.

4.2.1 <u>Simulation (scenario) methods</u>

This category of methods is characterized by not trying to estimate the optimal project alternative, but to show how important factors are influenced by different project designs. The purpose of such analyses is to throw light on certain important impacts of the various project alternatives, thus making it easier for the decision maker to choose a satisfactory alternative rather than finding the optimal one.

In the terminology of Figure 4.1 one may say that this category of models is aimed at exploring the impacts $x = f(a, z)$ for various central project (policy) alternatives a, and not at mapping W(x).

Often, methods in this category focus on estimating the impacts for various interest groups.[2]

Typical examples of such methods are the socalled "positional analysis" (SÖDERBAUM 1973, 1986), and the "planning balance sheet method" (LICHFIELD, KETTLE & WHITEBREAD 1975).

The simulation (scenario) method is easily adapted to computer calculations incorporating feedback structures, and for stochastic analysis, for example as shown by FEDRA (1979, 1983).

4.2.2 Optimization methods

In contrast to simulation, optimization methods seek the best alternative out of a set of alternatives. There exist many optimization methods which can be used for socio-economic project analysis. It might be convenient to distinguish between single criterion and multi-criteria methods. By a single-criterion method is meant that the decision is based on only one criterion, whereas in multi-criteria optimization the decision is based on more than one criterion. It should be mentioned, however, that there is no strict border here, as some methods could be classified in both categories.

4.2.2.1 Single criterion methods

4.2.2.1.1 Cost-benefit analysis

By cost-benefit analysis I mean a project appraisal method which aims at achieving maximum social efficiency (welfare) in a Kaldor-Hicks compensation sense[3] based on a single criterion, and which is used for selection among a definite number of project alternatives.[4]

In order to judge which alternative is preferable it is necessary to introduce a set of values on the inputs and outputs which reflects how the society or the decision makers rank the various goods and services relative to each other. In theory this would be a set of values reflecting the society's needs, availability of resources and objectives. In practice shadow prices are used, and the problem is to obtain reasonably accurate estimates of the shadow prices.

In the notation of Figure 4.1 and BOHM (1974:92-93), each of the project alternatives (a) will have impacts in a number (n) of dimensions and during a number of periods. Denoting the effects of dimension i in period t by x_{ti}, the total impacts of the project can be listed like this:

Period 1: $x_{11}\ x_{12}\ \cdots\ x_{1n}$

Period 2: $x_{21}\ x_{22}\ \cdots\ x_{2n}$

Period t: $x_{t1}\ x_{t2}\ \cdots\ x_{tn}$

The cost-benefit criterion will then be[5]:

$$\sum_{t=1}^{\infty} \frac{\sum_{i=1}^{n} p_{ti}x_{ti}}{(1+r_1)\ (1+r_2)\ (1+r_3)\ \ldots\ (1+r_t)} > 0 \qquad (4.4)$$

where

p_{ti} is the value of impact x_{ti}

r_t is the calculation rate of interest for period t

In practice one will have to use a limited number of periods T, beyond which the impacts are assumed to be zero, and most often a constant calculation rate of interest, giving the following criterion[6]:

$$\sum_{t=1}^{T} \frac{\sum_{i=1}^{n} p_{ti}x_{ti}}{(1+r)^t} > 0 \qquad (4.5)$$

According to BOHM op.cit. major steps in a cost-benefit analysis are:

(1) The quantification problem. How should the costs and benefits, x_{ti}, of the project be identified and measured in physical terms?

(2) The valuation problem. How should the socially relevant values of the physical effects of the projects, that is the p_{ti}, be determined?

(3) <u>The discounting problem</u>. How should the discount rate (r) relevant for the economy as a whole be determined?

(4) <u>The constraints problem</u>. How should the constraints on project design (if relevant) and on project approval be determined and formulated?

(5) <u>The uncertainty problem</u>. How can we allow for the fact that future effects, weights (prices), discount rates and constraints are often impossible to determine with certainty?

The literature in this field is vast (e.g. MISHAN 1971, BOHM 1974, DASGUPTA & PEARCE 1972, LAYARD 1972, SUGDEN & WILLIAMS 1978). Among the most interesting ones regarding developing countries are UNIDO (1972), LITTLE & MIRRLEES (1974), SQUIRE & TAK (1975), and more recently for the forest sector FAO (1979) and OECD (1986).

In principle one may distinguish between two different approaches - the Paretian approach and the decision-making approach (SUGDEN & WILLIAMS 1978:91-95).

The decision-making approach assumes a social decision maker - i.e. someone responsible for making decision in the public interest. The objective is "social" in the sence that the intention is to make decisions which affect society as a whole. The decision maker occupies his position by virtue of a socially approved political process. He is accountable to the public for carrying out the task of making choices on behalf of the public, implying that he has to operationalize objectives for the society. With this approach, then, cost-benefit analysis is seen as a process of appraising decision problems in the light of objectives chosen by such a decision maker. This school of thought is advocated for example by UNIDO (1972) and LITTLE & MIRRLEES (1974).

The other main school of thought - the Paretian approach - looks at project appraisal from a rather different viewpoint, as described in SUGDEN & WILLIAMS (1978:94).

> "It starts from a distinct position about what the objectives of social decision-makers ought to be. These objectives should be distilled from a consensus of the value judgement of the individuals who make up society, and they should be propositions which would command universal, or at least very wide, assent. This interpretation of cost-benefit analysis sets it apart from the process by which actual decisions are taken in practice at any point in space or time. The analyst works independently of the political decision-making process and brings to his work his own independent norms. ---- The exponents of the Paretian approach argue that cost-benefit analysts should, as a matter of principle, confine themselves to using the potential Pareto improvement criterion (i.e. the Kaldor-Hicks compensation principle) and hence to measuring changes in economic efficiency. They argue that a cost-benefit analysis should aim to answer one question only: "by how much does the total sum of money that the gainers from a project would be prepared to pay to ensure that the project is undertaken, exceed the total sum of money that the losers from the project would accept as compensation for putting up with it?" The answer to this question does not amount to a statement about whether the project will increase or decrease social welfare; but it is a significant piece of information. It narrows the area of debate about the merits and demerits of the project. If, for example, a project is shown to cause a decrease in economic efficiency, then someone who argues that the project ought to be undertaken must argue that the decrease in efficiency is outweighted by an improvement along some other dimension of social welfare - perhaps that of distributional justice.
>
> In support of this approach, with its implication that cost-benefit analysis should not concern itself with any dimensions of social welfare other than that of economic efficiency, it may be argued that to attempt to go further is to attempt the impossible. It may not always be possible, even in principle, to identify increases and decreases in social welfare by using "consensus"-ethical judgements. Some writers, for example, argue that the different dimensions of social welfare are inherently incommensurable."

This sets the Paretian approach apart from the decision-making approach. The welfare economist may legitimately declare that it is not possible to know which of two social states would produce more social welfare. The decision maker, however, is not free to declare that it is impossible to choose between two alternative courses of action. It is his job to choose. According to the decision-making approach, cost-benefit analysis exists to assist him in choosing; he may, therefore, have to explore social objectives other than that of increasing economic efficiency. In this sense the decision-making approach is the more ambitious of the two approaches, since it permits a wider range of the effects of a project to be taken account of in cost-benefit analysis.

A typical exponent of the Paretian approach is MISHAN (1971).

It is worth noting that the Kaldor-Hicks compensation principle (cf. above) is usable in both the decision-making and the Paretian approach.

The above mentioned problem regarding the extent to which the political issues should be left explicitly to the decision-makers themselves to decide on, is not easy to solve in practice. However, one important point in such analyses must be to state as clearly as possible the assumptions underlying the set of shadow prices used and carry out calculations of efficiency with different sets of shadow prices reflecting different options.

In many circumstances valuing the benefits are more difficult than valuing the costs. If the outputs of the technological alternatives are equal regarding the quality and the quantity of the output produced, it will therefore be convenient to use cost efficiency as an indicator, thus avoiding the problem of valuing the output.

This short presentation of the cost-benefit method has just touched upon the many theoretial and practical problems of applying this method. For a more thorough discussion - for example regarding the problems of defining and deriving a social welfare function, the complexities raised by "second-best" arguments, the proper choice of discount rate - reference is made to the literature mentioned above.

4.2.2.1.2 Mathematical programming methods

There exist many single criterion optimization methods for systems where the relations between the variables are formulated mathematically. The main difference between these types of methods and cost-benefit analysis is that in the former case there are an indefinite number of alternatives to choose among in searching for the optimal solution.[7]

The major methods may be listed as follows:

(i)	Unconstrained multi-variable calculus	TC
(ii)	Dynamic programming	DC
(iii)	Linear programming	LP
(iv)	Optimal control theory (calculus of variation)	OCT

Each method represents one way of finding this optimum, and which method to choose depends on the problem at hand.

These methods demand rather detailed information about the connections between the variables involved, and are, therefore, of limited interest regarding choice of technology in LIC (cf. Ch. 4.3.1). For a more thorough discussion of the methods reference is made to INTRILIGATOR (1975, 1981) and KENDRICK (1981). A comparison of the methods related to forestry is presented in SOLBERG (1982).

4.2.2.2 Multi-criteria optimization methods

The literature on multi-criteria methods is vast, and various types of classifications are used.

According to MACCRIMMON (1973:275) one may distinguish between 4 categories of multi-criteria methods:

(A) Weighting methods, characterized by:

- a set of alternatives and clearly defined decision criteria
- a comparison of alternatives by means of weights
- a clearly defined preference structure leading to an aggregate value for each alternative
- selection on the basis of aggregate weights.

(B) Sequential elimination methods, characterized by:

- a set of alternatives and clearly defined decision criteria
- a scale (cardinal or ordinal) by means of which the outcomes of the decision criteria can be ranked
- a set of side-conditions with regard to the various criteria
- an algorithmic procedure via successive comparisons of alternatives on the basis of the performances related to decision criteria.

(C) Mathematical programming methods, characterized by:

- a large or infinite set of alternatives within a feasible area
- a set of side-conditions
- one or more objective functions
- an algorithmic procedure selecting more preferred points in order to arrive at an optimum.

(D) Spatial proximity methods, characterized by:

- a set of alternatives, sometimes with fuzzy criterion values
- a procedure for generating intra- and inter-attribute values
- a construction of a spatial representation

- the determination of ideal configurations as well as choice rules for calculating the proximity of alternatives with respect to the ideal situation.

This classification may seem artificial. For example the main differences between category D and categories A and B may be unclear. It is also seen that there is a difference between category C, which is based on a large or infinite set of alternatives, and the other three categories, which are based on a given set of alternatives. Thirdly, categories A, B and C may all be expanded to include spatial and stochastic elements which is the essential point with category D. It may, therefore, be better to distinguish between the following two categories of multi-criteria methods:

(1) Mathematical programming methods for an infinite set of alternative combinations, characterized by:

- a large or infinite set of alternatives within a given feasible area
- a mathematical description covering the whole set of alternatives
- a set of side conditions
- two or more objectives[8]
- an algorithmic procedure selecting more preferred points in order to arrive at an optimum.

(2) Methods for a given definite set of alternatives, which includes category A and category B defined above.

In the following sections a brief discussion of categories 1 and 2 is presented.

4.2.2.2.1 Mathematical programming methods for an infinite set of alternatives

The methods under this category have in later years become important elements of decision-making, and are most often classified as multi-objective optimization theory. The terms multi-dimensional optimization theory or vector optimization theory are also used.

This category of models gives solutions of the following problem:

$$\begin{aligned} &\max\ w_1\ (x_1, \ldots, x_I) \\ &\quad\vdots \\ &\max\ w_J\ (x_1, \ldots, x_I) \end{aligned} \tag{4.6}$$

subject to:

$$\begin{aligned} &g_1\ (x_1, \ldots, x_I) \leq \bar{g}_1 \\ &\quad\vdots \\ &g_K\ (x_1, \ldots, x_I) \leq \bar{g}_K \end{aligned}$$

in which w_j ($j=1,J$) represents the jth objective function, g_k ($k=1,K$) is the kth constraint function, and x_i ($i=1,I$) corresponds to the vector X defined in Ch. 4.1 - i.e. a description of the state of the economy necessary for adequately estimating the objective functions and the constraints in (4.6).

The relevance of the multi-objective approach in the context of choice of technology on project level is that it provides a tool for taking into account a variety of competing decision criteria (e.g. maximizing employment or profit, minimizing the use of foreign exchange, etc.) in the W(x) in Figure 4.1.

The most common classes of multi-objective optimization models are utility maximization models, penalty models, goal programming models, constraint models, hierarchical optimization models, and Pareto optimization models. In the following each of these is described more in detail. The description is mainly based on TELL (1976), TELL & WALLENIUS (1976), NIJKAMP (1977), WIERBICKI (1979), KEENEY (1982), ZELENY (1982), and CHANKONG & HAIMES (1983).

Utility maximization models

The utility models are based on the assumption that the whole series of relevant objective functions (or decision criteria) can be integrated into a utility function by means of a weighting procedure - i.e. the trade-offs between the various objective functions are explicitly specified. Thus, the problem (4.6) is reduced to a one-dimensional programming problem as described in Ch. 4.2.2.1.2.

Different weighting procedure may be used as described e.g. in Ch. 4.2.2.2.2.

Penalty models

Penalty models assume that it is possible to specify a desired (satisfying or normative) value w_j^+ for each objective function. A deviation of an actual value w_j from w_j^+ will be penalized by means of a penalty function. These penalty functions are frequently of a quadratic nature so as to penalize higher deviations. A formal representation of a penalty model is:

$$\min X = \sum_{j=1}^{J} \alpha_j (w_j - w_j^+)^2 \qquad (4.7)$$

subject to:

$$g_k(x_1, \ldots, x_I) \leq \bar{g}_k, \quad \forall k$$

where the coefficients α_j (j=1, ..., J) (for the diagonal matrix $\hat{\alpha}$) represents the weights attached to the jth deviation. These penalty models imply again a transformation to a traditional uni-dimensional optimization model, viz. a quadratic programming model. A drawback of this approach is that both the coefficients α_j and the desired values w_j^+ have to be specified.

Goal programming models

Goal programming models bear a close resemblance to penalty models and can to a certain extent be considered as a linear subclass of penalty models: In the context of goal programming a desired level w_j^* is specified for each decision criterion to be achieved by an

appropriate choice of decision variables. Goal programming can be formalized as:

$$\min X = \sum_{j=1}^{J} (w_j^+ + w_j^-) \qquad (4.8)$$

subject to:

$$g_k(x_1, \ldots, x_I) \leq \bar{g}_k, \quad \forall k$$
$$w_j - w_j^+ + w_j^- = w_j^*, \quad \forall j$$

where w_j^+ and w_j^- represent the respective overachievements and underachievement of w_j with respect to w_j^*. Either w_j^+ or w_j^- may be set equal to zero, dependent on the question as to whether a positive or negative deviation is allowed.

Constraint models

Constraint models are an alternative way to take account of prespecified values of the decision criteria. If these prespecified values are included as upper or lower constraints in a normal optimization model, the following decision problem may be formulated (assuming that one of the decision criteria, i.e. the first one, can be selected as a dominant criterion):

$$\max w_1 (x_1, \ldots, x_I) \qquad (4.9)$$

subject to:

$$g_k(x_1, \ldots, x_I) \leq \bar{g}_k, \quad \forall k$$
$$w_j^{min}(x_1, \ldots, x_I) \leq w_j < w_j^{max}(x_1, \ldots, x_I), \quad \forall j$$

where w_j^{min} and w_j^{max} represent the lower and upper levels of the objective functions, respectively.

Hierarchical optimization models

Hierarchical optimization models are based on the assumption that the entire set of different objective functions can be ranked according to decreasing degree of relative priority. After an hierarchical rank order of decision criteria (to be specified by the decision maker), an optimization procedure is carried out in which lower-order objective functions are only considered after higher-order objective functions. Clearly, this procedure requires information in terms of relative priorities for incompatible objective functions $w_1, w_2, \ldots, w_J$.

Therefore, hierarchical optimization procedures can be described by means of the following successive stages:

$$\begin{cases} \text{I} \begin{cases} \max w_1(x_1, \ldots, x_I), \\ \text{subject to} \\ g_k(x_1, \ldots, x_I) \leq \bar{g}_k, \quad \forall k; \end{cases} \\ \text{II} \begin{cases} \max w_2(x_1, \ldots, x_I), \\ \text{subject to} \\ g_k(x_1, \ldots, x_I) \leq \bar{g}_k, \quad \forall k, \\ w_1(x_1, \ldots, x_I) \geq \beta_1 w_1^0; \end{cases} \\ \text{III} \begin{cases} \max w_3(x_1, \ldots, x_I), \\ \text{subject to} \\ g_k(x_1, \ldots, x_I) \leq \bar{g}_k, \quad \forall k, \\ w_1(x_1, \ldots, x_I) \geq \beta_1 w_1^0, \\ w_2(x_1, \ldots, x_I) \geq \beta_2 w_2^0; \end{cases} \\ \text{etc.,} \end{cases} \tag{4.10}$$

where w_1^0 and w_2^0 are the optimum values of w_1 and w_2 achieved by means of steps I and II of equation (4.10), respectively. The parameters β_1 and β_2 define a certain tolerance area of w_1 and w_2 considered allowable by the decision-maker.

<u>Pareto optimization models</u>

A final class of multi-objective optimization models are the Pareto models. This type of models is based on the concept of a Pareto-optimal solution, which is also called efficient, dominant or non-dominated solution. Pareto models are based on the common feature of multiple objective functions that the value of one objective function cannot be improved without affecting the value of other objective functions. The aim of Pareto (or effi-

cient) programming techniques is to identify the set of feasible efficient solutions.

In formal terms a Pareto solution can be defined as follows: A Pareto solution is a point $(x_1^+, \ldots, x_I^+)$ for which no other feasible solution $(x_1, \ldots, x_I)$ does exist such that

$$w_j(x_1, \ldots, x_I) \geq w_j(x_1^+, \ldots, x_I^+), \quad \forall j \tag{4.11}$$

and

$w_j(x_1, \ldots, x_I) \neq w_j(x_1^+, \ldots, x_I^+)$ for at least one j.

In general, a multi-objective optimization problem does not have only one solution, but a whole series of efficient solutions. Consequently, in general an efficiency frontier of multiple objective functions can be drawn.

If the number of Pareto solutions is small, a selection of a satisfactory solution out of the set of efficient solutions can be made by applying a discrete multi-criteria analysis.

Besides being of considerable practical interest, the Pareto models have theoretical importance because they place multi-objective optimization in the broader context of Pareto optimality in economic welfare theory.

In particular regarding interactive modelling the use of Pareto-models have proved useful.

<u>Interactive decision models</u>

Interactive decision models are based on an interplay between the analyst and the decision maker. The idea of interactive decision-making is based on the fact that the optimum solution of a programming model (or decision model) does not necessarily meet the preferences of a decision maker due to uncertainties and bounded rationality. In this case a more satisfactory equilibrium solution (a compromise solution) can be achieved by means of a recursive process. Such a recursive process implies that, given the set of efficient solutions, a first provisional solution is suggested to the decision maker. Then he may propose certain amendments, so that the decision problem has to be adjusted accordingly. The solution procedure is based on a progressive articulation of preferences of the decision maker. The aim of an interactive decision model is to generate feasible and successively improved solutions through active involvement of the decisionmaker.

Interactive decision strategies can be associated with all the models described above and in Ch. 4.2.2.2.2. As such the interactive decision models are not a separate class of models, but more another way of using the classes of models already mentioned.

4.2.2.2.2. Multi-criteria methods for a given, definite set of alternatives

Under this category we have (a) a limited number of clearly defined set of plan (project) alternatives, and (b) a given set of criteria (objectives). The problem is to find which of the alternative plans is best according to the given criteria.

Assuming I different criteria $i \in (i=1, \ldots, I)$ and J different plans $j \in (j=1, \ldots, J)$ the impact of the jth plan regarding criteria i can be denoted x_{ij}. We can then summarize the impacts of each plan in one large matrix X:

$$X = \begin{bmatrix} x_{11} & \cdots\cdots & x_{1I} \\ \vdots & & \vdots \\ x_{J1} & \cdots\cdots & x_{JI} \end{bmatrix}$$

It should be emphasized that contrary to the situation described in Ch. 4.2.2.2.1, we have here a set of distinct alternative projects which are clearly defined. The question is not to form the best alternative as is the case in Ch. 4.2.2.2.1, but to choose the best out of a given set of alternatives.

Based on the literature one may differentiate between two categories of models - (i) those which do not imply any weighting of the criteria, and (ii) those which associate a welfare index with each criterion, followed by adding of the indices. The adding can be done in various ways, according to what is supposed to reflect the preferences of the decision maker.

We may refer to category (i) as the "satisficing approach" and category (ii) as the "utility maximization approach".

The "satisficing approach"

This category of models is based on setting one standard for each criterion. The multi-criteria object is then compared, criterion by criterion, with the specific standards. Two types of models are often referred to - the conjunctive and the disjunctive model.

The conjunctive model represents Simon's notion of "satisficing" (SIMON 1955) and accepts a project only if it is above a defined standard according to all criteria. The model can be formalized like this:

$$W\ (x_1,\ x_2,\ \text{-----},\ x_I) = \begin{cases} \text{acceptable if } x_i > \bar{x}_i,\ i = 1, I \\ \text{not acceptable otherwise} \end{cases} \qquad (4.13)$$

where W is the welfare (objective) function associated with the criterion-values $x_1, x_2, \ldots, x_I$. The symbol $\bar{x}_i$ is the standard value for criterion number i.

The disjunctive model accepts an object if at least one of the criteria exceeds the present standard. This model can be formalized like this (same symbols as in (4.13)):

$$W(x_1, \text{----}, x_I) = \begin{cases} \text{acceptable if } x_i > \bar{x}_i \text{ for at least} \\ \text{one } i,\ i = 1, \text{---}, I, \text{ not acceptable} \\ \text{otherwise} \end{cases} \quad (4.14)$$

This "satisficing" types of models are easy to use as the main problem is to decide upon the standards $\bar{x}_i$, i=1,2..I. However, they give little help if more than one of the evaluated alternatives (projects) pass the test. In such situations it is necessary to use one of the utility maximization models.

Utility maximization approach

Models using this approach are based on the principle of choosing the project which gives highest score on a cardinal utility index. Many types of models exist here. The most common ones seem to be the linear type, the additive type, the continous conjunctive type, and the minimum type.[9]

The linear model is probably the one that is most used. It can be formalized as:

$$W(x_1, \text{---} x_I) = \sum_{i=1}^{I} a_i x_i \quad (4.15)$$

where x_i (i=1,I) is a measure for the ith criterion, a_i is a parameter expressing the relative importance of this measure, I is the number of criteria, and W is the utility function. The same symbols are also used in equations (4.16) - (4.18).

The additive model represents a refinement of (4.15) to avoid purely linear connections, and can be formalized as:

$$W(x_1, \text{---} x_I) = \sum_{i=1}^{I} a_i u_i(x_i) \quad (4.16)$$

where u_i is some function of x_i that may be interpreted as a unidimensional utility function of the ith criterion, i=1,I.

The continous conjunctive model can be formalized as:

$$W(x_1, \text{---} x_I) = \sum_{i=1}^{I} u_i(x_i)^{a_i} \quad (4.17)$$

The minimum model emphasizes the weakest point in a system, and can be formalized as:

$$W(x_1, \text{---} x_I) = \min_i u_i(x_i) \quad (4.18)$$

Distance models use the deviation from an ideal value as criterion index. One type of such models can be formalized as:

$$W(x_1, \text{---} x_I) = \sum_{i=1}^{I} a_i^2 (c_i - x_i)^2 \quad (4.19)$$

where c_i (i=1,I) is a preset value (for example could c_i be the maximum possible value of x_i).

4.2.2.3 Other methods

There are also other methods which could be of interest regarding socio-economic project analysis, for example game theory, fuzzy set theory and topological methods.

Game theory is a method for predicting the probable outcome of activities of two or more rational agents, where the outcome matters to each agent and depends in a prescribed way on the actions of all of them. BACHARACH (1976) gives a discussion of this topic. However, regarding the question of technological choice in development projects as intended in this paper, the method seems not particularly useful, although it may be of interest to focus special aspects, e.g. as shown by JOHANSEN (1974, 1983), HOEL (1978) and SOLBERG (1978).

In recent years L.A. Zadeh's fuzzy set theory (ZADEH 1965, 1973) has attracted increased attention in analysis of complex systems. Fuzzy set theory is a generalization of Boolean algebra, which is based on a semantic model of four words from natural language; "if", "not", "or" and "and". The model can be used for appraising the truth of any proposition containing the four words. The propositions are either true or not true, which in the equivalent set theory corresponds to an object either being or not being a member of a given set. In fuzzy set theory the main idea is that in human life - i.e. wherever human value judgements play an important role - situations can often not be reduced to a sharp two valued logic assuming that certain relationships are either true or not true. Consequently, the fuzzy set theory is based on the assumption that objects can be members of sets to different degrees. Such sets are called fuzzy sets, i.e. sets with unsharp boundaries. For solving problems including fuzzy sets, new algorithms have been developed (ZIMMERMANN 1978). As pointed out in YAGER (1977, 1980) and ZIMMERMANN, ZADEH & GAINES (1984) the theory of fuzzy sets presents a good method for solving multicriteria decision problems. Regarding the question of technological choice in development projects as intended in this paper, the method seems promising, as it describes, in my opinion, realistically the starting point in many of these projects, e.g. unclear objectives, uncertainties about input costs and production outputs. However, the method seems to be quite demanding regarding technical skill and contact with the decision maker(s). For these reasons, I have not gone further with this method at this stage.

Topological methods in the social science are based on mapping a given real-world situation into a standard geometrical structure, and study that structure by using the existing mathematical tools of topology to say something meaningful about the original problem. CASTI (1979, 1981) give a thorough description of these methods (singularity theory, polyhedral dynamics, etc.). The methods seem mathematically quite complex, and to be most relevant for qualitative analysis of larger, complex systems. From my understanding of the method, they seem to be of relatively small interest regarding analysis of technological choice on project level.

4.2.3 Stochastic models

Each of the above mentioned models can be used in a stochastic way by for example specifying a distribution function for each of the criteria involved and for each of the project alternatives analysed (in game theory and fuzzy set theory certain stochastic elements are incorporated - cf. above).

By using random generators and repeated calculations one will get a frequency distribution of the ranking of the project alternatives. An example of this is presented in NIJKAMP (1977:290-291).

For a detailed discussion of stochastic models it is referred to GRAUER et al. (1982), SINN (1983) and BORCHERDING et al. (1984).

4.3 Recommendation of method

4.3.1 General remarks

The difference between the simulation and optimization models is not so clear as it may look from Ch. 4.2. Like optimization, the simulation efforts are done to improve the basis of decision and hence to arrive at better decisions. The two main methods also share the problem of whose preferences should be emphasized (cf. Ch. 4.2.2.1.1), as one also in the simulation models has to secure that all factors of interest for the decision maker(s) are included. One main difference between the two approaches is that in simulations there are no overall objectives to be maximized or minimized. However, there may be parts of the simulation procedures which demand optimization - for example a simulation model which includes as one part the investment behaviour under profit maximization. Likewise, it is possible in a multi-criteria simulation model to include as one criterion economic production efficiency calculated with the social cost-benefit method described in Ch. 4.2.2.1.1, assuming that the other criteria can not be included with a reasonable degree of realism in the production efficiency calculation (cf. Ch. 4.3.2).

The utility maximization multi-criteria method described in Ch. 4.2.2.2.2 and all methods described in Ch. 4.2.2.1 except the Pareto optimization method are actually one-dimensional optimization methods similar to the cost-benefit method described in Ch. 4.2.2.1.1. The main difference is that in the latter method the starting point is the information regarding preferences reflected in the market prices, however, adjusted for income distribution, market imperfections etc. Otherwise the weighting procedure is very much similar to what is used in the above mentioned multi-criteria methods.

There are in principle three methods which can be used to estimate and evaluate how well the models (with corresponding coefficients) seem to fit a given decision maker's preferences: direct estimation technique, indirect estimation technique and interactive programming. A direct estimation technique is used when the decision maker is asked to express his preference for the criteria. Indirect estimation is used when the decision maker's preferences are derived from his past choices, or from evaluated alternatives. Interactive programming may be classified inbetween these two methods, as it tries to reveal the decision maker's preference through his repeated choices (trial and error) to arrive at the best possible result in a choice between alternative plans where the relevant criteria are involved. For further reading of this subject I refer to TELL (1976), ZELENTY (1982), GOTTSCHALK & WENSTØP (1983).

The Pareto optimization multi-criteria models described in Ch. 4.2.2.2.1 are unique in the sense that they identify the set of feasible efficient solutions.

The methods described in Ch. 4.2 differs in particular regarding one aspect - complexity. The complexity increases in at least three directions:

(a) when going from simulation to optimization
(b) when going from one-criterion to multi-criteria (multi-objective) methods
(c) when going from deterministic to stochastic methods.

With the term "complexity" I mean factors like:

- Data input requirement
- Resources requirement (personnel, technical calculation means, time, financial resources)
- Understanding by the decision maker, and, thus, the decision maker's confidence in the results.

In deciding which method to use, given a choice between technological alternatives, the factors mentioned above are important. In general one has to consider the costs and benefits of going from one method to a more complex one for the particular problem being analysed. Among the most important <u>costs</u> elements are:

- Data collection
- Technical expertise

- Technical equipment (EDP capacities, etc.)
- Degree of understanding and involvement from the decision-makers , and from interest groups being influenced by the technological choice.

The <u>benefit</u> to consider will be the potential improvement of the decisions. For example one will have to consider:

- Are conflicting interests a significant part of the problem?
- Are subjective preferences a significant part of the problem?
- Do market prices adequately reflect the value of the resources used and created in the project?
- Is the dynamic perspective (i.e. time) important?
- Do the decision makers have the necessary understanding of the method?

These cost and benefit factors depend on the development objectives which are thought valid, and the structure of the problem (i.e. what factors are affected by the technological choice, their interrelationships and how exactly they can be quantified).

It is, therefore, not easy in general to recommend one of the methods, as each problem has to be considered separately.

However, in my experience, it is in most development projects not possible to quantify exactly enough the relationships between the various factors involved for applying the mathematical methods described in Ch. 4.2.2.1.2 and Ch. 4.2.2.2.1. In most cases one will have a limited set of technological alternatives to choose among. Often there will be more than one criterion to consider, and difficult to aggregate the criteria into one single criterion using the approaches described in Ch. 4.2.2.2.2. Conflicting interests will usually be involved, and the resources available (technological expertise, equipment, degree of understanding and involvement among the decision makers, time and financial resources) are in most cases rather limited.

All this points to the fact that, in the terminology of Ch. 4.2, it may be wise to use a <u>multi-criteria simulation</u> approach.

Assuming (a) that the target for the project's output as well as the technological alternatives available for providing this output are known[10], (b) the development objectives are explicitly given (or possible to arrive at implicitly), and (c) the Government of the country we have in mind looks upon the choice of technology as a steering perameter in its development strategy (cf. Ch. 1.3), the major steps in choosing technology on project level in a given country will then be:

1. Define a set of criteria which reflects reasonably well the development objectives, and select, whenever possible, operational indicators for each of the development criteria. These should, ideally, be the same for all projects considered in the country.

2. Decide what technological alternatives that are relevant.

3. Analyse the impacts of the alternatives on the operational indicators/development criteria.

4. Decide which of the technological alternatives that best fulfills the objectives.

This procedure is illustrated in Figure 4.2, showing major interactions between the factors described above. It is important to realize that the question of choice of appropriate technology cannot be regarded as purely a technical/economic exercise, but has to be done with due regard to the political aspect. In Figure 4.2 I have tried to indicate the role of politics. It should, in my opinion, be strong when deciding and clarifying development objectives and when selecting development criteria and operational indicators. In defining the technological alternatives worth considering, I believe political considerations may pay a weaker role. When choosing technology based on the impact analysis of the alternatives (the last step in Figure 4.2), it will most often be necessary to choose between alternatives having different relative scores on the various criteria used, and political considerations will be important in explicitly or implicitly deciding relative weights between the criteria. Only when Pareto situations occur it will be possible to avoid political considerations at this stage (cf. the brackets in Figure 4.2).

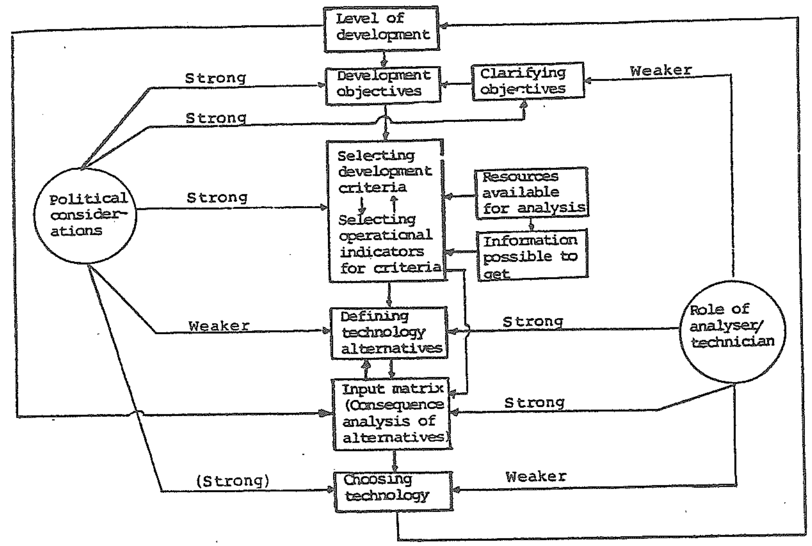


Figure 4.2. An overview of main issues regarding choice of appropriate technology.

The role of analysers/technicians are also indicated in Figure 4.2. Their role will be strong regarding defining what technological alternatives that are worth considering, and in doing impact analyses. Although weaker, the analyser could also influence on the clarification of objectives and the choosing process. The latter influence should not be overlooked as the analyser can hardly be fully objective. He will have to take subjective decisions for example regarding how to describe intangibles, what kind of sensitivity analysis to perform, how to present the results, etc.

Decisions on what technologies to consider may theoretically result in many alternatives. However, in reality, it is my experience that it is often fairly easy to reduce the number of interesting alternatives to an acceptable level.

A more important problem in practice is to secure that all relevant alternatives are included in the set of techniques selected for analysis. There is a considerable danger that the decision maker(s) might settle upon a given set of alternatives too fast. ZELENY (1982:100-101) states:

"The assumption that alternative decision options are prespecified is one of the most serious misrepresentations of real-world decision making that formal decision analysis makes. Preanalysis or predecision stages are rarely completed; rather, they represent the most active and important part of the decision-making process. Assuming otherwise leads to suboptimization, inflexibility, and poor adaptability".

The problem of generating decision alternatives are discussed quite in detail in e.g. ZELENY (1982:100-114) and CONWAY (1985). Regarding choice of technology, it is in my opinion very important at this stage of the decision prosess to use technical (engineering) expertise who has a broad knowledge of the problem analysed and a good understanding of the socio-economic and technical environment in which the technology is to be used. It is also highly important here to have a close cooperation between the technical expertise and the social scientists.

4.3.2 Operationalization of a set of criteria

This section aims at illustrating the previous sections by presenting an example of a set of criteria for choosing technology on project level in a nation X, and describing how the criteria might be operationalized. It is assumed a priori that the criteria set reflects adequately the development objectives of nation X's government and that the choice of technology on project level is regarded as an important steering parameter for development.

The criteria are not chosen by chance, but are supposed to reflect major development objectives in Tanzania, as discussed in Ch. 5.1.1 and Ch. 5.2.1. However, the criteria are supposed to be of interest also for other less industrialized countries, although their relative importance will vary from country to country as well as over time. The criteria are:

- Production efficiency in macro
- Employment
- Working conditions
- Distributional effects
- Integration
- Independency
- Ecological effects

- Risks (flexibility, uncertainty, irreversibility)
- Other factors

4.3.2.1 Production efficiency in macro

The term "production efficiency" is here used in a wide context meaning to describe the output of goods and services compared to the quantity of production inputs. The aim of efficiency is - assuming all other factors equal - to produce the desired quantity of goods and services with a minimum use of resources, or to produce a maximum quantity given the total amount of inputs.

Usually different technologies differ regarding relative use of inputs measured in physical terms or regarding quality of output. In order to judge which alternative is preferable it is necessary to introduce a set of values on the inputs and outputs wich reflects how the society ranks the various goods and services relative to each other - i.e. the set of p_{ti} in Eq. (4.4). In theory this would be a set of values reflecting the society's needs, available resources and objectives. In practice shadow prices are used, and the problem is to obtain reasonably accurate estimates of the shadow prices. As mentioned in Ch. 4.2.2.2.1 the literature on this field is vast. It seems, however, fair to say that one delicate issue in social cost-benefit analysis is just how much of the political issues should be left explicitly to the decision makers themselves to decide on. This dilemma is not easily solved, but the main point in such analysis must be to state as clearly as possible the assumptions underlying the set of shadow prices used, and carry out calculations of efficiency with different sets of shadow prices reflecting different options.

Most commonly used as operational indicators of production efficiency are: a) internal rate of return (IRR); b) net present value (NPV); benefit/cost ratio. According to DASGUPTA & PEARCE (1972) the considerable literature devoted to this topic appears to favour NPV as decision criteria. If the outputs of the different technological alternatives are equal in quality and quantity, it will in most cases be convenient to use <u>cost efficiency</u> as an indicator, thus avoiding the problem of valuing the output.

4.3.2.2 Employment creation

With some widening of the description of SEN (1975) it is possible to distinguish between at least five aspects of an increase in employment (it should be noted that several of these aspects are closely interrelated):

(i) the income aspect - i.e. employment gives an income directly to the employee, whose spending then indirectly affects the income of others

(ii) the production aspects - i.e. employment yields increased production, which again through forward and backward linkages influence production elsewhere

(iii) the recognition aspect - i.e. employment gives a person the recognition of being engaged in something worth while and can thus be a factor in selfesteem and in esteem by others

(iv) the disutility of efforts - i.e. employment might imply higher physical and mental stress, less freetime, etc. for the employee

(v) the stability aspect - i.e. increased employment might be of value e.g. to prevent vagrancy and crime and to keep political stability.

In theory the shadow price of employment used in the production efficiency (cost/benefit) analysis mentioned in the previous section should take care of all factors influenced by marginal changes in employment. It is possible in most cases to get reasonably accurate estimates on the above mentioned production and income aspects by considering previous employment/income, marginal propensities to save, and the marginal increase in production and income as shown for example in UNIDO (1972). However, regarding aspects (iii), (iv) and (v) it is in most cases impossible to estimate the effects with even a reasonable degree of accuracy. In such cases all employment effects are not included in the estimate of the shadow price of employment, and employment must be taken as a seprate decision criterion in addition to the production efficiency criterion.

As operational indicator could be used total employment measured as e.g. manyears.

In most developing countries the employment situation is worst for the unskilled and semi-skilled population. The employment indicator above should, therefore, recognize these categories as well as other groups given high employment priority (e.g. women, people from special districts, ethnic minority groups etc.).

It should be noted that if all aspects regarding employment are considered in the estimation of the shadow price of employment by using different sets of distribution weights and values as described e.g. in SQUIRE & TAK (1975), it will be double counting to consider the above mentioned indicators in addition to the production efficiency indicators discussed in the previous section.

4.3.2.3 Working conditions

It is important to analyse the employees' working conditions when appraising the various technological alternatives. At least the following factors should be considered (they are in many cases closely related).

- Physical strain
- Psychological factors - e.g. mental stress,isolation in work, satisfaction of creative work, boring routine labour
- Risk of accidents
- Influence on major decisions regarding own working situation.

The degree of physical strain could in some cases be indicated through ergonometric studies, and the risk of accident estimated by using relevant statistical data when available. However, most of the factors regarding working conditions cannot be given any operational indicators and have to be left to verbal appraisal.

SQUIRE & TAK (1975) show how these factors in theory could be incorporated in the calculation of the shadow price of labour as the variable "disutility of efforts". In practice, however, I believe that such incorporation is very difficult to do within reasonable degree of accuracy.

4.3.2.4 Integration

The essential point to consider is here: To what degree are the various technological alternatives integrated with first, the existing technological, economic and social structure of the country, and secondly, with the goals for the country's future development.

As indicators of degree of integration with the existing economic and technological structure could be used the forward and backward economic linkages. These linkages should be split according to both economic sectors and geographical areas (district, region, whole country, import/export). Estimates on direct and indirect effects by using economic-base theory or input/output analysis should also be done when possible. Any changes in existing production and employment should of course be considered.

It is difficult to find any indicators regarding integration with the existing social structure, and this point will therefore have to be outlined verbally. Examples of questions to consider here are (UNEP 1975): To what degree does a technological alternative lead to human settlement beneficial to the collective and individual lives of people rather than to the requirement of agglomerations of productive units? Will the existing fabric of social life be disrupted? Does the technological alternative increase, rather than diminish, the possibility and effectiveness of social participation and control? An important topic here is the organizational and managerial requirements of the technological alternatives.

Regarding integration with future development, it is difficult to find other operational indicators than the ones described above, adjusted for future structural changes planned. Most of the appraisal here has, therefore, to be done verbally. Among the important issues to considered are according to RWEYEMAMU (1976):

> "First, does the technology to be introduced stimulate new and wanted skills, capabilities, organization - i.e. does it contribute to institutional building? Secondly, does it lead towards more technological autonomy or towards increaed perpetuation of dependency? Thirdly, is it compatible with reasonable resource management on regional and macro level?"

These questions are closely related to the term "technological capability" analysed in FRANSMAN & KING (1984).

Regarding this criterion (integration) one should be particularly aware of the problem of double-counting, as several of the other proposed criteria (e.g. production efficiency, independency, other factors), may incorporate many of the aspects discussed above regarding integration.

4.3.2.5 Independency

Independency is here supposed to mean the capacity to stand alone. As outlined in GALTUNG (1974) and STEWART (1978) this is an important factor for most of the less industrialized countries. For the purpose of this presentation it is convenient to distinguish between independency on two levels: at the project (micro) level and at the macro level.

At the micro level, because of limited possibilities in most LIC of subsidizing industrial projects, a necessary condition for survival is, in most cases, that the projects are financially self-reliant - i.e. commercially profitable. In such cases, therefore, an important indicator of project level independency will be the financial profitability of the various technology alternatives. Other operational indicators to be used on this matter could simply be the distribution over time of subsidies and other transfers necessary for operating.

Regarding independency at the macro level the import of goods and services for investments and maintenance which the various technological alternatives demand and their dependency of exporting the output produced, are important factors. Here, the following operational indicators are suggested:

- Import of goods (type, quantity, costs)
- Import of personnel services (type, manyears, costs)
- Share of total production to be exported

The importance of the independency aspects will of course vary from country to country according to prevailing development strategy, resource basis, trade balance situation etc. It should also be noted that the macro level independency described above could be reflected in the shadow prices of imports and exports. If that is done, one should not include this criteria separately, to avoid double-counting. Also, it is seen that there are relatively close connections to the integration criterion described in Ch. 4.3.2.4. However, it should be pointed out that the independency criterion emphasizes the political aspects of being self-reliant, whereas the integration criterion emphasizes the economic and social aspects.

4.3.2.6 Ecological effects

Ecology means the study of the interrelationship between organisms and the environment. It is important to consider the technological alternatives' ecological effects regarding pollution, erosion, impact on vegetation and fauna, etc. (cf. PORTER & ROSSINI 1980, NORGARD 1987, PALO 1987, WRIGHT & GREEN 1987). In particular, irreversible changes should be given considerable attention.

As operational indicators various physical measures on pollution and erosion could be used, as well as measures of changes in number of endangered animal and tree species, etc.

4.3.2.7 Distributional effects

The point is here to consider the gain and loss distribution between the various interest groups influenced by the technological alternatives.

The income distribution is here of central interest, and as employment is one of the most effective means of affecting income distribution, the discussion above will be relevant also here. In this connection attention should also be paid to the spatial distribution on regions and districts, and the effects on particular interest groups as e.g. those mentioned under the employment section.

The classification of interest groups should be done according to overall development goals with a view to identifying the various groups affected by the technological alternatives.

In addition to the direct effects the indirect effects should also be included by using for example input/output analysis or economic-base theory if idle capacity can be assumed. In general, however, the estimates of indirect effects are burdened with considerably higher uncertainty than estimates of direct effects, and should, therefore, be presented separately.

As an operational indicator of the income distribution effect could be used the Gini-coefficient as defined in e.g. JAIN (1975). However, it might be easier understandable for the decision makers just to present the most probable distribution effects over time of the various interest groups considered. As shown in SQUIRE & TAK (1975) it is possible in theory to include the income distribution considerations in the estimation of shadow prices. However, this has to be done under certain assumptions regarding a welfare function of the society, and as these assumptions in most cases are highly debatable, such a method might cause more confusion than clarification. UNIDO (1972:289-290) shows how regional effects can be incorporated directly into the production efficiency estimates by giving special weights to the income accruing to particular regions. The advantage of such an approach is that, properly understood by the decision makers, it might give a more coherent decision process. However, as shown by HARBERGER (1978), the use of distributional weights in social cost-benefit analysis might involve analytical problems which are very difficult to solve.

4.3.2.8 Risks

Another important factor to consider is the flexibility of the various technological alternatives - i.e. how easily they are adjusted if changes occur. This problem is closely related to the question of risks[11]: What is the likelihood of failure - are any alternatives safer than others? The importance of explicitly recognizing the risks in our expectations about the future is discussed e.g. in LUNDGREN (1976).

A special case occurs when irreversibility is involved. As outlined in KRUTILLA & FISHER (1975) one should, in such cases, be aware that there is some benefit in refraining from irreversible development that appears warranted by relative benefits and costs when uncertainty is ignored. The analytics of this are described by ARROW & FISHER (1974) and FISHER & HANEMANN (1987), whose main conclusion is: The passage of time results in new information about the benefits (and costs) of alternative uses of our environment, which can in turn be taken into account if a decision to devote it to irreversible development is deferred. A decision leading to an irreversible development cannot be affected by the presence of new information which might suggest that the decision was a mistake. The main result is, then, that there is a benefit - an option value - in refraining from irreversible action even when no risk aversion and only expected values are considered. As pointed out by KRUTILLA & FISHER (1975) it is hard to quantify the size of this option benefit, although we know in what direction the effect should operate.

In theory there are several ways in which risk can be operationalized - cf. for example SAGE & WHITE (1980), SINN (1983), BORCHERDING et al. (1984). However, in practice it is not easy to estimate operational indicators, and in many cases this factor will have to be dealt with verbally.

4.3.2.9 Other factors

Here should be considered all factors of relevance not taken into account in the previous sections. This could be effects on micro-level, for example the various technological alternatives influence on the basic conflicts in the community they are to operate within: the dominance/dependence relationships, the division between rich and poor, the division within and among the underprivileged groups etc. HAQUE et al. (1977) elaborates this and concludes that one main criterion on micro-level should be what happens with the social conciousness and political power of the underprivileged groups (e.g. the ability to understand the extent of their psychological and material dependence, and their ability to assert their rights and bring out their potentials).

No operational indicators exist here, and verbal appraisal has to be used.

4.3.2.10 Awareness of double counting

It is important to emphasize the problem of double counting as mentioned several times above - i.e. to avoid that the same effect is used more than once in the proposed multi-criteria approach. This can be done only by explicitly specifying what types of effects are included in the various criteria used.

4.3.2.11 Impact matrix

First stage in the impact analysis will be to estimate the effects of technological alternatives on the criteria/indicators chosen, and establish an impact matrix e.g. of the type indicated in Ch. 4.2.2.2.2. If time and resources allow, and the benefit of using a more sophisticated method seems promising, one may proceed by using one of the multi-criteria optimization techniques described in Ch. 4.2.2.2.

It is also possible to weight all the criteria in one measurement unit and perform a traditionally cost/benefit analysis as outlined in Ch. 4.2.2.1.1. Such a weighting means that shadow prices on all criteria has to be decided upon. In theory this is possible, but in practice complications may easily arise as mentioned in Ch. 4.3.2.1 because of lack of empirical data. SHARIF & SUNDARARAJAN (1983) presents a quantitative model for this.

The method advocated above, implies a multidisciplinary approach. One problem will be to encompass a breadth of expertise while at the same time generating a common argument on worthwhile practical actions. For this the procedure described in CONWAY (1985) could be used.

4.3.2.12 The proposed method in a planning context

In this section I try to discuss briefly what type of planning is implicitly assumed in the appraisal method proposed in Ch. 4.3.2. For this I have used the theoretical framework outlined in FALUDI (1973) and used e.g. by FORSS (1985). This framework is not exhaustive, but comprehensive enough to give some connections worth while considering between project appraisal and planning theory.

One main hypothesis of FALUDI (op.cit.) is that the existing literature on planning can be paired together in three "bipolar dimensions", each characterized by two extreme types of planning. The three dimensions are:

(i) Blueprint versus Process mode of planning
(ii) Rational - comprehensive versus Disjointed - incrementalist mode of planning
(iii) Normative versus Functional mode of planning.

Blueprint versus process mode
The blueprint mode of planning derives mainly from civil engineering. The key role of the planner is to produce a best plan consisting of goals, means to achieve the goals, appraisal of the means, and budgets specifying resources needed and financial arrangements. The plan should be followed in detail.

The basic assumption of the blueprint planning mode is that it is possible to achieve given objectives with certainty. When the complexity of intervening variables is low and the rate of system change is slow, blueprint planning might be highly successful - for example in engineering works like dam constructions, large-scale factories and irrigation works.

In the process mode of planning flexibility is the basic concern. The plan document itself becomes far less significant than in the blueprint mode, as the main idea is to build in possibilities of changing directions as new knowledge is accumulated during the implementation phases. The role of the planners is to set long-term goals and to indicate ways of achieving them. The details of implementation are not decided beforehand, but during the implementation phases.

The appraisal method proposed in Ch. 4.3.2 falls within both these modes of planning, depending upon among other things:

(i) the complexity of the problem, and
(ii) the time lags between different phases of the implementation of the technologies.

If the complexity is high (i.e. many difficult technical and socio-economic factors are involved), and relatively long implementation time is necessary, risk, uncertainty and flexibility will be important, and the process mode of planning will be relevant regarding the choice of technology. If, on the other hand, risk and uncertainty are negligible, the blueprint model of planning will be relevant.

Rational-comprehensive versus disjointed-incrementalist mode of planning
The rational-comprehensive mode of planning assumes that the planning agency identifies all possible courses of action, all their desirable and undesirable effects, and makes the correct choice of action for the society. According to FALUDI (op.cit.:155) the rational-comprehensive planning is the approach "--- whereby the programmes put forward for evaluation cover the available action space and where the action space has itself been derived from an exhaustive definition of the problem to be solved".

The disjointed-incrementalist mode of planning, originated by Lindblom (LINDBLOM 1965, 1979), attacked the rational-comprehensive mode with particularly the following arguments (FALUDI 1973):

- It is not adapted to man's limited intellectual capacities
- It is not adapted to inadequacy of information
- Nor is it adapted to the costliness of analysis
- It is not adapted to failure, which must be anticipated in many circumstances
- It is not adapted to the closeness of observed relationship between fact and value in policy-making
- It is not adapted to the openness of systems of variables with which it must contend
- Finally, it is not adapted to the diverse forms in which policy problems actually arise.

LINDBLOM (op.cit.) argues that planning should proceed in a piecemeal fashion, the planners should focus on increments by which alternatives differ from the status quo - i.e. on an assessment of marginal differences. As FORSS (1985:32) says:

"The point of Lindblom's argument is that rational-comprehensive planning is simply not feasible; it is too distant an ideal ever to be reached. But the attempt to act according to the ideal distracts planners from more feasible approaches, such as strategies of simplifying decision problems. Lindblom argues that planning should proceed in a piecemeal fashion, the planners should focus on increment by which alternatives differ from the status quo; that is, on an assessment of marginal differences. This is so because it lies within the reach of human competence, information is likely to be available and the cost of analysis is low; also, non-incremental alternatives are often politically unfeasible because of the need for compromise. Rather than striving for a comprehensive evaluation of alternatives, planners should limit courses of action to those for which adequate information is available. Furthermore, the planner should eliminate consequences that are of no interest to him, and also those that are remote, imponderable, intangible and poorly understood. Planning should be undertaken with regard to a few, well understood ends".

Lindblom's view has been much critisized, among other thing because it is too pessimistic (it cannot be wrong to try to be rational in decision-making, even if the goal is set high), and because his mode of planning is inherently conservative as it strongly preserves status quo.

The appraisal method proposed in Ch. 4.3.2 is in my opinion built on the rational-comprehensive mode of planning. However, risk and uncertainty (Ch. 4.3.2.8) provides, to a certain degree, a link to the disjointed-incrementalist mode of planning.

Functional versus normative mode of planning

WEBER (1965) distinguishes between two types of rationality: "formal" and "value" rationality. Formal rationality refers to the efficiency in attaining given goals. Value rationality, on the other hand, is concerned with the basic considerations of what the purpose of man activities should be - i.e. one asks what the goals should be.

FRIEDMANN (1966/67) uses the term "functional" and "normative" planning.

Functional planning accepts the goals as given and the main purpose is to fulfill the goals as efficient as possible - i.e. the planners are rational with respect to the means only. Normative planning on the other hand, is equally concerned with ends and means and submits both to constant scrutiny.

The appraisal method proposed in Ch. 4.3.2 is a typical example of "formal" rationality in the above mentioned sense, or "functional" mode of planning in the terminology of FRIEDMANN (op.cit.). However, one should note that it is nothing in the method proposed in Ch. 4.3.2 that prevents from including the value or normative aspects as discussed above. This will increase and complicate the analysis as both goals and means have to be simultaneously discussed, but the final appraisal method will be the same.

NOTES CHAPTER 4

[1] I have not found any work where the major methods are compared. One reason could be that traditionally the multi-criteria approaches have been used mostly by engineering or other technically oriented professions, whereas cost-benefit analysis has been used by economists.

[2] This could for example be groups based on income class, sex, geographical location and age. The vectors a and x can in theory easily be expanded by one dimension to include these parameters.

[3] The Kaldor-Hicks compensation principle declares, in simple terms, a social state Y "socially preferable" to an existing state X if those who gain from the move to Y can compensate those who loose because of the move and still have some gains left over (KALDOR 1939, HICKS 1939). This criterion is also named the potential Pareto-improvement criterion.

[4] Assumption of definite number of alternatives is necessary for distinguishing between this method and the mathematical programming methods described in the proceeding chapters (cf. Ch. 4.2.2.2).

[5] Most commonly used as operational indicator of production efficiency are: a) net present value; b) internal rate of return; c) benefit/cost ratio. According to e.g. DASGUPTA & PEARCE (1972) the considerable literature devoted to this topic appears to favour NPV as decision criteria, at least for public investment decisions.

[6] One should be aware that the use of the net present value criterion is based on strict assumption regarding type of welfare function - cf. e.g. ARROW & KURZ (1970) and HOEL (1977).

[7] Dynamic Programming is an exception, as it covers only a definite number of alternatives - although they might be numerous.

[8] Several of the methods described in the previous chapters can be used also here.

[9] A vital task is to check to what degree the model chosen reflects the decision maker's preferences.

[10] As mentioned in Ch. 1.3 the project concept used includes the alternatives created by the following two questions: (a) Can a new, more appropriate technology be developed to produce the wanted output A? (b) Can output A be substituted by other technologies whose output and use are more attractive for the society than A from an overall point of view? These two questions just increase the number of technological alternatives to be analysed.

[11] In this study I use the term "risk" both when objective probabilities are assumed to exist and when subjective probabilities are used. I.e. I do not distinguish between uncertainty and risk as I assume that the former term is covered by subjective risk.

III ANALYSES OF CHOICE OF TECHNOLOGY IN PRACTICE - A CASE STUDY OF A FOREST PROJECT IN TANZANIA.

5 BACKGROUND DATA FOR THE ANALYSES

5.1 Socio-economic and geographical data

This chapter gives some background information for the analysis to be presented in Ch. 6 - Ch. 8 to increase the readers' possibility of judging the relevance of the empirical studies for other areas. Most of the technological choices in the project analysed were taken around 1975, and to cover the objective (iv) in Ch. 1.1.2 the

Map. 5.1. Tanzania.
(From FORSS 1985:XV).

background information is, therefore, focused on the situation in that period. The generality of the results obtained are then checked by analyzing the relative price development of the major production inputs shown in Appendix 4. Because of lack of data some of the information presented below is not up to date. However, most of that data have not changed significantly since 1977 with respect to the information of interest in the present study.

5.1.1 Tanzania

Tanzania[1] comprises an area of 945,00 sq.km (see Map. 5.1). Total population was in 1981 18.5 mill. with an estimated growth of 3.4 % p.a. (TANZANIA 1981:15). Average life expectancy was about 47 years in 1980, and GDP per capita 2,400 shs or about 300 US $ (op.cit:v, 13, 14).

Development objectives

The major policy institution in Tanzania since independence has been the political parties TANU (Tanganyika African National Union) and ASP (Afro-Shirazi Party) in Zanzibar - Pemba, which in 1977 were amalgamated into one party for the whole country - Chama Cha Mapinduzi (CCM) - the Revolutionary Party. It is beyond the scope of this paper to give a more detailed description of the political system in Tanzania, and readers are referred to NYERERE (1966, 1968, 1977), HYDEN (1980), RUDENGREN (1981). The following section concentrates on the development objectives in the three Five Year Plans of the country since independence. For a more detailed description I refer to SKARSTEIN & WANGWE (1986).

The First Five Year Plan (1964-1969) set the following long term objectives for 1980 (TANZANIA 1964):

(i) increasing the per capita income to shs 900 per year (at 1964 price level).

(ii) attainment of self sufficiency in high level manpower requirements.

(iii) improvement of the living standards of the population and increasing the life expectancy to 50 years.

In addition to these long term objectives, the plan had the following goals:

(i) to achieve an annual GDP growth rate of 6.7 per cent and to increase the investment to shs 4,920 million per year by the end of the plan period.

(ii) to reduce the predominance of agriculture and mining in the GDP to 50 per cent and to raise the contribution to GDP by industry to 7.5 per cent

The Second Five Year Plan (1969-1974) emphasized in addition to the objectives set forth in the long term plan (1964-69) the implementation of the principles outlined in the Arusha Declaration. These principles are (TANZANIA 1969):

(i) Self reliance - development through maximum mobilization of domestic resources, particularly through mobilization of the people.

(ii) Social equality - the spreading of the benefits of development through society to avoid wide disparities in income and wealth.

(iii) To encourage the development of economic activities undertaken through collective and cooperative efforts.

(iv) Economic cooperation with other African states.

The Plan aimed at achieving a GDP growth rate of 6.5 % per annum.

The Third Five Year Plan (1976-1981)[2] took up the same main objectives as the two previous Five Year Plans. Together with these objectives, the Third Plan emphasized the following (TANZANIA 1979):

"(i) Self sufficiency in food requirements by 1981.

(ii) Ensure that most of the primary commodities are processed into final and/or semi-final products both for home consumption and exports.

(iii) Develop and restructure the industrial set-up by laying due emphasis on basic industries and self sufficiency. Through this strategy the natural resources like iron and coal will be used as inputs in the production of various machine tools to satisfy Tanzania's basic requirements. By developing basic and heavy industries a strong base for the development of the various sectors of the economy shall be created, thus making it possible to produce within the country the industrial machinery for the industries that already exist. In order to fully develop the industries the production of raw materials such as iron will be emphasized.

(iv) Implement projects which together with ensuring permanent and efficient development of the economy, will have short gestation period.

(v) Give high priority to developing science and technical education, satisfying the requirements for water and electricity for industrial use, developing and strengthening transport and communication.

(vi) Regarding social infrastructure to complete and strengthen Universal Primary Education, to provide basic water and medical services in urban and rural areas, and to speed up the completion of village planning and the construction of permanent houses in villages.

(vii) Strengthen work organization and work discipline."

In the Third Five Year Plan GDP was projected to grow at an average rate of 6 % p.a. - monetary GDP at 6.75 % p.a. and subsistence GDP at an average rate of 3.9 % p.a.

According to MSUYA (1977) Tanzania has decided on a long-term industrial development strategy for the period up to 1995, in which seven national goals are identified to be used as a guide in selecting industrial projects: Industrial growth; structural change; employment generation; increased equality of income distribution; increased equality of regional development; workers' influence in industry; increased self reliance. The basic goal of the strategy is to raise the share of industry in GDP to 20 % by 1996. A further objective is that by 1996 60 % of industrial output should consist of intermediate and capital goods and 40 % of consumer goods. The new strategy emphasizes the development of basic industries - basic in the sense of (a) using domestic resources to meet the basic needs of the people; and (b) activities which establish the foundation of a self sustaining economy. The coordination of the different industries to create backward and forward linkages in the Tanzanian economy is emphasized in the strategy. It explicitly states that effectiveness in achieving the goals of growth, employment creation and regional dispersion of the industry will depend on the choice of technology, as in some industries the choice of technology is restricted, whereas in others a whole range of techniques is available. In the latter cases the strategy that

wherever suitable smallscale methods of production are available, they should be adopted.

Economics

One has to be cautious in drawing firm conclusions about the performance of the Tanzanian economy on the basis of the conventional GDP data. For one thing, there are considerable weaknesses in the official statistics. Secondly, the year to year fluctuations of GDP estimates are so sharp that any grouping of years can give a misleading picture. This is seen from the figures of the growth of GDP presented in Table 5.1.

Table 5.1. Growth of Tanzanias GDP at 1966 prices ,factor cost (% p.a.).

Year	Annual growth
1965	12.8
1966	4.0
1967	5.2
1968	1.8
1969	5.8
1970	4.2
1971	6.7
1972	3.0
1973	2.5
1974	5.5
1975	6.4
1976	6.5
1977	5.7
1978	5.5
1979	3.5
1980	3.1
1981	-1.7
1982	2.0
1983	-0.6
1984	2.6

Source: TANZANIA (1979) for the years 1968-76
TANZANIA (1983) " " " 1977-81
EIU (1986:10) " " " 1982-84

The figures reveal the importance of agriculture, as for example 1965 had exceptional high agriculture production, whereas 1968, 1972 and 1973 were years with severe droughts.

Gross domestic investment as a ratio of GDP rose from 15 % in 1965 to 22 % in 1973, and was in 1982 23 % (ILO 1978, TANZANIA 1983). This impressive growth in investment was not reflected in a higher

Table 5.2. Gross domestic product at factor cost by industrial origin.
(At 1966 prices).

(Million shs)

Industry	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Percentage Change 1981/82
1. Agriculture, Hunting, Forestry and Fishing	3,166	3,425	3,458	3,315	3,596	3,772	4,104	4,326	4,357	4,560	4,184	3,819	8.7
2. Mining and Quarrying	152	119	91	88	73	95	104	70	81	69	74	72	- 2.7
3. Manufacturing	784	850	888	900	903	1,063	1,152	1,104	1,244	1,048	761	568	- 25.4
4. Electricity and Water Supply	96	106	114	122	139	135	147	168	193	212	218	232	+ 6.4
5. Construction	300	402	418	413	392	360	358	347	406	419	504	479	- 5.0
6. Wholesale & Retail trade Restaurants and Hotels	972	990	1,039	1,068	1,074	1,092	1,181	1,127	1,170	1,166	1,107	989	- 10.7
7. Transport Storage & Communication	814	869	905	958	977	1,033	1,170	1,217	1,187	1,284	1,317	1,350	+ 3.1
8. Finance Insurance, Real Estate and Business Services		831	867	929	941	957	997	1,034	1,070	1,111	1,148	1,194	+ 4.0
9. Public Administration and Other services	952	1,071	1,157	1,362	1,581	1,790	1,986	2,013	2,107	2,313	2,673	2,907	+ 8.8
10. Less Imputed Bank Serice Charges	115	124	137	140	143	134	146	153	158	168	174	183	+ 5.2
11. GDP at factor Cost Subsistence Production	8,001	8,539	8,800	9,020	9,533	10,163	11,061	11,253	11,667	12,014	11,812	11,453	- 3.2
12. Agriculture, Hunting, Forestry and Fishing	1,644	1,805	1,833	1,799	2,029	2,097	2,302	2,632	2,644	2,246	2,847	1,592	-13.8
13. Construction	58	60	61	63	64	66	68	70	71	73	75	77	+ 2.7
14. Owner-occupied dwellings	521	536	551	568	584	602	618	638	657	676	696	719	+ 3.3
15. Total Subsistence Production	2,223	2,401	2,445	2,430	2,677	2,765	2,988	3,340	3,372	2,995	2,618	2,388	- 8.8
16. Total Monetary Production	5,778	6,138	6,355	6,590	6,856	7,398	8,073	7,879	8,259	9,019	9,194	9,047	- 1.6
17. Total Production (Subsistence & Monetary	8,001	8,539	8,800	9,020	9,533	10,163	11,061	11,219	11,667	12,014	11,812	11,435	- 3.2

Source: TANZANIA (1983).

Table 5.3. Gross domestic product at factor cost by industrial origin.
(At 1966 prices).

(Percentage)

Industry	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1. Agriculture, Hunting Forestry and Fishing	39.6	40.1	39.5	36.8	37.6	37.1	37.1	38.4	37.3	37.9	35.4	33.3
2. Mining & Quarrying	1.9	1.4	1.0	1.0	0.7	0.9	0.9	0.6	0.6	0.5	0.6	0.6
3. Manufacturing	9.8	10.0	10.0	10.0	9.4	10.4	10.4	9.8	10.6	8.7	6.4	4.9
4. Electricity & Water Supply	1.2	1.2	1.3	1.4	1.4	1.3	1.3	1.4	1.6	1.7	1.8	2.0
5. Construction	4.7	4.7	4.8	4.4	4.1	3.5	3.2	3.0	3.4	3.4	4.2	4.1
6. Wholesale & Retail trade Restaurant and Hotels	12.1	11.6	11.8	11.8	11.2	10.7	10.6	10.0	10.0	9.7	9.3	8.6
7. Transport Storage & Communication	10.2	10.2	10.3	10.4	10.4	10.1	10.6	10.8	10.1	10.6	11.1	11.8
8. Finance, Insurance, Real Estate and Business Services	10.0	9.7	9.9	10.3	9.8	9.4	9.0	9.1	9.1	9.2	9.7	10.4
9. Public Administration and Other Services	11.9	12.6	13.2	15.1	16.5	17.6	17.9	17.8	18.0	19.2	22.6	25.4
10. Less Imputed Bank Service	1.4	1.5	1.7	1.2	1.1	1.0	1.0	0.9	0.7	0.9	1.1	1.1
11. GDP at Factor Cost	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: TANZANIA (1983).

growth in output: in fact the incremental capital/output ratio rose continuously throughout the late 1960 s and early 1970 s and is estimated to have trebled between 1967 and 1974 (ILO 1978:10). One main explanation for this is (op.cit.) said to be the allocation of investments to long-gestating capital-intensive projects, mainly infrastructure, and the relatively poor performance of the agricultural sector.

The sectoral trends indicate that the relative contributions of manufacturing to GDP have increased steadily since the beginning of the 1960's until 1974, while that of agriculture has declined. Between 1961 and 1975 the percentage share of agriculture of GDP changed from about 56 to 41, while that of manufacturing increased from about 4 to 11 (ILO 1978:11). However, from about 1975 it is seen from Table 5.2 and Table 5.3 that the relative contribution of manufacturing in GDP has stagnated and declined, while that of public administration and other services has considerably increased.

Table 5.4: Tanzania's foreign trade.
(Mill. shs, current prices).

Year	Import (1)	Export (2)	Trade deficit (2) - (1)
1968	1,834	1,585	-249
1969	1,710	1,667	-43
1970	2,274	1,689	-585
1971	2,725	1,735	-990
1972	2,878	2,028	-850
1973	3,479	2,232	-1,247
1974	5,258	2,552	-2,706
1975	5,694	2,548	-3,146
1976	5,421	3,815	-1,606
1977	6,048	4,408	-1,640
1978	8,798	3,761	-5,127
1979	8,885	4,434	-4,451
1980	10,210	4,776	-5,434
1981	9,740	4,806	-4,934
1982	9,278	4,295	-4,983
1983	8,877	4,139	-4,738
1984	11,953	5,661	-6,292
1985(provisional)	15,552	5,440	-10,112

Sources: ILO (1978:30) for the years 1968-76.
TANZANIA (1983:30) for the years 1977-81.
EIU (1986:24) for the years 1982-85.

Tanzania has during the last years had an increasing deficit in balance of payment, as shown in Table 5.4. The deficit has been covered by foreign borrowing, foreign grants and by depleting the reserves of foreign currency. By the end of 1984 gross external liabilities stood at $ 3.23 bn of which $ 2.65 bn was long term debt. The gross external liabilities was in 1984 85 % of GNP, whereas in 1980 it was 51 % (EIU 1986:28).

<u>Employment</u>

ILO (1978) estimates that Tanzania's total labour force in 1975 was 6.3 million, of which only 470,000 had wage employment. The wage employment increased at a rate of 3.3 % p.a. during 1964-1974. In 1984 the total labour force was about 9,2 million, of which 732,000 had wage employment (EIU 1986:12).

This means that during the period 1975-1984 the labour force increased by 2.9 million persons or 4.3 % p.a. on the average, while the number of wage employment opportunities increased by 263,000, or 5.1 % p.a. on the average.

The estimates of un- and underemployment are somewhat unreliable, and seem to vary more with changes in definition than with time (ILO 1978:18). However, (op.cit.) an estimate of open unemployment in urban areas of 7-12 % is given. For rural areas the underemployment concept, though both conceptionally and statistically difficult to define, is a more realistic term than unemployment. The concept can be defined to include both seasonal and uneven utilization of labour, low productivity and low income. Viewed in terms of uneven utilization of labour it is stated (op.cit:16) that underemployment was a serious problem in Tanzania at least until villagisation was achieved. Studies (e.g. RUTHENBERG 1968) indicate that around 1967-68 only 20-50 % of the labour potential was absorbed in field work.

According to ILO (1978) it is clear that unemployment affected different groups in very different ways. For example, BIENEFELD & SABOT (1972) record an average unemployment of 4.5 % among males, while the corresponding rate for females was 20.9 %, and for youths between the age of 14 and 19, 23.2 %. Among migrants to cities the rate recorded (op.cit) was 18.2 % for those who had arrived in the city during the previous six months, 7.2 % for those who had arrived one year previous to that, and 3.9 % and below for earlier arrivals.

Equality

Regarding equality ILO (1978:13-14) states:

"Among the greatest achievements of the Tanzanian economy must be counted measures that have been instituted to reduce the extent of income inequality in the country. These measures have comprised a redistribution of productive assets through the nationalisation of estates, industries, financial institutions, wholesale trade and housing properties, as well as through the villagisation movement. Changing the direction of Government expenditure (more to agriculture, health and education particularly in rural areas), has also played an important part regarding greater equality. In the field of wages and salaries in the public sector the trend may be illustrated as follows: At the time of Independence (1963) the income of the top salaried personnel was about 50 times that of the lowest income-earner; by 1967 the ratio was down to 29, as compared to the minimum wage; and by 1976 (after changing the basis somewhat to compare after-tax incomes because of more progressive income tax being introduced), the ratio was 9."

The progress made during the last decades does not, however, imply that the Tanzanian economy is not facing serious problems. President Nyerere's description of the situation in 1977 seems to be valid also today (NYERERE 1977:1-2):

"Ten years after the Arusha Declaration Tanzania is certainly neither socialist, nor self-reliant. The nature of exploitation has changed, but it has not been altogether eliminated. There are still great inequalities between citizens. Our democracy is imperfect. A life of poverty is still the experience of the majority of our citizens. Too many of our people still suffer from the indignities of preventable desease and ignorance, and the aged and disabled do not all live in decency or even security, despite the clear statement in the Declaration that they have a right to support. Further, our nation is still economically dependent upon the vagaries of the weather, and upon economic and political decisions taken by other peoples without our participation or consent. And this latter is not a reciprocal situation; Tanzania is still a dependent nation, not an interdependent one".

Forestry and forest industry

The following presentation is mainly based on TANZANIA (1975) and DYKSTRA (1983). 44.4 million ha - i.e. about 50 % of Tazania mainland - is classified as forest, the main part being savanna woodland with a sparse tree vegetation. Average standing volume is thus only about 40 cu.m per ha. The different types of forest with corresponding standing volumes are shown in Table 5.5.

Table 5.5. Area and standing volume of the indigenous forests of Tanzania, 1975.

Type of forest	Area (1,000 ha)		Standing volume	
	Gross area	Net prod. area	Total (cu.m(r) mill.)	Cu.m per ha gross area
Closed forests	936	337	66	197
Woodland	32,641	25,803	1,213	47
Intermediate woodland	10,794	8,486	127	15
Total	44,374	34,636	1,406	41

Source: TANZANIA (1975:11).

The forest area includes 540 forest reserves comprising 13 million ha or about 30 % of the total forest area. Of this 1.6 million ha are classified as catchment forest. Plantation area covered 48,000 ha of softwood and 17,000 ha of hardwood in 1975, of which about 10,000 ha were local fuelwood plantations. In 1981 the area of forest plantations (man-made forests) totalled 640,000 ha (DYKSTRA 1983).

The domestic demand for wood is steadily increasing. In 1975 the total wood consumption was about 34 mill. cu.m, and was expected to raise to about 37 mill. cu.m in 1980 and about 48 mill. cu.m by the year 2000. At present almost 98 % of the total wood consumption comprises fuelwood, wood for charcoal and poles. Even by the year 2000 this part of the consumption is expected to be as high as 94%. The annual demand for industrial wood which was about 430,000 cu.m(r) in 1975, is expected to increase to about 1.1 mill. cu.m(r) in 1990 and about 2.9 mill. cu.m(r) in the year 2000.

In order to meet the increasing wood demand the forest plantation program was stepped up. During the Second Five Year Plan about 17,300 ha of softwood plantations were established. In the Third Five Year Plan the softwood plantation target was 34,400 ha, of this 18,000 ha aimed at producing pulpwood for the pulp and paper mill at Mufindi. The remaining 16,400 ha was for sawlog production. Moreover, the Third Plan comprised planting 6,000 ha of fine hardwood, mainly teak. The policy is to use more cheap softwood in the domestic market and reserve the fine hardwood for export. To satisfy the large demand for fuelwood about 67,000 ha of fast growing fuelwood plantations were to be established during the Third Plan period.

Sawmilling forms the major part of Tanzanias forest industry today. According to DYKSTRA (op.cit.) sawnwood production in 1981 totalled 87,000 cu.m, of which about 20,000 cu.m was from private sawmills, about 25,000 cu.m came from pitsawers, and the rest was produced by Government controlled sawmills. In addition the country has one particleboard mill and one fibreboard mill. By 1985 the Mufindi Pulp and Paper Mill, scheduled to produce about 65,000 tons of pulp per year, was ready.

More than 95 % of the forests in Tanzania is publicly owned by the Government. About 4,000 workers were employed by the Forest Division in 1975, whereas the parastatal organization TWICO (Tanzania Wood Industries Corporation) employed about 3,500 workers. According to TANZANIA (1975:65) the implementation of the forestry and forest industry plans in the Third Five Year Plan period needed an additional employment of about 8,000 full-time engaged workers (3,300 in forest industries) and about 90,000 short-time engaged workers.

5.1.2 Iringa Region and Mufindi District

Geography and ecology

Iringa region, comprising about 57,000 sq.km of land, is situated in the southern part of Tanzania and consists of three administrative districts - Njombe, Mufindi and Iringa Districts (cf. shaded area on Map 5.2).

Map 5.2: Iringa region within Tanzania. (From UNDP 1976:2.53).

The topography of the Region has two major features; firstly, a wide plateau running through Iringa and Mufindi Districts from north-east to south-west, with a steep scarp slope on the eastern side down to the Kilombero Valley, and a gentler dip slope, or more typically a series of wide steps, descending to the basin of the Great Ruaha River on the western side. Secondly, near the junction of Mufindi and Njombe Districts this plateau reaches the wide highland block of Njombe which rises towards the higest areas in the West. Then the surface declines to the Rift Valley, which is occupied largely by Lake Nyasa.

Rainfall occurs in one rainy season which is followed by a dry season. Mean monthly rainfall in excess of two inches occurs in only five months (December to April inclusive) over most of the Region. Exceptions to this are some of the highland zones of Iringa, Mufindi and western Njombe, where this period is seven months or more. The probability of annual rainfall is shown in Map 5.3. This pattern is explained by two features; firstly, the effect of the steep scarp slope of the Iringa highlands lying across the path of the south-east monsoon which carries moist air inland from the Indian Ocean. A rain-shadow effect on the north-western side of the Region is created. Secondly, a local climatic effect from Lake Nyasa is experienced on the far western part of Njombe District where rainfall in excess of 50 inches per annum is experienced, distributed over ten or eleven months of the year.

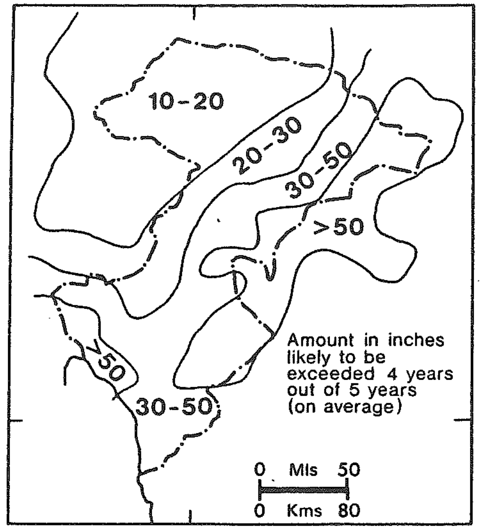
From an ecological point of view the Region can be divided into five main areas (UNDP 1976:2.13):

(i) The High Rainlands: The eastern fringe of all three districts and the Ukinga highlands can expect on average more than 50 inches of rain (1,270 mm) in four years out of five.

(ii) The Upper Plateaus: In central Mufindi and over much of Njombe there are high plateaus with a good probability of annual rainfall of 30-50 inches (760-1,270 mm),but in places with soils of low fertility.

(iii) The Medium-dry Intermediate Zone: In the west of the Region there is a zone of plateau steps and foothills between the high plateaus and the Usangu Plains. Rainfall diminishes rapidly westward and unreliability increases. About 35 per cent of the people of the Region live in this area which covers only 20 per cent of the land area.

Map. 5.3. Probability of Annual Rainfall in Iringa Region. Source: UNDP (1977:3.2).



(iv) The Dry Northern Fringe: This covers the largest land area but supports only a small proportion (4 %) of the total population. Five thousand square miles (12,950 sq.km) are covered by the Ruaha Game Park. Rainfall is low and the sandy soils are of very low fertility. Cattle are important and cultivation of paddy, maize and oilseeds takes place in the valleys.

(v) The Lake Nyasa Shore Zone.

Human population

According to UNDP (1976) and THOMAS (1976) the region had in 1975 about 850,000 inhabitants, with an estimated dependency distribution as shown in Table 5.6. About 150,000 persons were situated in Mufindi District, whereas Njombe and Iringa Districts had respectively about 360,000 and 340,000 inhabitants (op.cit.).

Table 5.6. Estimated population of Iringa Region in 1975 distributed on occupation dependency.

	Estimate I[a]	Estimate II[b]
Total regional population	885,000	837,000
Population dependent on agriculture	690,000	660,000
Population dependent on agricultural wage employment 1974-75	43,000	43,000
Population dependent on non-agricultural wage employment 1974	125,000	125,000
Population dependent on informal sector employment	27,000	9,000

[a]Source: UNDP (1976)
[b]Source: THOMAS (1976)

Actual and projected population growth rate is shown in Table 5.7.

Table 5.7. Actual and projected population growth in Iringa Region (% p.a.).

Period	Iringa District (rural)	Iringa Sub-District (urban)	Mufindi District	Njombe District
1967-70	3.4	7.0	3.0	2.4
1970-75	3.6	7.0	3.4	2.6
1975-80	4.0	7.0	3.7	2.9
1980-85	4.0	7.0	3.9	2.9
1985-90	4.1	7.0	3.9	2.9

Source: SOLVANG (1974)

THOMAS (1976) gives the sex and age distribution of the Iringa Regions population as shown in Table 5.8.

Table 5.8. Age and sex structure of Iringa Region's Population in 1975.

Age (years)	No. of persons		Excess no. of females	Males as percent of females
	Males	Females		
0-14	172,163	173,602	1,439	99
15-49	120,643	158,460	37,817	76
50-75+	30,034	34,456	4,422	88
Total (rounded off)	322,000	367,000	43,700	88

Source: THOMAS (1976).

The combined effect of inter-sex differences in migration and in mortality rates is seen in the marked differences of sex ratios for the different age groups.

In 1977 Mufindi District had about 170,000 inhabitants. About 9,900 had paid employment as shown in Table 5.9. The majority was seasonal (about 3 months per year) occupation in the two tea estates Brooke Bond and Stone Valley.

Table 5.9. Distribution of paid employment in Mufindi District 1977.

Employer	No. of employees (approximately)
Brooke Bond Tea Estate	5,000
Stone Valley Tea Estate	3,000
Forest Division	1,000
Services/Transport etc.	500
Sao Hill Saw Mill	200
District administration, etc.	200
Total	9,900

Source: DISTRICT DEVELOPMENT OFFICE (1977).

Agriculture

Although the statistics are somewhat unreliable it seems probable that around 85 % of the population of the Region were, by 1980, either completely or very nearly dependent upon agriculture for their source of livelihood for both food and cash income. The natural resource endowment of the region is favourable for a wide range of agricultural activities. UNDP (1976) has summarized the situation as follows by 1975:

(i) of the total land area of 56,850 sq.km, less than 5 % was cultivated.

(ii) 54 % of the land area had adequate rainfall for crop growth (taken as a probability of receiving 750 mm in nine years out of ten).

(iii) 29 % of the areas had soils of medium to high fertility with high development potential, and 21 % has soils of low to moderate fertility with moderate development potential.

Table 5.10 gives the size of the agricultural holdings and number of people engaged in agriculture in the three districts of Iringa Region. Table 5.11 gives the main crops cultivated in Mufindi District.

Communication

Two main communication lines connect the Region with other parts of Tanzania - the Tanzam Highway crossing Iringa, Mufindi and Njombe Districts, and the Tanzara Railway having stations at Kilombero and Makumbako (cf. Map 5.4.).

Map. 5.4. Iringa Region - main rivers and communications. (From UNDP 1976:2.2).

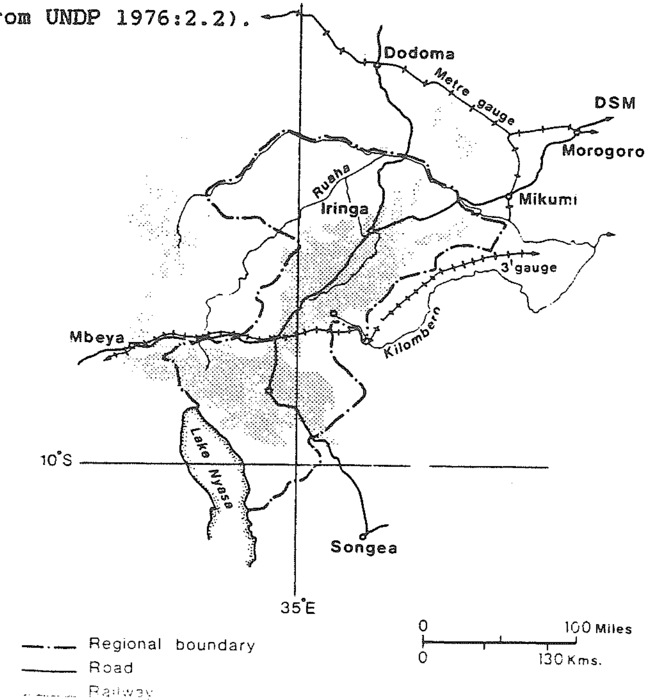


Table 5.10. Size of agricultural holdings by district, Iringa Region, 1971/72.
Source: UNDP (1976:2.32).

District	Total holding area (ha)	No. of parcels	No. of holders	Distribution of holdings by size class (ha) <0.5	0.5-1.0	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	5.0-10.0	10.0-20.0	>20.0	No. of people engaged in agriculture	No. of people dependent on agriculture
Iringa	52,900	74,142	41,985	15,321	10,866	9,253	2,329	748	1,167	1,997	304	-	87,400	195,500
Mufindi	26,800	36,725	20,764	5,949	4,055	6,361	3,683	97	522	97	-	-	50,500	100,900
Njombe	111,900	254,573	76,040	17,516	23,005	20,257	8,305	1,225	1,877	505	505	-	152,800	300,400
Iringa Region	191,600	365,404	136,789	38,786	37,626	35,870	14,316	4,195	2,915	3,971	809	-	290,700	596,800

Table 5.11. Small farm systems* in Mufindi Districts in 1976.
Source: UNDP (1976:2.34).

Type of Agricultural Enterprise	Subsistence Activities		Food/Cash Activities				Inedible Cash Crops	
Livestock (nos.)	"Other stock" Poultry	15,109 113,155			Cattle	24,851		
Legumes/oilseeds (ha)	Beans	200			Groundnuts Sunflower	300 300		
			Beans/maize/sunflower Beans/maize Peas/maize Beans/peas/maize	200 9,500 700 1,100				
Cereals (ha)	Millets	700			Maize Maize/wheat Wheat Paddy	4,600 800 200 200		
			(Other mixtures	1,000)				
Root crops (ha)	Sweet potatoes	300			Irish potatoes	200		
Cash crops (ha)							Pyrethrum	1,400

*Estate production is not included.

Table 5.12. Gazetted forest area by type and district Iringa region 1968.

		Closed Forest	Woodland	Grassland	Total
A. Productive Forest (ha)					
Iringa and Mufindi districts	C. Government	2,896	25,903	411	29,110
	Local authority	108	-	- -	108
	Total	3,004	25,903	411	29,218
Njombe district	C. Government	30	-	676	706
	Local authority	-	-	-	-
	Total	30	-	676	706
Iringa region	C. Government	2,926	25,903	1,037	29,816
	Local authority	108	-	-	108
	Total	3,034	25,903	1,087	29,924
B. Productive Forest (ha)					
Iringa and Mufindi districts	C. Government	205,864	417	72,970	279,251
	Local authority	1,498	-	-	1,498
	Total	207,362	417	72,970	280,749
Njombe district	C. Government	9,345	1,555	34,559	45,359
	Local authority	4,519	-	1,243	5,762
	Total	13,864	1,555	35,802	51,121
Iringa region	C. Government	215,209	1,972	107,529	324,710
	Local authority	6.017	-	1,243	7,260
	Total	221,226	1,972	108,772	331,970

Source: CONYERS (1969).

Forestry

The gazetted forests officially treated as lying within Iringa Region was in 1971/72 as stated in Table 5.12. The gazetted productive forest area was in 1968 less than 9 % of the total gazetted forest area of the Region, and the part under productive closed forest was approximately 1 % of the same area. In 1974 forest reserves were reported to be the same (UNDP 1976:4.91).

The areas of forest reserve as a proportion of total areas of districts are shown in Table 5.13.

Table 5.13. Gazetted forest area as a proportion of District and Regional areas 1968.

	Forest area (1)	District size (2)	Forest area (1) as % of (2)
Iringa and Mufindi District	3,100 sq.km.	35,800 sq.km.	8.7
Njombe District	518 "	21,030 "	2.5
Iringa Region	3,618 "	56,830 "	6.4

Source: UNDP (1976:4.91).

In addition to the above mentioned areas come forest plantations, which by 1973/74 were about 22,000 ha, of which 12,600 ha was wattle plantations in Njombe District (UNDP 1976:4.91).

In addition to the forest reserves and plantations an estimated 81 % of the area of Iringa and Mbeya regions is covered with unreserved forest or bush. This is mostly woodland of the open savannah type, although more dense forest occurs in the rainfall areas such as the Dabaga area of Iringa District. No regular records of changes in this area are maintained, but a Ministry of Development Planning report is quoted as referring to "much uncontrolled burning of forests" (UNDP (1976:4.91)).

However, apart from the localised areas around townships or adjacent to intensive tobacco production, UNDP (1976) assumes that in view of the large areas available per capita in Iringa Region, the supply of timber was adequate for the local rural consumption during the period of Tanzania's Second Plan.

The biggest sawmill in the Region is Sao Hill Sawmill producing about 15,000 cu.m of sawnwood per year. Except for the Mufindi Pulp and Paper Mill started operating in 1985, no other major forest industry exists in the Region.

5.1.3 Sao Hill

Sao Hill lies in Mufindi District (cf. Map 5.1, 5.2 and 5.5). The area is relatively flat with gently undulating slopes and wide flat bottomed valleys, ranging in altitude from 1,750 - 1,950 m a.s.l. Soils are kaolinetic with a low base exchange capacity.

There is a single peak rainfall of around 1,000 mm a year rising to about 2,000 mm a year near the Kilambero escarpment to the East. Table 5.14 shows the mean annual rainfall at various metereological stations in the Sao Hill/Mufindi area.

Most of the rainfall comes in the period from December to April. Figures 5.1 and 5.2 show the monthly mean amount of rainfall at Msiwasi Sawmill (point C on Map 5.5) and Irundi Height.

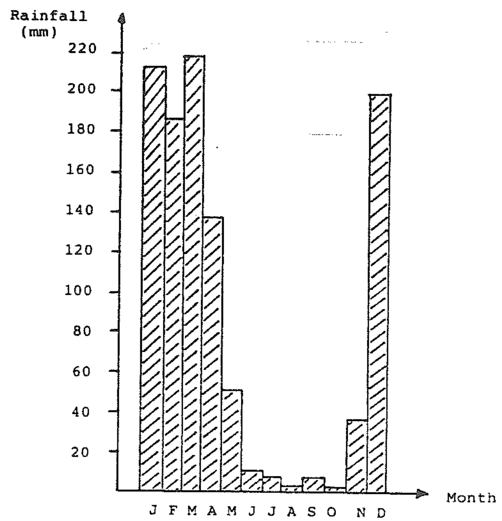


Figure 5.1. Msiwasi Sawmill - monthly mean rainfall in mm for the years 1956-1970.
Annual mean 1,057 mm.
Source: NYKVIST (1976).

Table 5.14. Mean annual rainfall of different meteorological stations in the Sao Hill-Mufindi area.
Source: NYKVIST (1976).

Station No.	Station	Lat. South	Long. East	Alt. m	Mean annual rainfall (mm)	Years measured
9834000	Madibira Mission	8°14'	34°49'	1159	667	1931-1972 (39)
001	Malangali School	8°34'	34°50'	1524	812	1931-1972 (37)
9835007	Mufindi Forest Station	8°40'	35°15'	1891	2009	-1975 (33)
008	Sao Hill Highlands Hotel	8°20'	35°12'	1981	936	1933-1951 (18)
009	Kilima, Mufindi	8°35'	35°20'	1860	1452	-1975 (31)
011	Mkewe Estate	8°24'	35°02'	1886	999	-1969 (27)
013	Wasa Mission	8°07'	35°15'	1678	858	-1972 (28)
017	Ulete Mission	8°07'	35°24'	1678	985	-1971 (19)
019	Ifupira Mufindi	8°30'	35°26'	1691	1274	-1975 (20)
021	Kidope, Mufindi	8°37'	35°15'	1983	1515	-1972 (21)
022	Luiga, Mufindi	8°37'	35°17'	1952	1534	-1975 (18)
023	Luisenga, Mufindi	8°37'	35°35'	2059	1705	-1973 (20)
024	Kiwere, Mufindi	8°38'	35°14'	1983	1679	-1975 (21)
025	Idege Tea Office	8°42'	35°12'	1922	1216	-1974 (21)
030	Msiwasi Saw Mill	8°29'	35°21'	1952	1057	-1970 (15)
033	John's Corner	8°15'	35°20'	1830	800	-1975 (7)
034	Matagutu	8°35'	35°21'		1282	-1975 (11)
035	Irundi Hill	8°26'	35°17'	1830	984	-1971 (10)
036	Irundi Hill North	8°28'	35°16'	1739	912	-1969 (5)
037	Irundi Hill West	8°29'	35°14'	1830	929	-1972 (4)
038	Ngwazi			1890	963	-1968 (1)
039	Mafinga Nat. Service	8°19'	35°18'	2074	665	-1972 (2)
040	Sao Hill Livestock	8°20'	35°18'	2074	829	-1975 (4)
042	Sadani	8°15'	35°00'		1169	-1972 (1)
044	Usokomi	8°15'	35°34'		976	-1972 (1)
046	Kisanga	8°37'	35°09'		889	-1972 (1)
047	Mapanda	8°26'	35°45'		1429	-1972 (1)

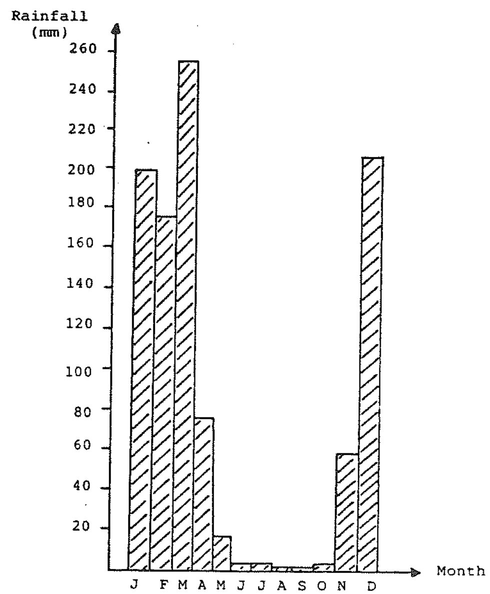
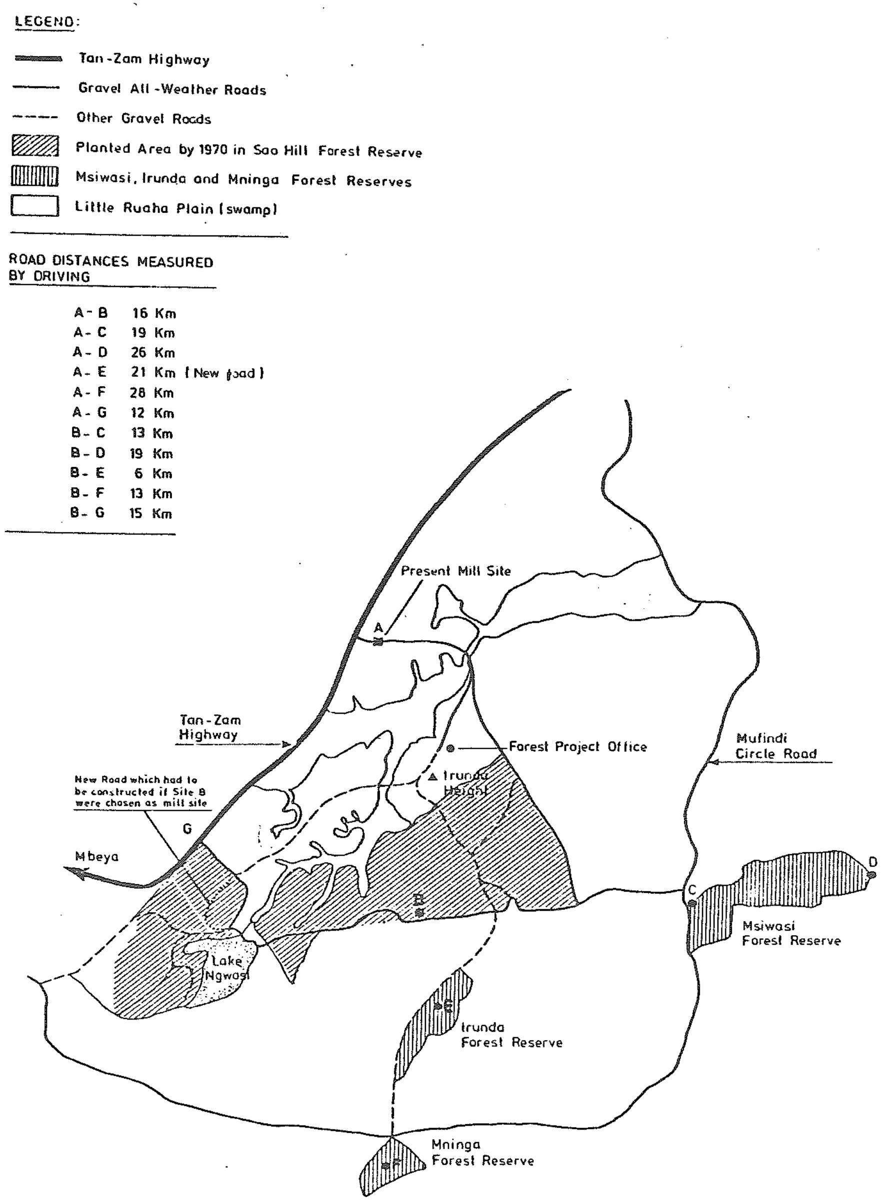


Figure 5.2. Irundi Hill - monthly mean rainfall in mm for the years 1962-1971.
Annual mean 984 mm.

Map 5.5. Sketch of Sao Hill Sawmill's log supply area. (From FERGUS et al. 1977:62).



Temperature varies from $15-30^{o}$ C in the day, to $5-15^{o}C$ in the night. At night temperature occasionally goes down to $0^{o}C$ (NYKVIST 1976).

The main communication line is the Tanzam Highway, which bypasses Sao Hill. Makumbako, about 60 km west of Sao Hill along the Tanzam highway, is the nearest railway station (cf. Map 5.4).

No settlement is allowed in the forest reserves. In 1977 about 13,400 persons were living in villages situated at the boundary of Sao Hill, Irunda and Msiwasi Forest Reserves, as shown in Table 5.15.

Table 5.15. Number of persons living in villages at the boundary of Sao Hill, Irunda and Msiwasi Forest Reserves in 1976.

Name of village	Total no. of inhabitants	Adults	Children (0-18 years)
Sawala	1,299	979	320
Mtwango	1,290	481	809
Igowole	2,294	1,700	594
Ibatu	477	179	298
Nzivi	1,970	570	1,400
Mpanga	1,256	447	809
Lufuna	1,001	442	559
Kibau	1,421	704	717
Ikwega	1,380	800	580
Ifupiro	970	500	470
Total (rounded off)	13,400	6,800	6,600

Source: DISTRICT DEVELOPMENT OFFICE (1977).

No industry except the Sao Hill Sawmill and the tea factories existed in the area in 1980, and most of the people are employed in agriculture. In the period February - May the two tea estates, Brooke Bond and Stone Valley, offer employment opportunities, but competition for this work is high from people of other neighbouring villages.

Forestry

Very little indigenous forests exist around Sao Hill. The softwood forest plantations of the area are spread on four forest reserves - Sao Hill Forest Reserve (F.R.), Msiwasi F.R., Irunda F.R. and Mninga F.R. (cf. Map 5.5). Their age, size and distribution of species were by 1977 as shown in Table 5.16.

Table 5.16. Size, time of establishment and major species of the Forest Reserves around Sao Hill. Source: FOREST DIVISION (1975).

Name of Forest Reserve	Area per 1975 (ha)	Standing sawlog volume per 1976 (cu.m u.b.)[a]	Year of estab.	Major species planted (%)		
				P. patula	P. radiata	Other
Sao Hill F.R.	8,422		1960-74	45	0	55[b]
Msiwasi F.R.	592	200,000	1951-58	85	0	15
Irunda F.R.	278	90,000	1957-59	35	65	0
Mninga F.R.	126	60,000	1954-56	70	30	0

[a]Estimates given by the Logging Manager at Sao Hill Sawmill, 1977.

[b]Mainly Pinus elliotti.

Access roads for log transport in 1977 were as shown on Map 5.5. The soil and terrain at Sao Hill are easy for road construction and logging (cf. Appendix 5).

5.2 Main assumptions in the analyses

All analyses of choice of technology have to be based on certain assumptions regarding physical, social and economic factors. In addition to the particular assumptions presented in the beginning of each of Ch. 6, Ch. 7 and Ch. 8, the analyses of the Sao Hill Sawmill project are based on the main assumptions described in the following sections.

5.2.1 In general

In the analyses the method described in Ch. 4.3.2 is used, and they refer to the overall conditions described in Ch. 5.1 for Tanzania, Iringa Region, Mufindi District and Sao Hill.

An average of 225 working days per year is assumed, based on the following estimate:

Total number of days	365	days per year
Sundays	52	"
Public holidays	25	"
Vacation days	30	"
Sick leave	10	"
Misc. out of production	23	"
Number of working days	225	days per year

5.2.2 Forest resources

The analyses are based on the forest plantations at Sao Hill described in Ch. 5.1.3. KLITGAARD & MIKKELSEN (1976) give yield tables for Pinus patula in Northern Tanzania, based on sample plots from the area around Mt. Kilimanjaro and Mt. Meru. ADEGBEHIN (1977) and ADEGBEHIN & PHILIP (1979) give a yield study of Pinus patula from the Sao Hill plantations. Based on these results and on MTUY (1975: Appendix IA) it seems realistic to classify the majority of the Pinus patula plantations at Sao Hill in site class III of Klitgaard's and Mikkelsen's study - i.e. having a dominant height of 26 m (24-28 m) at the age of 20 year (KLITGAARD & MIKKELSEN 1976:15).

Estimated yield of this site class is presented in Appendix 6. Based on that and on the data in Appendix 7 together with information given by the Sao Hill Sawmill's logging section, the average dimensions to be expected in Pinus patula plantations are estimated in Table 5.17.

Data regarding distribution of length and diameter of the logs are given in Appendix 7. The average log volumes estimated there do not correspond exactly to the log volumes given in Table 5.17, mainly due to different ways of calculating the average volume.

Pinus patula is the dominant species at Sao Hill. For the other species (mainly Pinus radiata and Cupressus lusitanica), it is assumed that the extraction volume per ha and volume per log on the average will be as shown in Table 5.17.

Table 5.17. Assumed dimensions in thinnings and clearfellings of Pinus patula at Sao Hill - site index 26 m.

	Age	Mean dbh[a]	Height (m)[a,b]		Prescribed nos. of stems cut	Average distance between trees cut	Volume (cu.m o.b.) per tree felled		Prescribed volume cut (cu.m o.b./ha)		Actual volume extracted[e]	Volume (cu.m) per log cut		Nos of logs per tree cut[h]
			H_{dom}	Average			Gross[a]	Net (to 14 cm top)[d]	Gross	Net (to 14 cm top o.b.)[d]		u.b.[f]	o.b.[g]	
	(Years)	(cm o.b.)			(stems/ha)	(m/trees)[c]					(cu.m o.b./ ha)			
1st thinning	12	8	18.0	15.0	600	4.1	0.050		30					
2nd thinning	18	17	24.4	21.5	350	5.3	0.271	0.195	95	68	60	0.095	0.103	1.9
3rd thinning	24	21	28.3	25.5	150	8.2	0.467	0.416	70	62	55	0.110	0.119	3.5
Clearfelling	30	31	30.0	28.0	400	5.0	1.250	1.213	500	485	435	0.200		5.5

[a] From KLITGAARD & MIKKELSEN (1976:9).

[b] Dominant height (H_{dom}) is the height corresponding to the average diameter of the 100 trees per ha with largest dbh, read on the diameter/height curve.

[c] Estimated assuming regular spacing of felled and standing trees.

[d] The following reduction % from gross volume is used, based on STRAND (1967): 2nd thinning: 28 %
3rd thinning: 11 %
Clearfelling: 3 %

[e] Net prescribed volume reduced by 10 % according to KLITGAARD & MIKKELSEN (1976:37). The estimates are rounded off to the nearest 5 cu.m/ha.

[f] Based on Sao Hill (1978 b:2) and Sao Hill (1979:3).

[g] Assuming, based on MTUY (1975:Appendix III), a barkvolume of 8 %, 8.5 % and 9 % for respectively 2nd thinning, 3rd thinning and clearfelling.

[h] Volume per tree divided by volume per log.

5.2.3 Calculation of direct financial effects

If not otherwise stated, all market prices quoted refer to 1977 price level in Tanzania.

To avoid bias in favour of the more labour intensive methods it is assumed that all employees are permanently employed - i.e. it is assumed that casual labourers, who in 1977 were paid about 30 % less than the permanent employed persons, are not employed.

Social benefits for the workers paid by the employer are assumed to be 15 % of gross salary[3]. In the following the quoted salaries include social benefits if not otherwise stated.

Except for the sawmilling alternatives analysed in Ch. 8, the analyses do not include costs regarding living houses for the employees, because it is assumed that they provide their own housing.

In the analyses the term "direct import" refers to items for which there were no sales agency in Tanzania in 1977, and which therefore had to be imported directly by a project. Stock of spare parts is assumed to be 10 % of the initial investment amount if the machinery is sold by Tanzanian agency and 20 % of initial investment amount if the machinery is imported directly, whereas working capital is assumed to be 30 % of recurrent expenditures (i.e. all cost except depreciation and interest costs)[3]. For buildings and road investments no stock of spare parts is assumed.

In the financial analyses depreciation costs, d, are calculated using a linear formula

$$d = \frac{I-A}{n}, \text{ where}$$

I is initial investment amount
n is write-off time
A is scrap value of the item in question

If nothing else is stated, A is assumed to be 10 % of I, and n:

5 years for vehicles
10 years for sawmill machinery and equipment
20 years for roads and buildings

3, 6, 9 and 12 % p.a. calculation rate of interests are used in the financial analysis. The interest costs are calculated separately for machinery, stock of spare parts and working capital. Interest costs of capital are assumed to be 9 % p.a. of $\frac{I+A}{2}$ (simplified formula) whenever total annual costs are calculated.

The analyses are based on cost-efficiency - i.e. it is assumed that the production outputs are equal quantitatively as well as quality-wise for the technological alternatives analysed.

The results are calculated without considering taxes[4].

The cost efficiency is estimated as net present values using the formula

$$NPC_f = \sum_{t=0}^{n} \sum_{i=1}^{m} \frac{C_{t,i}}{(1+r_f)^t} \quad \text{where} \qquad (5.1)$$

NPC_f is net present value of costs
n is length of the project (years)
m is maximum nos. of cost components considered
t is time, $t \in (0, n)$
i is cost component, $i \in (1, m)$
$C_{t,i}$ is amount of cost component i at time t
r_f is financial calculation rate of interest

5.2.4 Calculations of direct economic effects

In the economic analyses shadow prices differing from the market prices are used for unskilled, semiskilled and skilled labour, and foreign exchange. For all other production factors market prices are assumed to reflect economic values reasonably well.

As mentioned in Ch. 4.3.2 the calculation of shadow prices is not an easy task in practice. In the analyses I have therefore used various set of shadow prices on labour and foreign exchange. However, mainly based on WORLD BANK (1977) and HUGHES (1977), I have chosen the following as most probable estimates:

Un- and semiskilled labour	0.7 of market price
Skilled labour	1.3 "
Foreign exchange	1.6 "

The classification in Appendix 4 regarding labour skill, is used throughout the analyses. As calculation rate of interest is used 3, 6, 9 and 12 % p.a. Based on the discussion in WORLD BANK (1977) and HUGHES (1977), I have chosen 9 % p.a. as most likely estimate for Tanzania.

The economic efficiency criteria is cost efficiency estimated as in equation (5.2):

$$NPC_e = \sum_{t=0}^{n} \sum_{i=1}^{m} \frac{C_{t,i} \cdot s_i}{(1+r_e)^t}, \quad \text{where} \qquad (5.2)$$

NPC_e is net present value of costs
n is length of the project (years)
m is maximum nos. of cost components considered
t is time, $t \in (0, n)$
i is cost component, $i \in (1, m)$
$C_{t,i}$ is amount of cost component i at time t
s_i is shadow price of component i
r_e is economic calculation rate of interest

5.2.5 Calculations of indirect economic effects

The indirect economic effects of the various alternatives of technology analysed, are calculated using the input/output table for Tanzania from 1970 shown in Appendix I. The table has 45 production sectors. The indirect effects of the technology alternatives are estimated by adding one sector ("project sector") to the originally input/output matrix. In addition, the matrix is expanded by another sector to include consumption. This is done by taking Wages & salaries of Table A.1 (Appendix I) as delivering sector and Private consumption expenditures of Table A.1 as receiving sector. Thus, an input/output matrix of 47 sectors is used, satisfying the following relationship:

$X + MX - AX = Y$, where (5.3)

X is vector of activity level (each element x_j of X gives gross production of sector j, $j \in (1,47)$)

M is import vector

A is the technology matrix (each element a_{ij} of A gives the direct use of commodity i by sector j, i, $j \in (1,47)$

Y is the vector of final demand (each element y_i of Y gives final demand for the commodities of sector i, $i \in (1,47)$

Assuming among other things (CHENERY & CLARK 1959):

- production functions with constant elasticities of scale
- free production capacities
- constant input /output coefficients over time

Eq. (5.3) gives by multiplying with the identy matrix I:

$$(I + M - A)X = Y \quad (5.4)$$

Matrix inversion then gives:

$$X = (I + M - A)^{-1}Y = RY \quad (5.5)$$

$$R_T = R \cdot y_T \quad (5.6)$$

$$F_T = R_T - A \cdot y_T \quad (5.7)$$

where

R is the inverse matrix $(I + M - A)^{-1}$

y_T is the final demand of the logging technology alternative analysed

R_T is the vector of direct and indirect effects of Y_T

F_T is the vector of indirect effects

The production input structures of each of the technological alternatives are then put as y_T, and R_T and F_T are calculated as in the equations (5.6) and (5.7). The calculations are done for two alternative assumptions regarding consumption. First, it is assumed that increased direct and indirect incomes do not affect the total demand - i.e. it is assumed that the marginal propensity to save is one or the increase in consumption due to increased income in this project is offset by a corresponding decrease in other areas of the economy. Second, it is assumed that the marginal consumption propensity is 0.5 or 0.9 - i.e. that the increase in income (profit and salaries) caused by the project increases the total demand for goods and services according to these marginal consumption propensities. To make possible calculations of this effect, the matrix A was expanded by one sector (Private consumption and Wages and salaries) as described above.

As for all models, the use of input/output models represents simplifications of reality. Most decisive here is probably the increase in import prices from 1970 to 1977 in Tanzania (in particular after 1974/75) followed by changes in domestic and export prices. This has in practice probably lead to changes in the production structure trying to substitute import with domestic goods and services.

This is likely to have implied that the indirect economic effects in 1977 would be underestimated when based on an input-/output model from 1970.

NOTES TO CHAPTER 5

[1]Tanganyika gained independence on December 9, 1961. In 1964 a federation was formed between Tanganyika, Zanzibar and Pemba and the new state was named Tanzania.

[2]The period 1974-1976 was not covered by any Five Year Plan.

[3]This corresponds to the practice in 1977 at the Sao Hill Sawmill project.

[4]Taxes are not considered, mainly because it would complicate considerably the analyses, as factors like profit, loan (financing) conditions, inflation, marginal income tax rates, depreciation rules, fund establishment possibilities, etc. then would have to be included (cf. e.g. LUNNAN (1988) for examples of including such factors). Besides, it is doubtful whether the ranking of the technological alternatives would change, as the Tanzanian rules for calculating income taxes seem to be rather flexible.

[5]The marginal saving ratio of income in Tanzania is probably lower than 0.5. Very few empirical data exist here. However, O'KTINGATI & KOWERO (1984) indicates a marginal comsumption propensity closer to 0.8-0.9.

6 CHOICE OF TECHNOLOGY IN SKIDDING FROM SOFTWOOD THINNINGS

6.1 Brief description of the methods analysed

Three methods for thinnings in softwood plantations are analysed: The most capital intensive method, alternative A, is using agricultural tractor with 2-drum winch (Ford 6600-2 with Igland Compact 5000 winch). The second method, alternative B, is using sledge-skidding with oxen; and the third method, alternative C, is to pull the logs out manually by using skidding sulkies.

6.2 Assumptions

6.2.1 General

The analysis refers to skidding of logs from 2nd thinnings (age 15-18 years) in softwood (Pinus patula) plantations under conditions as described in Ch. 5.2. Smooth terrain with maximum slope of about 15 % is assumed. Mean dbh, volume per log, and extraction volume per ha are stated in Table 5.17 - i.e. respectively 17 cm, 0.103 cu.m o.b. per log and 60 cu.m o.b. per ha. Average distance between the trees extracted is about 5 m, and log size distribution as described in Appendix 7.

The access roads and the method of the log road transport from forest to industry are assumed to be the same for the three alternatives of technology, and are, consequently, left out of the analysis.

The branch roads are assumed to be used only for the 2nd thinnings with construction and maintenance costs as described in Ch. A 5.1, assuming optimal road spacing.

The piling costs are assumed to be approximately the same for the three methods.

Alternative C involves about one third more people than the alternatives A and B, and will therefore probably demand more work regarding personnel administration. Alternatives A and B are on the other hand likely to demand higher overhead costs regarding procurement of fuel, spare parts, repair and maintenance, fodder, medicines etc. I have therefore assumed that the overhead costs are the same for the three alternatives.

The calculations are based on an annual extraction volume of 9,000 cu.m o.b., assuming optimal utilization of all three technologies.

6.2.2 Particular assumptions, alternative A (agricultural tractor

Thinning is assumed to be done by taking out every 8th row of trees (i.e. about 20 m apart) to give place for the tractor. In between the rows selective thinning is done, giving a combination of a row and individual tree selection.

Each tractor is assumed to engage one driver with a salary of 7,200 shs per year and two helpers with a salary each of 5,400 shs per year. Investment and recurrent costs are assumed to be as described in Appendix 3 (Ch. A 3.3).

The tractor is assumed to run 7 hours per (8 hour) working day. Average skidding distance is 45 m (cf. Ch. A 5.3). The average productivity per 8 hour working day is assumed to be 22 cu.m o.b. per tractor.[1] 225 working days per year imply that two tractors will be necessary for extracting 9,000 cu.m o.b. per year, with an overcapacity of 10 %.

The costs of the tractor skidding are presented in Table 6.1, based on the data in Appendix 3 (Ch. A 3.1).

Table 6.1 Costs at 1977 market prices of skidding 9,000 cu.m o.b. per year with agricultural tractor in softwood thinnings.

Cost component	Annual costs (shs/year)		shs/cu.m o.b.	
	Total	Direct import	Total	Direct import
Depreciation (5 years write-off time)	68,000	18,000		
Interest: On machinery	18,600	5,000		
" stock of spare parts	4,400	1,200		
" working capital	3,600			
Insurance	3,000			
SUM (rounded off)	98,000	24,000	10.90	2.70
Fuel	29,800			
Lubrication oil	2,600			
Tyres	15,000			
Spare parts	46,000	4,000		
SUM machinery costs (rounded off)	191,000	28,000	21.20	3.10
Labour: Un/semiskilled	21,600			
Skilled	14,400			
TOTAL (excl. road costs)	227,000	28,000	25.20	3.10
Road costs: Labour - Un/semiskilled	4,400			
- Skilled	600			
Other costs	7,400			
TOTAL (rounded off)	239,000	28,000	26.50	3.10

6.2.3 Particular assumptions, alternative B (oxen)

Only a few data exist regarding ox-skidding in East-Africa. However, efforts have been made to arrive at realistic estimates based on the information available.

Productivity

FAO (1976:67-69) documents an average productivity of 11 cu.m o.b. per day per pair of oxen for 100 m skidding distance, flat terrain, eight-hour working day, average load size of 0.23 cu.m o.b. and chain skidding (i.e. the logs front end is neither lifted nor protected during skidding). If sledge skidding is assumed (i.e. the front end of the logs is protected or raised off the ground), an average skidding productivity of 21.5 cu.m o.b. per day (0.75 cu.m per load on average, otherwise same assumptions as above for chain skidding) is reported (op.cit.).

For chain skidding in softwood plantations in Malawi NDISALE (1978) reports a daily output per pair of oxen ranging from 2.8 cu.m (800 m skidding distance and rough terrain) to 14.2 cu.m (smooth terrain, skidding distance not mentioned). It is stated (op.cit.) that the best Malawi pair of oxen can drag a 0.57 cu.m green log more than 90 m without undue fatigue. It is unclear whether the volume figures given are measured over or under bark.

Based on 172 observations from 4 different pairs of oxen using chain skidding in softwood thinnings in Malawi, SOLBERG & SKAAR (1986) presents the following function of productivity:

$$PRODWP = 4.53 - 0.0284\ DIST + 4.32\ 10^{-5} DIST^2 + 5.00\ VOL - 0.27\ NRLOG \quad (6.1)$$

$R^2 = 0.78$

where

- PRODWP is skidding productivity per work place hour per pair of oxen (cu.m o.b. per hour)
- DIST is skidding distance in m (one way)
- VOL is load volume of timber in cu.m o.b.
- NRLOG is number of logs per load
- R^2 is correlation coefficient

Average terrain speed (skidding and return) observed was 2.7 km per hour (including necessary delay time for rechoking of logs and adjustment of load during skidding, but no other delay time included).

The terrain gradient varied from flat to 10 % downhill skidding.

All coefficients in equation (6.1) were statistically significant on 0.01 % level. Observed maximum, minimum and mean values were as follows:

	Maximum	Minimum	Mean
DIST (m)	410	15	194
VOL (cu.m o.b.)	0.932	0.102	0.476
NRLOG	6	1	2.9

The only information available from Tanzania regarding ox-skidding refers to two pilot studies done by the Division of Forestry, University of Dar es Salaam, Morogoro and recorded in HEDING & OLE-MEILUDIE (1979). The studies refer to skidding with one pair of oxen in a 16-year old *Pinus patula* compartment at Sao Hill Forest Reserve. The terrain gradient was 10 % and the ground surface smooth.

Two ox-skidding methods were analysed. The simplest method was to have one end of the chain attached to the yoke and the other to the log(s). The second method was to use a skidding sledge, constructed of glassfibre and specifically designed for the skidding task. The sledge is shown in Fig. 6.1.

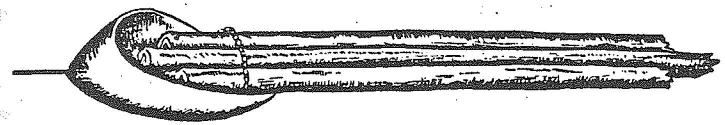


Figure 6.1 The skidding sledge.

The work cycle elements of the study are shown in Table 6.2. The average speed was recorded to be (op.cit.:8):

	Skidding	Return
Chain-skidding	1.8 km/hour	2.2 km/hour
Sledge-skidding	3.6 "	3.0 "

For sledge skidding the time for returning unloaded took more time than skidding loaded, which is a common result with draught animals. For chain-skidding, however, the situation was opposite indicating that the skidding now became more troublesome, and it is quite clear that the skidding sledge reduced the ground friction considerably, thus permitting higher speed.

Table 6.2 Work cycle element in ox-skidding.

Work cycle element	Chain-skidding: Time per load, min	Chain-skidding: % of total round trip	Sledge-skidding: Time per load, min	Sledge-skidding: % of total round trip
Loading	1.25	16.9	1.40	19.4
Skidding	2.71	36.7	2.21	30.7
Unloading	0.53	7.2	0.28	3.9
Return	2.23	30.2	2.61	36.2
Delay	0.67	9.0	0.71	9.8
TOTAL	7.39	100.0	7.21	100.0

(Source: HEDING & OLE-MEILUDIE 1979:8).

The average size of load in the study was 0.18 cu.m o.b. for chain-skidding, the biggest load recorded being 0.24 cu.m o.b. Using sledge the average loadsize increased to 0.21 cu.m o.b. and, more importantly, the maximum loadsize to 0.45 cu.m o.b.

In the study logs bigger than 0.45 cu.m o.b. could not be pulled by a pair of oxen with the sledge alone. However, by using in addition a sulky to lift the rear end of the log off the ground, the pair of oxen carried without difficulties three large loads of respectively 0.52, 0.41 and 0.52 cu.m o.b. to the landing. No upper limit for the load size was established in the study for this method.

HEDING & OLE-MEILUDIE (op.cit.) give the productivity figures shown in Table 6.3, which are based on the following assumptions:

- the time used for loading and unloading is constant
- the average skidding speed is 3.6 km per hour
- the average return speed is 3.0 km per hour
- the delay time is on average 9 % of the total effective time
- the total work place time is the sum of the delay time and total effective time
- the average load size is 0.21 cu.m o.b.

Table 6.3 Skidding distance, corresponding time consumption and productivity for sledge-skidding.

	Average skidding distance, m: 20	40	60	80	100	150	200
	Time, centiminutes						
Loading	140	140	140	140	140	140	140
Skidding	33	67	100	134	167	251	335
Unloading	28	28	28	28	28	28	28
Return	40	79	119	158	198	297	395
Total effective time	241	314	387	460	533	716	898
Delay	27	35	43	51	59	79	109
Total work place time per load	268	420	430	511	592	795	1009
Productivity in cu.m per work place hours	4.7	3.6	2.9	2.5	2.2	1.6	1.3

(Source: HEIDING & OLE-MEILUDIE 1979:9).

For doing the study, one ox-driver with two oxen and an assistant from a nearby village were hired. Neither the people nor the oxen were accustomed to work in the forest, and they got only one day of training before the pilot study. Also, the pattern of cutting was not planned in a way suitable for ox-skidding (op.cit.:7). For these reasons the figures recorded in the study are likely to reflect a lower productivity than can be expected with a properly trained crew.

Based on this information, average load size in sledge skidding is assumed to be 0.21 cu.m o.b. and the average terrain speed (skidding and return) 3.3 km/ha. This gives an optimal road density of about 65 m/ha, corresponding to an average skidding distance of 40 m (cf. Ch. A 5.4). Based on the data in Table 6.3, 3.2 cu.m o.b. per work place hour has been chosen as a probable estimate of productivity, assuming that actual delay time in practice will be about twice as high as recorded in Table 6.3. According to NESTANDE (1975) a 5 hour working day is realistic for oxen. This means an average productivity of 16 cu.m o.b. per day per pair of oxen. Based on 225 working days per year three pairs of oxen will be sufficient for skidding an annual quantity of 9,000 cu.m o.b., with an overcapacity of 20 %.

With the same assumptions as above and 1.3 logs per load on average Eq. (6.1) gives a productivity of 4.15 cu.m per work place hour. This indicates that the chosen productivity of 3.2 cu.m per work place hour probably is a low estimate.

Costs of using oxen

It is assumed that oxen of East-African origin are used (Zebus - of Nganda, Bukedi, Boran, Ankale or Madagascar breed) having an adult weight of about 300 kg (NESTANDE 1975:AM 3/2).[2]

The cost of a 3-4 year old half-breed ox is assumed to be 800 shs (MANGAZENI pers.comm.). The oxen need about one month's training to learn proper skidding, and this is assumed to cost 400 shs per ox at the ox training center at Rujevo, Iringa region (NESTANDE, pers. comm.). The ox is assumed to be in work 5 years, till the age of 8-9 years when the slaughter (meat) weight is assumed to be 150 kg per ox, with average meat price 8 shs/kg, and the market price of skin and intestines being 150 shs per ox (MANGAZENI pers. comm.).

Based on NESTANDE (1975:AM 8/1-10/1) 20 oxen need a shelter of about 100 sq.m with roof of currugated iron sheet, altogether costing about 2,000 shs with assumed life-time 10 years. For six oxen I have assumed in the analysis a shelter costing 800 shs.

Dipping of the oxen once a week to prevent ticks is necessary, as well as vaccination attention. The costs of this at Sao Hill will be quite low as dipping units already exist in connection with the ujamaa villages. However, in the analysis a cost of 100 shs per year per oxen is assumed (MANGAZENI pers. comm.).

Feeding and watching the six oxen is assumed to require one man employed 1/2 of total work time, corresponding to a cost of 200 shs/month. For operating the oxen one driver and one helper (for load preparing etc.) per pair of oxen are assumed, having a salary of respectively 550 and 450 shs/month.

Based on NESTANDE (1975:AM 10/1) 6.6 F.U. (feed units) per day per ox are assumed necessary for feeding:

For maintenance	2.6 F.U./day
For heavy work	4.0 "
SUM	6.6 F.U./day

It is assumed that each of the oxen by grazing on the fire breaks in the forest plantations will get about 3.0 F.U. of roughed per day (MANGAZENI pers. comm., NESTANDE pers. comm.). The rest, 3.6 F.U., is assumed to be provided by high energy food in proportions and at costs as below (MANGAZANI pers. comm., MCDONALD et al. 1973):

Maize brain	2.20 kg/day	costing	0.50 shs/kg
Cotton seed cake	0.70 "	"	1.60 "
Pyrethrum marc	0.70 "	"	0.55 "

This gives a daily cost for high energy food of 2.70 shs per ox including 0.10 shs per day for minerals, or 990 shs per ox and year. The amount is likely to be more on the high than the low side as the oxen will require less high energy food in the rainy season and during days out of work.

The skidding sledge is assumed to cost 1,400 shs (imported, cif. price Dar es Salaam)[3], with two and a half year write-off time (HEDING & OLE-MEILUDIE 1979:11). For dragging chain, yokes etc. a cost of 500 shs per year per pair of oxen is assumed. In addition one skidding sulky as described in Ch. 6.2.4 is assumed necessary for extracting the logs bigger than 0.45 cu.m o.b. Less than 1 % of the logs are likely to be of that volume, and it is assumed that one sulky will be sufficient for sharing between the 3 pair of oxen. The price of this sulky is 500 shs for the steel part with 5 years write-off time, and 500 shs for the tyre (direct import) with 2 1/2 years write-off time. The costs of ox-skidding at market prices are presented in Table 6.4.

Table 6.4 Costs at 1977 market prices of ox-skidding 9,000 cu.m o.b. per year of softwood thinnings.

Cost component	Annual costs (shs/year) Total	Annual costs (shs/year) Direct import	shs/cu.m o.b. Total	shs/cu.m o.b. Direct import
Depreciation: Sledges	1,500	1,500		
Sulky - steelframe	90			
Sulky - rubberwheels	180	180		
6 oxen (incl. training)	180			
Shelter	70			
Interest: (9 % p.a.) On oxen/equipment	1,000	230		
" stock of spare parts	100	80		
" working capital	1,250			
SUM (rounded off)	4,000	2,000	0,50	0,20
Dipping	600			
Food of oxen	5,900			
Dragging chain, yokes etc.	1,500			
SUM - nonelabour costs	12,000	2,000	1.30	0.20
Labour: Un/semiskilled	18,600		2.10	
Skilled	19,800		2.20	
TOTAL COSTS - excl. roads	50,400	2,000	5.60	0.20
Road costs: Labour - Un-/semiskilled	5,100			
- Skilled	700			
Other costs	8,800			
TOTAL COSTS (rounded off)	65,000	2,000	7.20	0.20

6.2.4 Particular assumptions, alternative C (manual skidding with sulky)

The sulky used is assumed to be of the type described in FOSSER (1976) and OLE-MEILUDIE (1977:12-13) having a steel frame and rubber tyred wheels with diameter 40 cm and width 10 cm. The sulky is constructed to carry loads up to about 250 kg, and its weight is approximately 25 kg.

It is assumed that the sulky is in full-time operation. In the Sao Hill Sawmill project, the only place where the sulky is being used, the thinning is done by groups of two persons who do both the felling and the skidding, and the sulky is not utilized full time. The costs of using the sulky will, however, probably not depend signi-

ficantly on the time in use, because firstly the depreciation and interest costs of the sulky method are quite low (cf. Table 6.5) and, secondly, combining cutting and skidding as done in Sao Hill will give more varied and efficient work for the employees.

Regarding productivity FOSSER (1976:ANNEX II) reports 1.2 cu.m o.b. per hour[4] per sulky for a skidding distance of 40 m, one person per sulky and terrain slope of 20 degrees. SKAAR (1973:1) gives an average production of 1.9 cu.m o.b. per standard hour (i.e. effective time plus necessary delay time) per sulky[5] for a skidding distance of 33 m, two persons, and terrain slope of 20 degrees.

OLE-MEILUDIE & OMNES (1979) report an average production of 1.9 cu.m o.b. per effective hour for an average skidding distance of 20 m and terrain slope of about 10 degrees. In the Sao Hill Sawmill project the average daily production (felling and skidding) was 2.8 cu.m u.b. per 2-men crew[6] for the three months July - September 1978 (SAO HILL 1979) with an average skidding distance of 20 m. Using the figures for felling and skidding given in OLE-MEILUDIE & OMNES (1979), this gives a skidding productivity of 11.2 cu.m o.b. per sulky per day, assuming 10 % bark volume.

In the analysis a daily productivity of 9 cu.m o.b. per sulky is assumed. This estimate is based on an average skidding distance of 25 m and a manpower requirement of 1.6 mandays per sulky per day for skidding and log loading preparation.[7] For skidding 9,000 cu.m o.b. per year 5 sulkies will be necessary, giving an overcapacity of 11 % and an annual labour requirement of 8 man-years.

Based on FOSSER (1976) and OLE-MEILUDIE & OMNES (1979), the investment costs per sulky are assumed to be 1,000 shs, half of this amount being for the tyres. Write-off time is assumed to be 5 years for the metal part and 2 1/2 years for the tyres. The tyres are assumed to be direct import. Annual repair and maintenance costs are assumed to be shs 150 per sulky, of which one half is direct import. Salary for the sulky operators and the helpers are assumed to be 450 shs/month per person.

The costs at market prices are presented in Table 6.5.

Table 6.5 Costs at 1977 market prices of skidding with sulky 9,000 cu.m o.b. per year of softwood thinnings.

Cost component	Annual costs (shs/year) Total	Annual costs (shs/year) Direct import	Shs/cu.m o.b. Total	Shs/cu.m o.b. Direct import
Decpreciation	1,400	900		
Interest: On machinery	200	100		
On stock of spare parts	100			
On working capital	1,200			
Sum	2,900	1,000		
Spare parts	800	400		
Sum - non-labour costs	3,700	1,400	0.40	0.15
Labour costs un- and semi-skilled	43,200		4.80	
Total costs - excl. roads	46,900	1,400	5.20	0.15
Road costs: Labour un- and semi-skilled	7,100			
Labour skilled	1,000			
Other costs	12,200			
Total costs (rounded off)	67,000	1,400	7.40	0.15

6.3 Calculation of direct and indirect economic effects

6.3.1 Direct effects

Based on the assumptions in Ch. 6.2 the following calculations of the direct economic effects of the three alternatives of technology are presented.

Table 6.1, Table 6.4 and Table 6.5 give the annual and per cu.m costs at 1977 market prices of the three methods, assuming 9 % p.a. calculation rate of interests.

Table 6.6, Table 6.7 and Table 6.8 give the resource flow, measured at 1977 prices, of the three alternatives of technology. Based on these figures, Tables 6.9, 6.10 and 6.11 give a sensitivity analysis of the discounted net present costs of the three methods at various shadow prices (un- and semi-skilled labour, skilled labour,

import), relative annual price increases (labour, energy, import, other costs), total price increases (labour, energy, import, other costs, investment costs and recurrent expenditures), and calculation rate of interest (3, 6, 9 and 12 % p.a.). For example, it is seen from the first and second line of Table 6.9 that if total labour costs are increased by 10 % above the estimate used in the first line, the net discounted costs of alternative A at 3 % p.a. calculation rate of interest (and shadow price 1.0) is increased from 1,015,000 shs to 1,033,000 shs (rounded).

When all shadow prices are 1.0, Tables 6.9 - 6.11 give the discounted net present costs at 1977 market prices, the first 35 lines of Tables 6.9 - 6.11 thus giving a sensitivity analysis of financial cost efficiencies. As stated in Ch. 5.2.4 most probable shadow prices in 1977 of un-/semi-skilled labour, skilled labour and import are assumed to be respectively 0.7, 1.3 and 1.6, the last 46 lines of Tables 6.9 - 6.11 thus giving a sensitivity analysis of the economic cost efficiencies of the three alternatives of technology.

Table 6.6: Resource flow of using agricultural tractor in skidding 9,000 cu.m o.b. per year of softwood thinnings. At 1977-market prices (shs per year).

	YEAR 0	1	2	3	4	5
1 Investments [a]						
1.1 Un- and semi-skilled labour						
1.2 Skilled labour						
1.3 Energy (fuel, oil)						
1.4 Other domestic inputs	348,000					-98,000
1.5 Import	102,000					-12,000
2 Recurrent expenditures						
2.1 Un- and semi-skilled labour		26,000	Same for all years			
2.2 Skilled labour		15,000	Same for all years			
2.3 Diesel, oil		32,000	Same for all years			
2.4 Other domestic inputs		67,000	Same for all years			
2.5 Import		4,000	Same for all years			

[a] Including working capital and stock of spare parts of respectively 43,000 shs and 48,000 shs. Of the spare part amount direct import is 20,000 shs.

Table 6.7: Resource flow of using oxen in skidding 9,000 cu.m o.b. per year of softwood thinnings. At 1977 market prices (shs per year).

	YEAR 0	1	2	3	4	5
1 Investments[a]						
1.1 Un- and semi-skilled labour						
1.2 Skilled labour						
1.3 Energy (fuel, oil)						
1.4 Other domestic inputs	26,900					-27,100
1.5 Import	5,700		4,200			- 1,500
2 Recurrent expenditures						
2.1 Un- and semi-skilled labour		23,700	Same for all years			
2.2 Skilled labour		20,500	Same for all years			
2.3 Diesel and oil			Same for all years			
2.4 Other domestic inputs		16,800	Same for all years			
2,5 Import						

[a] Working capital and stock of spare parts are respectively 18,300 shs and 1,000 shs.

Table 6.8: Resource flow of using sulky in skidding 9,000 cu.m o.b. per year of softwood thinnings. At 1977 market prices (shs per year).

	YEAR 0	1	2	3	4	5
1 Investments[a]						
1.1 Un- and semi-skilled labour						
1.2 Skilled labour						
1.3 Energy						
1.4 Other domestic inputs	22,000					-19,800
1.5 Import	3,000		2,300			- 800
2 Recurrent ecpenditures						
2.1 Un- and semi-skilled labour		50,300	Same for all years			
2.2 Skilled labour		1,000	Same for all years			
2.3 Energy (fuel, oil)			Same for all years			
2.4 Other domestic inputs		12,600	Same for all years			
2.5 Import		400	Same for all years			

[a] Working capital and stock of spare parts are respctively 19,300 shs and 800 shs.

Table 6.9: Discounted net present costs of using agricultural tractor in skidding of 9,000 cu.m o.b. per year of softwood thinnings (shs.).

SHADOW PRICES LABOUR US&SS	SK	IMPORT	REL. PRICE INCR. (% P.A.) LABOUR	ENERGY	IMPORT	OTHER	TOTAL PRICE INCREASE (%) LABOUR	ENERGY	IMPORT	OTHER	INVEST	RECUR.	CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.) 3.	6.	9.	12.
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1014590	974381	938617	906670
1.0	1.0	1.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	1033367	991652	954564	921449
1.0	1.0	1.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	1052143	1008923	970512	936229
1.0	1.0	1.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	1070920	1026193	986460	951008
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	1029245	987861	951064	918205
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	1043900	1001341	963511	929740
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	1058555	1014820	975958	941275
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	1025587	985370	949593	917630
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	1036584	996358	960569	928591
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	1047580	1007346	971545	939552
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	1071620	1030081	993108	960060
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	1128648	1085779	1047599	1013452
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	1185677	1141478	1102089	1066841
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	1050101	1011161	976467	945428
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	1085610	1047542	1014318	984186
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	1121120	1084721	1052167	1022944
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	1080537	1035039	994628	958576
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	1146483	1095695	1050639	1010487
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	1212429	1156352	1106648	1062395
1.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1025528	984602	947869	915078
1.0	1.0	1.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1037871	995359	957597	923911
1.0	1.0	1.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1050446	1006674	967823	933188
1.0	1.0	1.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1063680	1018574	978567	942926
1.0	1.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1023439	982358	945838	913232
1.0	1.0	1.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1032760	990754	953431	920126
1.0	1.0	1.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1042575	999585	961412	927367
1.0	1.0	1.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1052904	1008873	969758	934969
1.0	1.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	1014619	974445	938708	906781
1.0	1.0	1.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	1014619	974485	938779	906876
1.0	1.0	1.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	1014587	974499	938628	906954
1.0	1.0	1.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	1014521	974484	938654	907011
1.0	1.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1024319	983461	947107	914622
1.0	1.0	1.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1034319	992795	955834	922797
1.0	1.0	1.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1044591	1002384	964801	931157
1.0	1.0	1.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1055135	1012230	974009	939622

Continues ....

Table 6.9 continued....

SHADOW PRICES			REL.PRICE INCR. (% P.A.)				TOTAL PRICE INCREASE (%)						CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.)			
LABOUR US&SS	SK	IMP CRT	LAB CUR	ENERGY	IMP CRT	OTHER	LAB CUR	ENERGY	IMP CRT	OTHER	INVEST	RECUR.	3.	6.	9.	12.
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1065457	1026410	991637	960540
0.7	1.3	1.6	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	1062721	1042291	1006301	974130
0.7	1.3	1.6	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	1099987	1058171	1020965	987720
0.7	1.3	1.6	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	1117252	1074051	1035625	1001310
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	1080111	1039890	1004064	972075
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	1094766	1053369	1016531	983610
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	1109421	1066848	1028977	995146
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	1083050	1043991	1009158	978027
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	1100645	1061572	1026760	995615
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	1118239	1079153	1044321	1013152
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	1122486	1082105	1046128	1013931
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	1179514	1137806	1100618	1067320
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	1236541	1193505	1155104	1120710
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	1106466	1068770	1035139	1005009
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	1147473	1111132	1078641	1049479
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	1188480	1153492	1122140	1093946
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	1130990	1086687	1047297	1012124
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	1196525	1146965	1102957	1063707
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	1262060	1207243	1158617	1115290
0.7	1.3	1.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1075881	1035808	1000144	968271
0.7	1.3	1.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1086863	1045699	1009090	976394
0.7	1.3	1.6	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1098425	1056103	1018452	984924
0.7	1.3	1.6	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1110595	1067045	1028372	993880
0.7	1.3	1.6	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1074305	1034387	998858	967102
0.7	1.3	1.6	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1083627	1042782	1006451	973996
0.7	1.3	1.6	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1093441	1051614	1014432	981237
0.7	1.3	1.6	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1103770	1060902	1022818	988829
0.7	1.3	1.6	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	1065503	1026512	991782	960718
0.7	1.3	1.6	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	1065503	1026576	991896	960871
0.7	1.3	1.6	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	1065452	1026598	991975	960994
0.7	1.3	1.6	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	1065347	1026575	992016	961086
0.7	1.3	1.6	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1075185	1035490	1000126	968492
0.7	1.3	1.6	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1085185	1044824	1008854	970667
0.7	1.3	1.6	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1095457	1054412	1017821	985067
0.7	1.3	1.6	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1106002	1064257	1027029	993693
0.5	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1041643	1004506	971410	941799
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1065457	1026410	991637	960540
0.9	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1089271	1048314	1011863	979285
1.1	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1113084	1070218	1032069	998029
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1065457	1026410	991637	960540
0.7	1.5	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1079155	1039047	1003306	971354
0.7	1.7	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1092934	1051684	1014975	982168
0.7	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1043464	1004434	969685	938618
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1065457	1026410	991637	960540
0.7	1.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1087449	1048387	1013589	982462
0.7	1.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1109442	1070362	1035540	1004364

Table 6.10: Discounted net present costs of using oxen in skidding 9,000 cu.m o.b. per year of softwood thinnings (shs.).

SHADOW PRICES			REL.PRICE INCR. (% P.A.)				TOTAL PRICE INCREASE (%)						CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.)			
LABOUR US&SS	SK	IMP CRT	LAB CUR	ENERGY	IMP CRT	OTHER	LAB CUR	ENERGY	IMP CRT	OTHER	INVEST	RECUR.	3.	6.	9.	12.
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291250	271920	254815	239610
1.0	1.0	1.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	311452	290538	272007	255543
1.0	1.0	1.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	331734	309157	289200	271476
1.0	1.0	1.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	351976	327776	306352	287409
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	291250	271920	254815	239610
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	291250	271920	254815	239610
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	291250	271920	254815	239610
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	292066	272752	255641	240430
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	292923	273583	256467	241250
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	293759	274415	257293	242069
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	295296	279662	262278	246819
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	307342	287403	269742	254027
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	315388	295145	277205	261235
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	292438	273417	256570	241582
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	293622	274913	258325	243554
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	294816	276410	260079	245526
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	319186	297615	278542	261599
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	347122	323311	302269	283588
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	375056	349006	325996	305577
1.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	303472	282938	264789	248674
1.0	1.0	1.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	316347	294534	275277	258197
1.0	1.0	1.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	329903	306733	286301	268198
1.0	1.0	1.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	344171	319562	297884	278698
1.0	1.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291250	271920	254815	239610
1.0	1.0	1.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291250	271920	254815	239610
1.0	1.0	1.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291250	271920	254815	239610
1.0	1.0	1.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291250	271920	254815	239610
1.0	1.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	291275	271954	254856	239657
1.0	1.0	1.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	291292	271982	254892	239699
1.0	1.0	1.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	291301	272003	254922	239736
1.0	1.0	1.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	291301	272016	254946	239768
1.0	1.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	293462	274000	256773	241455
1.0	1.0	1.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	295724	276128	258776	243344
1.0	1.0	1.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	298035	278303	260825	245279
1.0	1.0	1.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	300393	280524	262919	247250

Continues ...

Table 6.10 continued ...

SHADOW PRICES LABOUR US&SS	SK	IMP CRT	REL.PRICE INCR. (% P.A.) LAB OUR	ENE RGY	IMP CRT	OTH ER	TOTAL PRICE INCREASE (%) LAB OUR	ENE RGY	IMP CRT	OTH ER	INV EST	REC UR.	CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.) 3.	6.	9.	12.
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291872	272866	256037	241068
0.7	1.3	1.6	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	311675	291081	272856	256655
0.7	1.3	1.6	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	331477	309255	289675	272242
0.7	1.3	1.6	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	351280	327509	306494	287629
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	291872	272866	256037	241068
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	291872	272866	256037	241068
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	291872	272866	256037	241068
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	293211	274197	257359	242379
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	294549	275528	258680	243691
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	295887	276858	260002	245003
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	299918	280608	263500	248276
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	307965	288350	270964	255484
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	316011	296091	278427	262693
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	293563	274862	258287	243532
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	295254	276858	260538	245996
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	296944	278853	262788	248459
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	319369	298157	279391	262711
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	346865	323448	302744	284354
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	374362	348739	326097	305997
0.7	1.3	1.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	303829	283645	265794	249935
0.7	1.3	1.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	316425	294950	276055	259251
0.7	1.3	1.6	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	329686	306923	286839	269035
0.7	1.3	1.6	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	343644	319474	298171	279307
0.7	1.3	1.6	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291872	272866	256037	241068
0.7	1.3	1.6	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291872	272866	256037	241068
0.7	1.3	1.6	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291872	272866	256037	241068
0.7	1.3	1.6	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291872	272866	256037	241068
0.7	1.3	1.6	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	291913	272921	256103	241143
0.7	1.3	1.6	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	291940	272966	256161	241210
0.7	1.3	1.6	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	291955	272999	256209	241270
0.7	1.3	1.6	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	291955	273020	256246	241320
0.7	1.3	1.6	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	294085	274946	257995	242913
0.7	1.3	1.6	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	296347	277074	259999	244801
0.7	1.3	1.6	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	298658	279249	262047	246733
0.7	1.3	1.6	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	301016	281470	264141	248708
0.5	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	270164	252900	237600	223981
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291872	272866	256037	241068
0.9	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	313580	292833	274474	258155
1.1	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	335288	312800	292911	275241
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291872	272866	256037	241068
0.7	1.5	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	310645	290137	271985	255848
0.7	1.7	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	329426	307408	287932	270627
0.7	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	290159	271203	254385	239429
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	291872	272866	256037	241068
0.7	1.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	293545	274530	257689	242707
0.7	1.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	295218	276193	259341	244347

Table 6.11: Discounted net present costs of using sulky in skidding 9,000 cu.m o.b. per year of softwood thinnings (shs.).

SHADOW PRICES LABOUR US&SS	SK	IMP CRT	REL.PRICE INCR. (% P.A.) LAB OUR	ENE RGY	IMP CRT	OTH ER	TOTAL PRICE INCREASE (%) LAB OUR	ENE RGY	IMP CRT	OTH ER	INV EST	REC UR.	CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.) 3.	6.	9.	12.
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	303872	282508	263651	246931
1.0	1.0	1.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	327366	304117	283605	265423
1.0	1.0	1.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	350860	325726	303559	283916
1.0	1.0	1.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	374354	347336	323513	302408
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	303872	282508	263651	246931
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	303872	282508	263651	246931
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	303872	282508	263651	246931
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	304503	283121	264246	247513
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	305134	283734	264845	248095
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	305765	284348	265443	248677
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	310135	288536	269465	252549
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	316397	294564	275279	258168
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	322660	300592	281093	263786
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	304812	283673	265006	248445
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	305752	284838	266360	249960
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	306692	286004	267715	251474
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	333320	309593	288662	270109
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	362768	336679	313672	293288
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	392215	363764	338683	316467
1.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	318058	295296	275227	257451
1.0	1.0	1.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	333002	308755	287400	268504
1.0	1.0	1.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	348735	322913	300194	280111
1.0	1.0	1.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	365295	337803	313638	292297
1.0	1.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	303872	282508	263651	246931
1.0	1.0	1.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	303872	282508	263651	246931
1.0	1.0	1.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	303872	282508	263651	246931
1.0	1.0	1.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	303872	282508	263651	246931
1.0	1.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	303995	282628	263765	247040
1.0	1.0	1.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	304127	282750	263882	247150
1.0	1.0	1.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	304257	282873	263999	247262
1.0	1.0	1.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	304388	282999	264119	247376
1.0	1.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	305579	284108	265155	248345
1.0	1.0	1.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	307327	285749	266696	249755
1.0	1.0	1.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	309115	287427	268274	251280
1.0	1.0	1.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	310943	289145	269889	252800

Continues ...

Table 6.11: continued ...

SHADOW PRICES			REL.PRICE INCR. (% P.A.)				TOTAL PRICE INCREASE (%)						CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.)			
LABOUR US&SS	SK	IMPORT	LABOUR	ENERGY	IMPORT	OTHER	LABOUR	ENERGY	IMPORT	OTHER	INVEST	RECUR.	3.	6.	9.	12.
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	239924	223887	209706	197109
0.7	1.3	1.6	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	256645	239267	223907	210270
0.7	1.3	1.6	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	273365	254646	238108	223431
0.7	1.3	1.6	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	290086	270025	252310	236592
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	239924	223887	209706	197109
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	239924	223887	209706	197109
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	239924	223887	209706	197109
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	240934	224869	210662	198040
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	241944	225850	211617	198972
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	242953	226832	212573	199903
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	246187	229915	215520	202727
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	252449	235943	221334	208346
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	258712	241971	227148	213964
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	241133	225319	211326	198886
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	242341	226752	212945	200663
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	243550	228184	214565	202440
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	262708	244844	229057	215043
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	285492	265800	248408	232976
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	308276	286757	267759	250910
0.7	1.3	1.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	250021	232988	217945	204596
0.7	1.3	1.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	260656	242567	226608	212462
0.7	1.3	1.6	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	271653	252643	235714	220723
0.7	1.3	1.6	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	283639	263240	245282	229356
0.7	1.3	1.6	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	239924	223887	209706	197109
0.7	1.3	1.6	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	239924	223887	209706	197109
0.7	1.3	1.6	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	239924	223887	209706	197109
0.7	1.3	1.6	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	239924	223887	209706	197109
0.7	1.3	1.6	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	240127	224080	209885	197283
0.7	1.3	1.6	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	240332	224275	210075	197460
0.7	1.3	1.6	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	240535	224473	210264	197640
0.7	1.3	1.6	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	240750	224673	210455	197822
0.7	1.3	1.6	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	241631	225488	211210	198523
0.7	1.3	1.6	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	243379	227128	212751	199973
0.7	1.3	1.6	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	245167	228807	214329	201456
0.7	1.3	1.6	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	246995	230524	215944	202979
0.5	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	193853	181511	170576	160845
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	239924	223887	209706	197109
0.9	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	285956	266264	248836	233373
1.1	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	332088	308640	287966	269637
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	239924	223887	209706	197109
0.7	1.5	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	240840	224730	210484	197830
0.7	1.7	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	241756	225572	211262	198551
0.7	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	238662	222660	208512	195945
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	239924	223887	209706	197109
0.7	1.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	241186	225114	210901	198273
0.7	1.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	242448	226341	212095	199437

6.3.2 Indirect economic effects

The indirect economic effects of the technological alternatives are calculated using the input/output table for Tanzania as described in Ch. 5.2.5. As vector y_T are used the columns in Table 6.12. The results are presented in Table 6.13.

Table 6.12. Recurrent expenditures[a] used in estimating indirect economic effects of different tecnologies in skidding of softwood thinnings (shs/year).

Input specification for input/output table	Technology alternative		
	Alt. A (ag. tractor)	Alt. B (oxen)	Alt. C (sulky)
Sector 9 (Food grains)		5,900	
" 22 (Sawmilling and carpentry)		1,500	
" 24 (Chemicals & petroleum)	32,400	600	
" 27 (Automobile repair)	57,000		400
" 33 (Construction)[b]	7,400	8,800	12,200
" 38 (Banking & insurance)	3,000		
" 45 (Unspecified)		600	
" 47 (Wages and salaries)	41,000	44,200	51,300
Imports	4,000		
Depreciation[c]	68,000	1,700	1,400
Gross domestic product	109,000	45,900	52,700
Gross output	212,800	63,300	65,300

[a] Based on Table 6.1, Table 6.4 and Table 6.5, excluding interest costs.

[b] Road costs, except labour costs.

[c] Including import component.

6.4 Discussion of effects on different criteria of development

The discussion below is based on the assumptions and calculations in preceding chapters and concerns appraisal of the three technology alternatives according to the criteria mentioned in Ch. 4.3.2.

6.4.1 Production efficiency from a national economic point of view

Direct economic effects

Tables 6.9, 6.10 and 6.11 show that the use of oxen or sulky is significantly more favourable from a national economic point of view than the use of agricultural tractor. This is true for all shadow prices, price differences and rates of interests chosen in this study. The main reason is the higher capital costs and recurrent expenditure involved in the case of the agricultural tractor. At 9 % p.a. rate of interest and shadow prices 0.7, 1.3 and 1.6 of respectively un/semi-skilled labour, skilled labour and import, alternative A is 3.9 and 4.7 times more costly than respectively alternative B and alternative C.

Tables 6.10 and 6.11 show that at the above mentioned shadow prices and most probable estimates, skidding with sulky implies 44,000 - 48,000 shs lower net discounted costs than using oxen. The sensitivity analysis shows that the difference between the alternatives is most sensitive to relative changes in labour costs. When shadow prices are changed around the most probable estimate, the economic difference between the two methods is little influenced by changes in the shadow prices of import, but highly influenced by changes of the shadow price of un/semi-skilled and skilled labour. The reason for this sensitivity pattern is that labour is a major cost component in both methods and that the sulky method involves only un/semi-skilled labour whereas using oxen involves considerable use of labour defined as skilled personnel.

For all cost alternatives considered in Tables 6.10 and 6.11 the sulky method is economically preferable to using oxen.

Indirect economic effects

Table 6.13 shows that the indirect use of economic resources are significantly higher for alternative A compared with alternative B and C, the latter two being approximately equal in this respect. This implies that alternative A generates a higher indirect operating surplus than alternatives B and C.

Table 6.13. Direct and indirect economic effects of alternative technologies in skiddings from thinnings, Tanzania 1977 ('000 shs/year).

Variable	Alternative A (agr. tractor)			Alternative B (oxen)			Alternative C (sulky)		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
1. Marginal consumption propensity is 0									
Domestic inputs*	99.8	47.2	147.0	17.4	7.2	24.6	12.6	7.4	20.0
Imports	4.0	35.3	39.3	0.0	3.8	3.8	0.0	3.5	3.5
Subsidies, custom duties, other indirect taxes	0.0	8.5	8.5	0.0	0.6	0.6	0.0	0.6	0.6
Wages and salaries	41.0	20.5	61.5	44.1	4.6	49.7	51.2	4.9	56.1
Operating surplus	0.0	31.0	31.0	0.0	7.8	7.8	0.0	3.1	3.1
Depreciation	68.0	5.1	73.1	1.7	0.6	2.3	1.4	0.6	2.0
Net value added	41.0	51.5	92.5	44.2	12.4	56.0	51.3	8.0	59.3
Gross value added	109.0	56.6	165.6	45.9	13.0	58.9	52.7	8.6	61.3
Total (gross) production	212.8	147.6	360.4	63.3	24.6	87.9	65.3	20.1	85.4
2. Marginal consumption propensity is 0.5									
Domestic inputs*	99.8	84.1	183.9	17.4	36.5	53.9	12.6	41.1	53.7
Imports	4.0	41.1	45.1	0.0	8.3	8.3	0.0	8.8	8.8
Subsidies, custom duties, other indirect taxes	0.0	11.8	11.8	0.0	3.3	3.3	0.0	3.6	3.6
Wages and salaries	41.0	25.4	66.4	44.1	8.5	52.6	51.2	9.4	60.6
Operating surplus	0.0	48.6	48.6	0.0	21.8	21.8	0.0	19.2	19.2
Depreciation	68.0	6.7	74.7	1.7	1.9	3.6	1.4	2.0	3.4
Net value added	41.0	74.0	115.0	44.2	30.2	74.4	51.2	28.5	79.8
Gross value added	109.0	80.7	189.7	45.9	32.1	78.0	52.7	30.6	83.3
Total (gross) production	212.8	217.7	430.5	63.3	80.2	143.5	65.3	84.1	149.4
3. Marginal consumption propensity is 0.9									
Domestic inputs*	99.8	113.6	213.4	17.4	59.9	77.3	12.6	68.1	80.7
Imports	4.0	45.7	49.7	0.0	11.9	11.9	0.0	13.0	13.0
Subsidies, custom duties, other indirect taxes	0.0	14.4	14.4	0.0	5.5	5.5	0.0	6.0	6.0
Wages and salaries	41.0	29.3	70.3	44.1	11.5	55.6	51.2	13.0	64.2
Operating surplus	0.0	62.7	62.7	0.0	33.0	33.0	0.0	32.0	32.0
Depreciation	68.0	8.0	76.0	1.7	2.9	4.6	1.4	3.1	4.5
Net value added	41.0	92.0	133.0	44.2	44.4	88.6	51.3	45.0	96.3
Gross value added	109.0	100.0	209.0	45.9	47.4	93.3	52.7	48.2	100.9
Total (gross) production	212.8	273.8	486.6	63.3	124.7	188.0	65.3	135.3	200.6

* Not including wages and salaries and operating surplus.

An interesting aspect is that the indirect import usage of alternative A is 9 - 10 times higher than the direct import usage. The main reason for this is that the agricultural tractors are assembled in Tanzania, thus giving a low direct import, but a high indirect import of assembly parts.

Alternative B and alternative C differ significantly regarding indirect economic effects only as far as operating surplus at marginal consumption propensity 0 is concerned, alternative B being about 100 % higher than alternative C. The reason for this is the higher use of domestic inputs in alternative B, giving higher indirect operating surplus effects. When marginal consumption propensity is increased to 0.5 and 0.9 the indirect operating surplus effects are almost equal for the two technological alternatives. The reason is that higher direct wage and salary component in alternative C now gives indirect effects.

Adjusting for indirect operating surplus and taking account of the indirect import effects as well as the usage of skilled and un/semiskilled labour, it seems fair to conclude that from a cost efficiency point of view the indirect economic effects of alternatives B and C are about equal and preferable to those of alternative A.

6.4.2 Employment

Direct employment

Table 6.14 shows the most probable direct employment effects of the three technological alternatives.

The total direct employment effects of alternative C are 9.4 manyears per year as compared to 6.9 and 7.5 manyears for alternative A and alternative B respectively. The relatively high employment effects of alternative A results from the assumptions of two helpers per tractor. It is possible to reduce this to one assistant per tractor, but then productivity per tractor will decline. As capital costs are high relative to labour costs, this is not economical in Tanzania. Similarly, one may discuss to what extent one helper per pair of oxen is necessary in alternative B.

Table 6.14 Direct employment effects[a] of skidding 9,000 cu.m o.b. per year of softwood thinnings.

Type of personnel employed	Direct employment generated (man-years per year)		
	Alt. A (tractor)	Alt. B (oxen)	Alt. C (sulky)
Un- and semi-skilled personnel	4.8	4.4	9.3
Skilled labour	2.1	3.1	0.1
Total	6.9	7.5	9.4

[a]Including employment in road construction (cf. Tables 6.1, 6.4 and 6.5) with assumed annual costs of 5,400 shs and 7,400 shs per manyear of un-/semiskilled personnel and skilled personnel respectively.

It is also seen from Table 6.14 that alternative C gives about 100 % higher employment of un- and semi-skilled personnel than the other two technology alternatives, the ox-drivers being classified as skilled labour.

Indirect employment effects

Wages and salaries in Table 6.13 may be a reasonably good indication of indirect employment effects, assuming approximately similar wages and salary levels in the various economic sectors.

Because of greater use of domestic production resources, the indirect employment effects of alternative A must be higher than those of alternatives B and C, as shown in Table 6.13 for wages and salaries. For alternative B and alternative C the indirect employment effects are approximately equal.

6.4.3 Working conditions

Alternative C gives higher physical strain for the employees than the other alternatives. However, FOSSER (1974) shows that on moderate slopes (20-30 % steepness and lower) and skidding distances shorter than 100 m, the physical strain, measured as pulse rate, is well below the pulse rates for Norwegian timber cutters working with powersaw. This indicates a physical strain for alternative C that should be acceptable. Between the alternatives A and B there is no significant difference regarding physical strain.

Regarding psychological strain it is difficult to state that one alternative is better than the others. Alternative A might give higher prestige than alternatives B and C. This might on the other side be viewed as a negative factor for other workers occupied in less capital intensive activities.

Although no relevant empirical data exist, the risk of accidents might be some higher for alternative A than for the other alternatives, which ought to be equal in this respect.

Regarding workers' influence on their own working situation, the three alternatives seem to be approximately equal, although it might be argued that in alternative B and C the workers will be more self-reliant and therefore have more control than in alternative A.

Based upon these arguments, I rank alternative B before alternative A, which again is ranked before alternative C with respect to working conditions.

6.4.4 Integration

Because alternative A as shown in Table 6.13 has a significantly higher direct and indirect import usage than alternative B and alternative C, it may be argued that the latter two alternatives are more integrated in the present economic structure of Tanzania, of course with the limitations of the input/output model used.

Regarding integration with the present social structure and the future economic and social development of Tanzania, I refer to the other criteria discussed in Ch. 6.4 and the discussion in Ch. 4.3.2.4. However, regarding technical skill formation, I rank alternative A before the other two alternatives, which are about equal on this aspect.

6.4.5 Independency

Regarding independency on micro level - i.e. financial profitability (cf. Ch. 4.3.2) - it is seen from Tables 6.9, 6.10 and Table 6.11 (for shadow prices 1.0) that alternative B is slightly better than alternative C, and that these two alternatives are significantly better than alternative A.

The same results emerge from Table 6.13 regarding independency on macro level indicated as direct and indirect import usage.

The reason for alternative B being more preferable than alternative C from a financial, but not an economic point of view is that the shadow prices 0.7 and 1.3 for respectively un/semiskilled and skilled labour favour alternative C, which demands no skilled labour.

6.4.6 Ecological effects

None of the three alternatives of technology is ecologically damaging. Although alternative B and alternative C are based upon more renewable resources than alternative A, the three alternatives are about equal with respect to ecological effects in Tanzania.

6.4.7 Distributional aspects other than personal income

The most important distributional effect not regarding personal income, is in this case regional income, where alternative B and alternative C are about equal. Because alternative A involves such a high use of resources, it is difficult to say which of the three alternatives has the greatest income effects in Iringa region or Mufindi District. Roughly, however, I regard the alternatives as equal in this respect.

6.4.8 Risks

The risks regarding skidding productivity estimates used in the analysis are in my opinion approximately equal for the three alternatives. However, alternative B has an overcapacity of 20 % whereas alternative A and C have an overcapacity of respectively 10 % and 11 %.

As alternative A consists of just two units, it is more vulnerable for breakdowns, availability of spare parts, changes in production output etc. than alternative B and alternative C.

Alternative A is also vulnerable for changes in import regulations and energy prices, which are likely to be less stable than wages and salaries in Tanzania.

Alternative B and alternative C are in my opinion about equal with respect to flexibility and uncertainty for breakdowns, changes in production outputs, sickness, etc., assuming proper caretaking of personnel and oxen.

On the whole, alternative B and alternative C are ranked before alternative A regarding flexibility and risks.

6.4.9 Other main factors

The three alternatives of technology are in my opinion not significantly different on other major development factors, like managerial implications, training requirements and organizational patterns.

6.5 Discussion and conclusions

Table 6.15 presents the ranking of the three alternatives on each of the criteria discussed above. It is seen that except for the criteria "Indirect employment" and "Technical skill formation", alternative A is inferior to B and C in a Pareto-optimal sense. As the importance of the indirect effects depends upon certain quite

Table 6.15. Ranking[a] of the alternatives of technology analysed for skidding 9,000 cu.m o.b. per year of softwood thinnings.

Criteria	Alt. A (agr. tractor)		Alt. B (oxen)		Alt. C (sulky)	
1 Economic efficiency (net discounted shadow priced[b] costs at 9 % p.a., shs)	3	(992,000)	2	(256,000)	1	(210,000)
2 Employment						
i. Direct employment - unskilled personnel (manyears per year)	2	(4.8)	3	(4.4)	1	(9.3)
- total personnel (manyears per year)	3	(6.9)	2	(7.5)	1	(9.4)
ii. Indirect employment - total personnel (manyears per year)[c, d]	1	(3.7)	2	(1.4)	2	(1.6)
3 Working conditions	2		1		3	
4 Integration						
i. In general	3		1		1	
ii. Technical skill formation	1		2		3	
5 Independency						
i. Financial profitability (net dicounted market costs at 9 % p.a. and market prices)	3	(939,000)	1	(255,000)	1	(264,000)
ii. Import need (shs per year direct and indirect)[c]	3	(50,000)	1	(12,000)	1	(13,000)
6 Ecological effects	1		1		1	
7 Distributional aspects except personal income	1		1		1	
8 Flexibility. Risks						
i. In general	3		1		1	
ii. Machine overcapacity (%)	2	(10)	1	(20)	2	(11)
9 Other factors	1		1		1	

[a] In brackets is presented most probable estimate of criterion indicated.

[b] Shadow prices 0.7, 1.3 and 1.6 for respectively un-/semi-skilled labour, skilled labour and foreign exchange.

[c] Marginal consumption propensity is 0.9.

[d] 8,000 shs per manyear is assumed.

strict assumptions (cf. discussion in Ch. 5.2.5) and the other two criteria mentioned above in my opinion are of less importance compared to particularly the economic efficiency discussed in Ch. 6.4.1, I think it is fair to conclude that alternatives B and C are preferable to alternative A.

It is seen from Table 6.15 that alternative C is superior or equal to alternative B for all criteria except "Working conditions", "Technical skill formation", and "Machine overcapacity". A decision maker who emphasizes increased employment of un/semi-skilled labour will therefore most likely choose alternative C. However, it should be noted that except for employment effects the alternatives B and C are approximately equal regarding the criteria analysed here.

One should be careful in drawing conclusions from this study for projects having other physical, technical and socio-economic characteristics than the Sao Hill Sawmill project. For example the road costs are quite decisive regarding choice of thinning method. The low road costs at Sao Hill favour particularly alternative C From Tables 6.4 and 6.5 it is seen that if the road costs were doubled relatively to the other costs, alternative B (ox-skidding) would be about 1.20 shs per cu.m o.b. cheaper than alternative C at 1977 market prices, all other factors being equal.[8]

The assumption in Ch. 6.2.3 of one helper per ox-driver could be discussed, not least because in actual ox-skidding operations in Malawi, no such helper was used (SOLBERG & SKAAR 1986). If no helper is assumed, it is seen from Table 6.4 that the cost efficiency of alternative B will improve by about 2.10 shs/cu.m o.b. or about 30 % of total costs, making it considerably more attractive than alternative C.

Also, the easy terrain conditions at Sao Hill favours the alternatives B and C. In particular alternative A is less sensitive to logging uphill compared to the other two methods.

For projects having physical and socio-economic conditions similar to the Sao Hill project, however, the result of this study should be of interest.

Finally, the analysis shows that labour intensive technologies exist which are highly compatible with modern capital intensive methods both from a financial and a socio-economic point of view in less industrialized countries.

NOTES CHAPTER 6:

[1]Based on OMNES (pers. comm.) and OLE-MEILUDIE & DYKSTRA (1982).

[2]Half-breeds of local cattle and imported beef- or dairy cattle such as Friesian or Hereford are well suited as draught animal as they normally are considerably heavier and stronger than the local cattle, but more expensive and difficult to obtain (NESTANDE 1975.).

[3]It should be possible to construct a sledge in Tanzania of steel and wood, thus lowering the costs considerably. However, in the analysis direct import is assumed.

[4]It is not stated whether this is effective hour or standard hour. Presumably it is standard hour.

[5]The sulky used in this experiment was not very well fit for its purpose having among other things steel wheels with diameter 0.15 m and a ground clearing distance of only 0.04 m (SKAAR 1973).

[6]Including piling in small piles at the road side.

[7]2 mandays per sulky per day and a daily productivity of 10-11 cu.m. o.b. per sulky might be more realistic according to SKAAR (pers. comm.).

[8]This is an important assumption as higher road costs will imply lower road density and lower productivity per day per unit of the thinning technologies analysed.

7 CHOICE OF TECHNOLOGY IN SKIDDING SOFTWOOD FROM CLEARFELLINGS

7.1 Brief description of the methods analysed

Three alternative methods for skidding of clearfellings from softwood forest plantations at Sao Hill are analysed. The most capital intensive one, alternative A, is using the forwarder Rottne Blondin 750, described in Appendix 3 (Ch. A 3.4). The second method, alternative B, is use of agricultural tractor (Ford 6600-2 with Igland Compact 5000 double drum winch), and the third method, alternative C, is using sledge skidding with oxen.

7.2 Assumptions

7.2.1 General

The analysis refers to skidding of logs from clearfellings of softwood plantations (Pinus patula) under conditions similar to those described in Ch. 5.2 for Sao Hill. Smooth terrain with maximum slope about 15 % is assumed. Mean dbh, volume per log, and extraction volume per ha are as stated in Table 5.17 - i.e. respectively 31.0 cm, 0.25 cu.m and 560 cu.m per ha. The log size distribution is shown in Appendix 7.

The method and distance of the log road transport from the forest to industry are assumed to be the same for the three alternatives, and the costs for this transport are, therefore, not included in the following comparison. Also, the stacking and loading costs at roadside are assumed to be equal for the three alternatives, and, therefore, not included in the analysis.

The road costs are as described in Ch. A 5.1. All alternatives are analysed assuming optimal road spacing as calculated in Appendix 5.

Alternative C involves significantly more people than the other alternatives, and is therefore likely to involve more work regarding personnel administration. On the other hand the more capital intensive alternatives will probably imply higher overhead costs

regarding procurement of fuel, spare parts, repair and maintenance, etc. I have therefore found it reasonable to assume that the overhead costs are the same for the three alternatives.

The calculations are based on an annual extraction volume of 22,000 cu.m o.b., which gives an optimal utilization of all three technology alternatives.

7.2.2 Particular assumptions, alternative A (forwarder)

Investments and annual running costs of alternative A are assumed to be as described in Appendix 3 (Ch. A 3.3). One helper per forwarder is assumed for preparing of loading, etc., with a monthly salary of 450 shs. Optimal road density is assumed to be 40 m/ha (cf. Ch. A 5.3.1).

No empirical data exist from Tanzania regarding productivity of forwarders, except for the two Volvo TC 860 forwarders which were used at Sao Hill. Their productivity in terrain transport is in SAO HILL (1978:10) recorded as maximum 10,000 cu.m u.b. per year per machine, taking into account the difficulties with break downs and repairs. Regarding forwarding with Rottne Blondin 750 SA (1978: Bilag 2) gives a productivity of 6.5 cu.m o.b. or 52 cu.m o.b. per work day (500 m transport distance). For the same machine SKOGSARBETEN (1978) records a productivity of 8.0 cu.m o.b. per G_{15} hour, which corresponds to about 64 cu.m per work day. Based on this and adjusting for the specific conditions at Sao Hill regarding availability of spare parts and service, 55 cu.m o.b. per machine per day is assumed as a reasonable productivity, corresponding to 12,400 cu.m per year. This means that two Rottne Blondin 750 forwarders will be necessary for extracting 22,000 cu.m o.b. per year, with an overcapacity of about 13 %.

The costs of alternative A are arranged in Table 7.1.

Table 7.1. Costs at 1977 market prices of skidding with forwarders 22,000 cu.m o.b. in softwood clearfellings in Tanzania.

Cost component	Annual costs (shs/year) Total	Annual costs (shs/year) Direct import	shs/cu.m o.b. Total	shs/cu.m o.b. Direct import
Depreciation	260,000	260,000		
Interest: On machinery	71,400	71,400		
On stock of spare parts	19,400	13,000		
On working capital	6,800			
Insurance	8,200			
Sum (rounded off)	366,000	344,600	16.60	15.60
Diesel	46,200			
Oil	9,600			
Tyres	39,000	39,000		
Repair and maintenance	120,000	60,000		
Total machine costs (rounded off)	581,000	443,200	26.40	20.10
Labour: Un-/semiskilled	10,800			
Skilled	18,000			
Total costs excl. roads (rounded off)	610,000	443,000	27.70	20.10
Road costs:				
Labour: Un-/semiskilled	5,100			
Skilled	1,000			
Other costs	14,100			
Total (rounded off)	630,000	443,000	28.60	20.10

7.2.3 <u>Particular assumptions, alternative B (agricultural tractor)</u>

The investment and annual running costs for alternative B are assumed to be as described in Appendix 3.

Optimal branch road density is assumed to be 50 m/ha (cf. Appendix 5, Ch. A 5.3.2).

Regarding productivity, experience from Sao Hill Sawmill gives 7,500 cu.m u.b. per year per tractor as a realistic estimate.

With 9 % bark volume this corresponds to 8,200 cu.m o.b. (rounded off) per tractor, which is used in the analysis - i.e. 36 cu.m o.b. per day per tractor on average. For logging the presumed quantity of 22,000 cu.m o.b. per year, 3 tractors are necessary, giving an overcapacity of about 12 %.

Each tractor is assumed to employ three persons (OLE-MEILUDIE & DYKSTRA 1982) - one tractor driver and two assistants preparing the loads, with salaries of respectively 600 and 450 shs/month. The cost of alternative B at market prices are arranged in Table 7.2.

Table 7.2. Costs at 1977 market prices of skidding with agricultural tractor 22,000 cu.m o.b. per year of softwood clearfellings.

Cost component	Annual costs (shs/year) Total	Annual costs (shs/year) Direct import	shs/cu.m o.b. Total	shs/cu.m o.b. Direct import
Depreciation	102,000	27,000		
Interest: On machinery	28,100	7,400		
On stock of spare parts	6,400	2,700		
On working capital	5,400			
Insurance	4,500			
Sum (rounded off)	146,000	37,000	6.60	1.70
Diesel	44,700			
Oil	3,900			
Tyres	22,500			
Spare parts	69,000	6,000		
Sum machinery costs	286,000	43,000	13.00	2.00
Labour: Un-/semiskilled	32,400			
Skilled	21,600			
Total excl. roads (rounded off)	340,000	43,000	15.50	2.00
Road costs:				
Labour: Un-/semiskilled	6,300			
Skilled	1,300			
Other costs	17,700			
Total (rounded off)	365,000	43,000	16.60	2.00

7.2.4 <u>Particular assumptions, alternative C (oxen)</u>

Here, same equipment and methods are assumed as described in Ch. 6.2.4 - i.e. ox skidding with sledge. However, because of larger logs in clearfellings than in thinnings (cf. Appendix 7) it is assumed that in addition to the sledge each pair of oxen is equipped with a sulky for extraction of logs larger than 0.45 cu.m o.b., as described in HEDING & OLE-MEILUDIE (1979). From Appendix 7 it is seen that these logs constitute less than 10 % of the total number of logs extracted in clearfellings[1].

Optimal road density is assumed to be 65 m/ha (cf. Ch. A 5.3.3), giving an average skidding distance of about 40 m.

Based on the same discussion as in Ch. 6.2.3, a daily productivity of 16 cu.m o.b. per pair of oxen is assumed, giving 3,600 cu.m per year per pair of oxen[2]. This implies that 7 pairs of oxen are necessary for extracting the presumed annual quantity of 22,000 cu.m o.b., with an overcapacity of about 15 %.

Shelter costs for the oxen are assumed to be 1,600 shs with 10 years write-off time. For feeding and watching the 14 oxen one person in full time employment is assumed to be necessary, with a salary of 450 shs per month. Other costs are assumed to be as described in Ch. 6.2.3.

The costs at 1977 market prices of using oxen in clearfellings are arranged in Table 7.3.

Table 7.3. Cost at 1977 market prices of skidding with oxen 22,000 cu.m o.b. per year in softwood clearfellings.

Cost component	Annual costs (shs/year)		shs/cu.m o.b.	
	Total	Direct import	Total	Direct import
Depreciation:				
Sledges (7)	3,500	3,500		
Sulkies (7)	1,900	1,300		
Oxen (14)	- 420			
Shelter	140			
Interest: On oxen/equipment	2,530	660		
On stock of spare parts	270	240		
On working capital	3,020			
Sum (rounded off)	10,900	5,700	0.50	0.30
Dipping	1,400			
Food for oxen	13,900			
Dragging chain, yokes, spare parts, etc.	7,000	2,800		
Sum - nonlabour costs	33,200	8,500	1.50	0.40
Labour: Un-/semiskilled	43,200			
Skilled	46,200			
Total - excl. roads	122,000	8,500	5.60	0.40
Road costs:				
Labour: Un-/semiskilled	8,200			
Skilled	1,700			
Other domestic costs	23,000			
Total costs (rounded off)	155,000	8,500	7.10	0.40

7.3 Calculation of direct and indirect economic effects

7.3.1 Direct economic effects

Based on the assumptions in Ch. 7.2, the resource flows of the three technology alternatives are presented in Table 7.4, Table 7.5 and Table 7.6. Based on these, Table 7.7, Table 7.8 and Table 7.9 give a sensitivity analysis of the discounted net present costs of the three methods, as described in Ch. 6.3.1.

7.3.2 Indirect economic effects

The indirect economic effects are calculated as described in Ch. 5.2.5 with the column figures in Table 7.10 as vector y_T. The results are shown in Table 7.11.

Table 7.4. Resource flow if skidding with forwarder 22,000 cu.m o.b. per year from softwood clearfellings. At 1977 market prices (shs/year).

	Year					
	0	1	2	3	4	5
1. Investments[a]						
1.1 Un- and semiskilled labour						
1.2 Skilled						
1.3 Diesel and lubricant oil						
1.4 Other domestic inputs	154,000					- 154,000
1.5 Import	1,588,000					- 288,000
2. Recurrent expenditures						
2.1 Un- and semiskilled labour		16,000	Same for all years			
2.2 Skilled		19,000	Same for all years			
2.3 Diesel and lubricant oil		56,000	Same for all years			
2.4 Other domestic inputs		82,000	Same for all years			
2.5 Import		99,000	Same for all years			

[a] Working capital is 82,000 shs and stock of spare parts amount to 216,000 shs, of which 144,000 shs is direct import.

Table 7.5. Resource flow if skidding with agricultural tractor 22,000 cu.m o.b. per year from softwood clearfellings. At 1977 market prices (shs/year).

	Years					
	0	1	2	3	4	5
1. Investments[a]						
1.1 Un- and semiskilled labour						
1.2 Skilled						
1.3 Diesel and lubricant oil						
1.4 Other domestic inputs	527,000					- 152,000
1.5 Import	180,000					- 45,000
2. Recurrent expenditures						
2.1 Un- and semiskilled labour		39,000	Same for all years			
2.2 Skilled		23,000	Same for all years			
2.3 Diesel and lubricant oil		49,000	Same for all years			
2.4 Other domestic inputs		107,000	Same for all years			
2.5 Import		6,000	Same for all years			

[a] Working capital and stock of spare parts amount to respectively 68,000 shs and 72,000 shs (30,000 shs of the spare part amount is direct import).

Table 7.6. Resource flow if ox-skidding 22,000 cu.m o.b. per year from softwood clearfellings. At 1977 market prices (shs/year).

	Year					
	0	1	2	3	4	5
1. Investments[a]						
1.1 Un- and semiskilled labour						
1.2 Skilled						
1.3 Diesel and lubricant oil						
1.4 Other domestic inputs	66,000					- 64,000
1.5 Import	16,000		12,000			- 4,000
2. Recurrent expenditure						
2.1 Un- and semiskilled labour		51,000	Same for all years			
2.2 Skilled		48,000	Same for all years			
2.3 Diesel and lubricant oil			Same for all years			
2.4 Other domestic inputs		42,000	Same for all years			
2.5 Import		3,000	Same for all years			

[a] Working capital and stock of spare parts amount to respectively 43,000 shs and 3,000 shs (2,700 shs of the spare part amount is direct import).

Table 7.7. Discounted net present costs of using forwarder in skidding of 22,000 cu.m o.b. per year of softwood from clearfellings (shs).

SHADOW PRICES			REL.PRICE INCR. (% P.A.)				TOTAL PRICE INCREASE (%)						CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.)			
LABOUR US&SS	SK	IMP ORT	LAB OUR	ENE RGY	IMP ORT	OTH ER	LAB OUR	ENE RGY	IMP ORT	OTH ER	INV EST	REC UR.	3.	6.	9.	12.
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2606395	2557460	2512703	2471685
1.0	1.0	1.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	2622425	2572203	2526319	2484303
1.0	1.0	1.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	2638453	2586948	2539932	2496919
1.0	1.0	1.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	2654483	2601690	2553546	2509535
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	2632040	2581050	2534484	2491871
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	2657688	2604638	2556266	2512058
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	2683333	2628228	2578049	2532244
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	2785689	2736440	2691291	2649828
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	2964985	2915421	2869880	2827974
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	3144280	3094403	3048469	3006118
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	2646063	2595892	2549988	2507902
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	2685731	2634327	2587274	2544124
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	2725402	2672759	2624560	2580345
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	2742466	2698629	2658174	2620802
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	2878538	2839800	2803646	2769922
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	3014610	2980970	2949118	2919041
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	2730961	2672036	2618502	2569732
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	2855529	2786614	2724300	2667783
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	2980058	2901190	2830100	2765831
1.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2616073	2566189	2520602	2478863
1.0	1.0	1.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2626269	2575369	2528908	2486402
1.0	1.0	1.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2637005	2585024	2537637	2494323
1.0	1.0	1.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2648303	2595187	2546809	2502637
1.0	1.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2621880	2571419	2525340	2483169
1.0	1.0	1.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2638192	2586111	2538627	2495235
1.0	1.0	1.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2655369	2601565	2552593	2507905
1.0	1.0	1.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2673445	2617822	2567270	2521208
1.0	1.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2607913	2559741	2515561	2474977
1.0	1.0	1.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2608785	2561487	2517979	2477910
1.0	1.0	1.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2608946	2562644	2519915	2480445
1.0	1.0	1.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2608332	2563164	2521319	2482537
1.0	1.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	2615243	2565922	2520789	2479405
1.0	1.0	1.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	2624175	2574482	2528978	2487235
1.0	1.0	1.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	2633174	2583122	2537262	2495166
1.0	1.0	1.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	2642226	2591837	2545629	2503189

Continues ....

Table 7.7 continued

SHADOW PRICES			REL.PRICE INCR. (% P.A.)				TOTAL PRICE INCREASE (%)						CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.)			
LABOUR US&SS	SK	IMP ORT	LAB OUR	ENE RGY	IMP ORT	OTH ER	LAB OUR	ENE RGY	IMP ORT	OTH ER	INV EST	REC UR.	3.	6.	9.	12.
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3686294	3635139	3587743	3543800
0.7	1.3	1.6	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	3702735	3650264	3601706	3556742
0.7	1.3	1.6	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	3719174	3665385	3615672	3569684
0.7	1.3	1.6	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	3735616	3680507	3629634	3582625
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	3711939	3658729	3609524	3563986
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	3737587	3682317	3631306	3584173
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	3763232	3705907	3653089	3604359
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	3973165	3921508	3873484	3828830
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	4260040	4207881	4159228	4113865
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	4546513	4494249	4444970	4398895
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	3725962	3673571	3625028	3580017
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	3765630	3712006	3662314	3616239
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	3805301	3750438	3699600	3652460
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	3902738	3858675	3817262	3778391
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	4119186	4082215	4046786	4012988
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	4335631	4305751	4276306	4247581
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	3838475	3775119	3716994	3663584
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	3990657	3915096	3846248	3783373
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	4142843	4055072	3975501	3903158
0.7	1.3	1.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3656220	3644089	3595843	3551164
0.7	1.3	1.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3706677	3653507	3604363	3558898
0.7	1.3	1.6	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3717686	3663411	3613315	3567021
0.7	1.3	1.6	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3729277	3673836	3622724	3575548
0.7	1.3	1.6	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3701779	3649098	3600380	3555284
0.7	1.3	1.6	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3718091	3663790	3613667	3567350
0.7	1.3	1.6	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3735268	3679244	3627633	3580020
0.7	1.3	1.6	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3753344	3695501	3642310	3593323
0.7	1.3	1.6	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3688726	3638788	3592316	3549069
0.7	1.3	1.6	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3690118	3641582	3596186	3553762
0.7	1.3	1.6	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3690377	3643436	3599283	3557817
0.7	1.3	1.6	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3689397	3644268	3601529	3561163
0.7	1.3	1.6	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	3695142	3643601	3595829	3551520
0.7	1.3	1.6	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	3704074	3652161	3604018	3559350
0.7	1.3	1.6	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	3713073	3660801	3612302	3567281
0.7	1.3	1.6	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	3722127	3669516	3620669	3575304
0.5	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3671637	3621659	3575296	3532266
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3686294	3635139	3587743	3543800
0.9	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3700949	3648618	3600191	3555336
1.1	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3715603	3662097	3612636	3566872
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3686294	3635139	3587743	3543800
0.7	1.5	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3703695	3651146	3602524	3557499
0.7	1.7	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3721100	3667153	3617305	3571197
0.7	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3327700	3277176	3230560	3187507
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3686293	3635137	3587742	3543799
0.7	1.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4044884	3993101	3944920	3900088
0.7	1.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4403474	4351063	4302098	4256379

Table 7.8. Discounted net present costs of using agricultural tractor in skidding 22,000 cu.m o.b. per year of softwood from clearfellings (shs).

SHADOW PRICES			REL.PRICE INCR. (% P.A.)				TOTAL PRICE INCREASE (%)						CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.)			
LABOUR US&SS	SK	IMP ORT	LAB OUR	ENE RGY	IMP ORT	OTH ER	LAB OUR	ENE RGY	IMP ORT	OTH ER	INV EST	REC UR.	3.	6.	9.	12.
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1562911	1503351	1450238	1402677
1.0	1.0	1.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	1591304	1529467	1474354	1425027
1.0	1.0	1.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	1619698	1555584	1498469	1447377
1.0	1.0	1.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	1648092	1581700	1522585	1469727
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	1585353	1523991	1469297	1420340
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	1607794	1544632	1488357	1438003
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	1630233	1565272	1507415	1455667
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	1579778	1520514	1467646	1420286
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	1596644	1537681	1485054	1437894
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	1613511	1554845	1502463	1455504
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	1651501	1589764	1534678	1485322
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	1740092	1676177	1619118	1567967
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	1828681	1762588	1703556	1650612
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	1616616	1559328	1508132	1462197
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	1670323	1615305	1566027	1521718
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	1724028	1671283	1623922	1581239
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	1665498	1597706	1537367	1483424
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	1768084	1692066	1624495	1564170
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	1870668	1786421	1711622	1644918
1.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1580055	1518806	1464228	1415392
1.0	1.0	1.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1598116	1535071	1478940	1428751
1.0	1.0	1.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1617130	1552180	1494402	1442778
1.0	1.0	1.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1637143	1570178	1510651	1457506
1.0	1.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1576462	1515566	1461295	1412725
1.0	1.0	1.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1590736	1528421	1472922	1423282
1.0	1.0	1.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1605763	1541943	1485143	1434369
1.0	1.0	1.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1621581	1556167	1497984	1446011
1.0	1.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1560531	1501348	1448547	1401250
1.0	1.0	1.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1557909	1499135	1446678	1399667
1.0	1.0	1.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1555031	1496702	1444620	1397921
1.0	1.0	1.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1551877	1494036	1442356	1395998
1.0	1.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	1578851	1518202	1464101	1415642
1.0	1.0	1.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	1595260	1533488	1478370	1428986
1.0	1.0	1.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	1612137	1549209	1493046	1442711
1.0	1.0	1.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	1629487	1565375	1508136	1456822

Continues ....

Table 7.8 continued

SHADOW PRICES LABOUR USS&SS	SK	IMP ORT	REL.PRICE INCR. (% P.A.) LAB OUR	ENE RGY	IMP ORT	OTH ER	TOTAL PRICE INCREASE (%) LAB OUR	ENE RGY	IMP ORT	OTH ER	INV EST	REC UR.	CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.) 3.	6.	9.	12.
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1642124	1586118	1536019	1491031
0.7	1.3	1.6	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	1668321	1610213	1558268	1511649
0.7	1.3	1.6	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	1694516	1634308	1580515	1532268
0.7	1.3	1.6	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	1720712	1658403	1602765	1552887
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	1664565	1606759	1555079	1508694
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	1687007	1627399	1574138	1526358
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	1709447	1648040	1593197	1544022
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	1669108	1613582	1563874	1519206
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	1696094	1641043	1591728	1547380
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	1723079	1668507	1619583	1575554
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	1730714	1672531	1620459	1573677
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	1819305	1758945	1704900	1656323
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	1907895	1845358	1789338	1738968
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	1704299	1650878	1602959	1559819
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	1766477	1715638	1669901	1628609
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	1828652	1780398	1736841	1697396
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	1744161	1679970	1622682	1571344
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	1846197	1773821	1709342	1651658
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	1948231	1867672	1796004	1731972
0.7	1.3	1.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1657942	1600376	1548926	1502760
0.7	1.3	1.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1674603	1615383	1562499	1515083
0.7	1.3	1.6	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1692148	1631167	1576765	1528028
0.7	1.3	1.6	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1710611	1647772	1591753	1541614
0.7	1.3	1.6	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1655675	1598334	1547076	1501079
0.7	1.3	1.6	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1669949	1611189	1558704	1511637
0.7	1.3	1.6	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1684975	1624711	1570925	1522723
0.7	1.3	1.6	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1700794	1638935	1583766	1534365
0.7	1.3	1.6	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1638314	1582911	1533316	1488748
0.7	1.3	1.6	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1634120	1579372	1530327	1486217
0.7	1.3	1.6	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1629512	1575481	1527030	1483422
0.7	1.3	1.6	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1624470	1571215	1523412	1480346
0.7	1.3	1.6	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	1658065	1600970	1549884	1503997
0.7	1.3	1.6	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	1674473	1616256	1564152	1517342
0.7	1.3	1.6	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	1691350	1631977	1578828	1531065
0.7	1.3	1.6	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	1708701	1648143	1593917	1545177
0.5	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1606403	1553262	1505679	1462915
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1642124	1586118	1536019	1491031
0.9	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1677845	1618974	1566357	1519149
1.1	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1713567	1651830	1596697	1547266
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1642124	1586118	1536019	1491031
0.7	1.5	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1663191	1605495	1553911	1507613
0.7	1.7	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1684258	1624871	1571804	1524194
0.7	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1608392	1551789	1501203	1455812
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1642124	1586118	1536019	1491031
0.7	1.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1675855	1620445	1570838	1526249
0.7	1.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1709587	1654775	1605657	1561468

Table 7.9. Discounted net present costs of using oxen in skidding 22,000 cu.m o.b. per year of softwood from clearfellings (shs).

SHADOW PRICES LABOUR USS&SS	SK	IMP ORT	REL.PRICE INCR. (% P.A.) LAB OUR	ENE RGY	IMP ORT	OTH ER	TOTAL PRICE INCREASE (%) LAB OUR	ENE RGY	IMP ORT	OTH ER	INV EST	REC UR.	CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.) 3.	6.	9.	12.
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	694131	648446	608015	572068
1.0	1.0	1.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	739470	690149	646522	607755
1.0	1.0	1.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	784805	731851	685030	643443
1.0	1.0	1.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	830148	773553	723537	679130
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	694131	648446	608015	572068
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	694131	648446	608015	572068
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	694131	648446	608015	572068
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	697891	652079	611531	575479
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	701651	655712	615048	578690
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	705411	659345	618565	582301
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	714445	667956	626791	590176
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	734759	687465	645568	608285
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	755073	706975	664345	626394
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	697596	652633	612805	577366
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	701062	656819	617595	582664
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	704527	661006	622386	587962
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	760078	709104	664025	623976
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	826026	769762	720037	675885
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	891974	830420	776047	727794
1.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	721507	673125	630354	592370
1.0	1.0	1.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	750345	699098	653845	613700
1.0	1.0	1.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	780708	726421	678536	636100
1.0	1.0	1.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	812666	755156	704481	659618
1.0	1.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	694131	648446	608015	572068
1.0	1.0	1.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	694131	648446	608015	572068
1.0	1.0	1.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	694131	648446	608015	572068
1.0	1.0	1.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	694131	648446	608015	572068
1.0	1.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	695058	649314	608829	572834
1.0	1.0	1.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	696010	650205	609664	573619
1.0	1.0	1.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	696986	651118	610521	574423
1.0	1.0	1.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	697986	652054	611398	575248
1.0	1.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	699995	653938	613163	576901
1.0	1.0	1.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	706019	659574	618446	581862
1.0	1.0	1.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	712189	665351	623864	586951
1.0	1.0	1.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	718509	671272	629418	592167

Continues ....

Table 7.9 continued

SHADOW PRICES			REL.PRICE INCR. (% P.A.)				TOTAL PRICE INCREASE (%)						CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.)			
LABOUR US&SS	SK	IMP ORT	LAB OUR	ENE RGY	IMP ORT	OTH ER	LAB OUR	ENE RGY	IMP ORT	OTH ER	INV EST	REC UR.	3.	6.	9.	12.
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	712569	666452	625616	589290
0.7	1.3	1.6	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	757496	707775	663273	624653
0.7	1.3	1.6	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	802423	749098	701930	660016
0.7	1.3	1.6	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	847349	790421	740087	695378
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	712569	666452	625616	589290
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	712569	666452	625616	589290
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	712569	666452	625616	589290
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	718585	672265	631243	594748
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	724601	678077	636870	600206
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	730617	683889	642457	605664
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	732883	685961	644392	607399
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	753157	705471	663169	625507
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	773511	724980	681946	643616
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	717466	672060	631816	595986
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	722363	677668	638017	602682
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	727260	683276	644217	609378
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	778925	727489	681976	641523
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	845285	788526	738337	693756
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	911648	849563	794698	745989
0.7	1.3	1.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	739696	690906	647752	609408
0.7	1.3	1.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	768272	716643	671030	630544
0.7	1.3	1.6	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	792359	743718	695496	652740
0.7	1.3	1.6	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	830027	772191	721204	676044
0.7	1.3	1.6	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	712569	666452	625616	589290
0.7	1.3	1.6	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	712569	666452	625616	589290
0.7	1.3	1.6	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	712569	666452	625616	589290
0.7	1.3	1.6	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	712569	666452	625616	589290
0.7	1.3	1.6	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	714053	667841	626919	590515
0.7	1.3	1.6	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	715575	669266	628255	591771
0.7	1.3	1.6	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	717136	670727	629625	593059
0.7	1.3	1.6	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	718737	672225	631030	594378
0.7	1.3	1.6	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	718437	671944	630764	594124
0.7	1.3	1.6	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	724457	677580	636047	599085
0.7	1.3	1.6	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	730627	683357	641465	604173
0.7	1.3	1.6	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	736947	689278	647019	609389
0.5	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	665856	623486	585941	552522
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	712569	666452	625616	589290
0.9	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	759282	709418	665290	626059
1.1	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	805995	752384	704964	662828
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	712569	666452	625616	589290
0.7	1.5	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	756534	706891	662956	623896
0.7	1.7	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	800499	747329	700297	658502
0.7	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	705049	659186	618582	582466
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	712569	666452	625615	589290
0.7	1.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	720089	673718	632649	596112
0.7	1.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	727609	680983	639683	602935

Table 7.10. Recurrent expenditures[a] used in estimating indirect economic effects of different technologies in skidding from softwood clearfellings (shs/year).

Input specifications for input/output table	Technology alternative		
	Alt. A (forwarder)	Alt. B (agr. tractor)	Alt. C (oxen)
Sector 9 (Food grain)			13,900
" 22 (Sawmilling and carpeting)			3,200
" 24 (Chemicals and petroleum)	55,800	48,600	1,400
" 25 (Metallic and non-metallic products)			1,000
" 27 (Automobile repair)	60,000	85,500	
" 33 (Construction)[b]	14,100	17,700	23,000
" 38 (Banking and insurance)	8,200	4,500	
" 45 (Unspecified)			
" 47 (Wages and salaries)	34,900	61,600	99,300
Imports	99,000	6,000	2,800
Depreciation[c]	260,000	102,000	5,100
Gross domestic product	294,900	163,600	104,400
Gross output	532,000	325,900	149,700

[a]Based on Table 7.1, Table 7.2 and Table 7.3, excluding interest costs.

[b]Road costs, excluding labour costs.

[c]Including import components.

Table 7.11. Direct and indirect economic effects of alternative technologies in skidding of 22,000 cu.m o.b. of softwood clearfellings ('000 shs/year).

Variable	Forwarder (alt. A)			Agric. tractor (alt. B)			Oxen (alt. C)		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
1. Marginal consumption propensity is 0									
Domestic inputs*	138.1	65.0	203.1	156.3	74.7	231.0	42.5	18.5	61.0
Imports	99.0	49.7	148.1	6.0	53.0	59.0	2.8	8.4	11.2
Subsidies, custom duties, other indirect taxes	0.0	11.5	11.5	0.0	13.9	13.9	0.0	1.6	1.6
Wages and salaries	34.9	31.7	66.6	61.6	33.3	94.9	99.3	11.8	111.1
Operating surplus	0.0	37.9	37.9	0.0	48.1	48.1	0.0	19.1	19.1
Depreciation	260.0	7.3	267.3	102.0	8.0	110.0	5.1	1.7	6.8
Net value added	34.9	69.6	104.5	61.6	81.5	143.1	99.3	30.9	130.2
Gross value added	294.9	76.9	371.8	163.6	89.4	253.0	104.4	32.5	136.9
Total (gross) production	532.0	203.1	735.1	325.9	231.0	556.9	149.7	61.0	210.7
2. Marginal consumption propensity is 0.5									
Domestic inputs*	138.1	105.0	243.1	156.3	131.7	288.0	42.5	85.1	127.6
Imports	99.0	56.0	155.4	6.0	62.9	68.9	2.8	18.8	21.6
Subsidies, custom duties, other indirect taxes	0.0	15.0	15.0	0.0	18.8	18.8	0.0	7.7	7.7
Wages and salaries	34.9	37.1	72.0	61.6	40.9	102.5	99.3	20.7	120.0
Operating surplus	0.0	56.9	56.9	0.0	75.3	75.3	0.0	50.9	50.9
Depreciation	260.0	9.1	269.1	102.0	10.4	112.4	5.1	4.5	9.6
Net value added	34.9	94.0	128.9	61.6	116.2	177.8	99.3	71.5	170.8
Gross value added	294.9	103.0	397.9	163.6	126.6	290.2	104.4	76.0	180.4
Total (gross) production	532.0	279.0	811.0	325.9	339.2	665.1	149.7	187.6	337.3
3. Marginal consumption propensity is 0.9									
Domestic inputs*	138.1	137.0	275.1	156.3	177.3	333.6	42.5	138.4	180.9
Imports	99.0	61.0	160.0	6.0	70.8	76.8	2.8	27.1	29.9
Subsidies, custom duties, other indirect taxes	0.0	17.9	17.9	0.0	21.3	21.3	0.0	12.6	12.6
Wages and salaries	34.9	41.4	76.3	61.6	47.0	108.6	99.3	27.8	127.1
Operating surplus	0.0	72.1	72.1	0.0	97.0	97.0	0.0	76.3	76.3
Depreciation	260.0	10.4	270.4	102.0	12.4	114.4	5.1	6.7	11.8
Net value added	34.9	113.5	148.4	61.6	144.0	205.6	99.3	104.0	203.3
Gross value added	294.9	123.9	418.8	163.6	156.4	320.0	104.4	110.8	215.2
Total (gross) production	532.0	339.8	871.8	325.9	425.8	751.7	149.7	288.9	438.6

* Not including wages and salaries and operating surplus.

7.4 Discussion of effects on different criteria of development

Based on the assumptions and calculations presented in Ch. 7.2 and Ch. 7.3 the following section concerns appraisal of the three technological alternatives according to the criteria presented in Ch. 4.3.2.

7.4.1 Production efficiency from a national economic point of view

Direct effects

Tables 7.7, 7.8 and 7.9 show that the use of oxen is significantly more favourable from a national economic point of view than the two other alternative methods analysed. This is true for all shadow prices, price differences, and rates of interests chosen. The main reason is higher capital costs as well as higher recurrent expenditures for alternatives A and B It is also seen that using forwarder involves more than double the costs of using agricultural tractor.

For the most probable assumptions (shadow prices 0.7, 1.3 and 1.6 of respectively un/semi-skilled labour, skilled labour and import - cf. Ch.5.2.4), zero price increases, and 9 % p.a. calculation rate of interest, it is seen that the net discounted costs will be 3.59 mill. shs using forwarders (Table 7.7), 1.54 mill. shs of using agricultural tractor (Table 7.8), and 0.63 mill. shs of using oxen (Table 7.9).

The costs of using forwarders are most sensitive to increases in price changes of import, energy and investments. The costs of using agricultural tractors are most sensitive to changes in other costs (i.e. mainly tyres and spare parts) and recurrent expenditures, whereas the cost of using oxen is most sensitive to changes in labour costs and recurrent expenditures (which includes labour costs - cf. Table 7.6).

Indirect economic effects

Table 7.11 shows that the indirect use of economic resources is significantly higher for alternatives A and B compared with alternative C. The main reason is higher recurrent expenditures.

The main difference in this respect between the alternatives A and B occurs regarding operating surplus (and thus net value added and gross value added), where alternative B compared with alternative A is about 27 % and 32 % higher for marginal consumption propensity of respectively 0 and 0.5.

Alternative B also gives a higher indirect operating surplus than alternative C. The difference between the alternatives, however, decreases considerably when going from consumption propensity 0 to 0.9, due to the high labour intensity of alternative C.

Regarding indirect import effect of using agricultural tractor, Table 7.11 shows the same as Table 6.13 - i.e. the indirect import is 9-10 times higher than the direct import. The reason is, as mentioned in Ch. 6.4.1, that the agricultural tractors are assembled in Tanzania.

Adjusting for the indirect operating surplus and taking account of the indirect import effects (cf. Ch. 5.2.5), it seems fair to conclude that from a cost efficiency point of view, the indirect economic effects of alternative C are preferable to those of alternatives A and B, and that alternative A is preferable to alternative B in this respect.

7.4.2 Employment

Direct employment

Table 7.12 shows the most probable direct employment effects of the three alternatives of technology.

Table 7.12. Direct employment effects* of skidding 22,000 cu.m o.b. per year of softwood from clearfellings.

Type of personnel employed	Direct employment generated (man-years per year)		
	Alt. A (Forwarder)	Alt. B (Agric. tractor)	Alt. C (Oxen)
Un- and semiskilled	2.9	7.2	8.5
Skilled	2.1	3.2	7.3
Total	5.0	10.4	15.8

*Including employment in road costs (cf. Tables 7.1, Table 7.2 and 7.3) with assumed annual costs of 5,400 shs and 7,400 shs per manyear of respectively un- and semiskilled personnel and skilled personnel.

Table 7.12 shows that alternative C gives about 3 times higher employment than alternative A, and about 50 % higher employment than alternative B. Regarding employment of un- and semiskilled personnel, alternative C gives about 20 % higher employment than alternative B. The high employment of skilled personnel in alternative C compared to alternative B, results from the ox-drivers being classified as skilled personnel.

Indirect employment effects

Wages and salaries in Table 7.11 may be a reasonably good indication of indirect employment effects, assuming approximately the same wage- and salary levels in the various economic sectors. Table 7.11 then shows that regarding indirect employment effects, alternatives A and B are about equal and preferable to alternative C.

Assuming here on average 8,000 shs per manyear, the indirect employment effects at marginal consumption propensity of 0.9 are, under the assumptions stated in Ch. 5.2.5:

Alternative A	5.2	manyear	per	year
" B	5.9	"	"	"
" C	3.5	"	"	"

7.4.3 Working conditions

Regarding physical strain the three alternatives are regarded about equal.

With regard to psychological strain it is difficult to state that one alternative is better than the other. Alternative A and alternative B might give the workers higher prestige than alternative C due to handling more sophisticated machinery. On the other hand, however, this might, as stated in Ch. 6.4.3, be viewed as a negative factor for other workers occupied in less capital intensive activities.

Although no relevant empirical data exist from Tanzania, the risk of personnel accidents is likely to be higher for alternative A and alternative B compared with alternative C.

Regarding workers' influence on their own working situation, the three alternatives seem, in my opinion, to be approximately equal, although it might be argued that in alternative A the workers will be more reliant on exogenous factors like technical skill of others, procurement of spare parts, import regulations, trade balance etc., than in alternative B, and particularly, in alternative C.

Based on this discussion, I rank alternative C before the other two alternatives, which I regard as about equal with respect to working conditions.

7.4.4 Integration

Table 7.11 shows that alternative C has significantly lower direct and indirect import usage than alternative B, which again has a significantly lower direct and indirect import content than alternative A. Therefore, it may be argued that alternative C is better integrated in the present economic structur of Tanzania than alternative B, which again is better integrated than alternative A, with the limitations of the input/output model used (cf. Ch. 5.2.5).

Regarding integration with the present social structure and the future economic and social development of Tanzania, I refer to the other criteria discussed in Ch. 7.4 and the discussion in Ch. 4.3.2.4. However, regarding technical skill formation alternative A and alternative B will, in my opinion, be about equal, and superior to alternative C.

The three alternatives are considered to be equal with respect to integration.

7.4.5 Independency

Regarding independency on micro level - i.e. financial profitability (cf. Ch. 4.3.2.5) - it is seen from Tables 7.7, 7.8 and 7.9 (for shadow prices 1.0) that alternative C is significantly more preferable than alternative B, which again is significantly more preferable than alternative A.

The same results emerge from Table 7.11 regarding independency on macro level indicated as direct and indirect import usage.

7.4.6 Ecological effects

None of the three alternatives of technology are ecologically harmful. Although alternative C is based more upon renewable resources than alternative A and alternative B, the three alternatives are, in my opinion, about equal with respect to ecological effects in Tanzania.

7.4.7 Distributional aspects other than personal income

The most important distributional effect, apart from personal income, is in this case regional income. Most of the production inputs of alternative A and alternative B come from outside Mufindi District and Iringa region, whereas for alternative C most inputs originates in Mufindi District. However, because alternative A and alternative B involve a relatively high use of resources, the income effects in Iringa region might be of the same size as alternative C. In Mufindi District, however, alternative C has a higher income effect than alternative A and alternative B.

7.4.8 Risks

The risks regarding skidding productivity estimates used in the analysis are in my opinion approximately equal for the three alternatives.

Alternative A consists of two units, alternative B of 3 units, and alternative C of 8 units, the former two alternatives being more vulnerable for break downs, changes in production etc. than the latter.

From Table 7.11 it is also seen that the alternatives A and B are more vulnerable to changes in import regulations and in energy prices than alternative C. Alternative C is, however, more vulnerable to changes in wages and salaries than the former two alternatives. Historically, however, wages and salaries have been more stable and have increased less than import and energy prices in Tanzania the last 20 years.

As shown in SOLBERG & SKAAR (1986) the risk of sickness and injuries in ox skidding is rather low, assuming proper treatment of the oxen.

The overcapacity of alternatives A, B and C is respectively 13 %, 12 % and 15 %.

Based upon this, alternative C is ranked before alternative B, which again is ranked before alternative A regarding flexibility and risk.

7.4.9 Other main factors

The three alternatives of technology are considered not significantly different on other major development factors.

7.5 Conclusions

Table 7.13 shows the ranking of the three alternatives according to each of the criteria discussed above. It is seen that except for the criteria "Indirect employment" and "Technical skill formation", alternative C is superior to alternatives A and B in a Pareto-optimal sense.

Regarding employment, however, considering the total direct and indirect employment, alternative C is superior to the other two

Table 7.13. Ranking[a] of the alternatives of technology analysed for skidding 22,000 cu.m o.b. per year of softwood from clearfellings.

Criteria	Alt. A (forwarder)		Alt. B (agr. tractor)		Alt. C (oxen)	
1 Economic efficiency (net discounted shadow priced[b] costs at 9 % p.a., shs)	3	(3,588,000)	2	(1,536,000)	1	(626,000)
2 Employment						
i. Direct employment - unskilled personnel (manyears per year)	2	(2.9)	3	(7.2)	1	(8.5)
- total personnel (manyears per year)	3	(5.0)	2	(10.4)	1	(15.8)
ii. Indirect employment - total personnel (manyears per year)[c,d]	2	(5.2)	1	(5.9)	3	(3.5)
3 Working conditions	2		2		1	
4 Integration						
i. In general	1		1		1	
ii. Technical skill formation	1		1		2	
5 Independency						
i. Financial profitability (net discounted costs at 9 % p.a. and market prices, shs)	3	(2,513,000)	2	(1,450,000)	1	(608,000)
ii. Import need (shs per year direct and indirect)[c]	3	(155,000)	2	(69,000)	1	(22,000)
6 Ecological effects	1		1		1	
7 Distributional aspects except personal income	2		2		1	
8 Flexibility. Risks						
i. In general	3		2		1	
ii. Machine overcapacity (%)	1	(13)	1	(12)	1	(15)
9 Other factors	1		1		1	

[a] In brackets is presented most probable estimate of the criterion.

[b] Shadow prices 0.7, 1.3 and 1.6 for respectively un-/semi-skilled labour, skilled labour and foreign exchange.

[c] Marginal consumption propensity is 0.9.

[d] 8,000 shs per manyear is assumed.

alternatives. It seems fair to conclude that alternative C is the best alternative, unless technical skill formation is given a very high weight.

As discussed in Ch. 6.5 for thinnings, one should be careful in drawing conclusions from this study for projects having other physical, technical and socio-economic characteristics. For example is alternative C favoured by the relatively low road construction costs and the easy terrain at Sao Hill, making it easy to avoid, among other things, skidding uphill. Also, some factors which could be important are not included in the analyses. Examples of this are that the alternatives A and B most likely have lower loading costs at road side than alternative C because of easier piling of logs, and that whole stem skidding is not considered. This method could favour the alternatves A and B relative to alternative C, but would complicate the analysis considerably as the timber felling and road transport operations (including loading and unloading) would have to be included in such an analysis.

NOTES CHAPTER 7

[1]In SOLBERG & SKAAR (1986) it is documented that in Malawi one pair of oxen could skid logs even larger than 1.0 cu.m o.b. However, the oxen used there were larger than assumed in this study.

[2]This estimate is more than 20 % less than what is used in SOLBERG & SKAAR (1986) and should, therefore, be more on the low than the high side.

8 CHOICE OF TECHNOLOGY IN SAWMILLING OF SOFTWOOD: ONE CENTRALLY LOCATED SAWMILL COMPARED WITH FIVE DECENTRALIZED SMALLER SAWMILLS

8.1 Brief description of the methods analysed

Three alternative technologies - A, B and C - for softwood sawnwood production are compared. Alternative A and alternative B represent one centrally located circular mill with annual production 14,000 cu.m(s) on one shift, of which about 2,500 cu.m(s) from thinnings. Alternative A is identical with the present Sao Hill Sawmill Project described in Appendix 4, while alternative B is a modified version of alternative A (cf. below). Alternative C consists of five smaller circular sawmills closer to the forest, each with a one-shift production of about 2,800 cu.m(s) per year. In alternative C it is assumed that the five sawmills have a common central unit for sorting, drying, trimming, dipping, impregnation and sales/marketing of the sawnwood, for repair and maintenance of the logging and sawing equipment, and for administration.

Alternatives A and B each consist of one double slabber, one circular split saw, two circular resaws and one circular double edger, as described in TWICO (1972). For the bigger logs there is an additional circular saw which can be operated as a separate unit or in combination with the resaws. Alternative C consists of two circular saws - a slabber and a resaw. Alternatives A and B are based on electricity from installed diesel generators, whereas alternative C takes the power directly from a 164 HP (SAE) diesel motor, one for each sawmill.

8.2 Assumptions

8.2.1 General

The comparison is based on the situation at Sao Hill described in Ch. 5.1.3. The annual logging quantity is assumed to be distributed as follows for the first 10-15 years (cf. Map 5.5, Table 5.16 and Table 5.17):

Forest Reserve	Type of logging	Annual sawlog quantity extracted (cu.m. u.b.)
Msiwasi F.R.	Clearcut	12,300
Irunda F.R.	"	6,200
Mninga F.R.	"	6,200
Sao Hill F.R.	Thinnings	5,200
SUM (rounded off)		30,000

Alternative A is located at the present Sao Hill Sawmill (point A on Map 5.5). Alternative B and alternative C are analysed assuming different locations of the sawmills. In alternative B the sawmill is located on site B of Map 5.5, due to the arguments given in FERGUS et al. (1977: 121-130). The central unit of alternative C is assumed situated on the same place as alternative B, whereas the five sawmills of alternative C are located as follows (cf. Map 5.5):

2 sawmills in Msiwasi Forest Reserve
1 sawmill in Irunda " "
1 " in Mninga " "
1 " at site B (Central Unit)

Social infrastructure costs (housing, etc.) of alternative A are assumed to correspond to the actual costs of the present Sao Hill Sawmill, as described in Appendix 4. For alternative B and C more of the employees are assumed to be recruited from the villages around the sawmills, and except for the skilled personnel, it is assumed that the employees live in their existing homes.

The need for access roads is the same in all three alternatives. However, in alternative C, skidding is mainly done directly from stump to industry, and less feeder roads are necessary.

In clearfellings in alternative A log skidding with Volvo TC 860 forwarders is used in the easy terrain and Ford County 1164 in the more difficult terrain, which accounts for about 20 % (or 6,000 cu.m o.b. per year) of the timber volume extracted.

In clearfellings in alternatives B and C log skidding with Ford 6600-2 agricultural tractor is used in the easy terrain and Ford County 1164 in the more difficult areas. In thinnings, sulky-skidding (cf. Ch. 6) is assumed in all alternatives.

NTI (1959) gives almost the same sawnwood recovery percentage (i.e. volume of sawnnwood produced in percentage of the sawlog input volume u.b.) for the machinery which at that time corresponded to alternative A (alternative B) and alternative C, with a slightly higher recovery for the machinery of the alternative C type. According to NAGODA (pers. comm.) it is realistic to assume that the recovery percentages of alternative A (alternative B) and alternative C are equal assuming similar maintenance efforts. KOWERO et al. (1985) reports of 48 % recovery on the average using mobile sawbenches in softwood thinnings in West-Kilimanjaro. At Sao Hill the average recovery percentage was about 47 % for sawnwood and 4 - 5 % for boxboard (SAO HILL 1977). Consequently, in the analysis the following recovery percentages have been applied for all three technology alternatives:

47 % for sawnwood production from clearfellings
44 % for sawnwood production from thinnings
5 % for boxboard production (mainly from clearfellings)

Finally, the analysis includes the sawmilling and corresponding logging activities only - i.e. the planing, boxboard and impregnation activities which take place at the present Sao Hill Sawmill are not considered. The reason is that these activities, under the assumptions made, will involve the same additional benefits and costs for all three sawmilling alternatives that are analysed.

8.2.2 Particular assumptions, alternative A

Alternative A is the present sawmill project described in Ch. 8.1 and Appendix 4.

Based on the assumptions in Ch. 8.2.1 and the data in Appendix 4, the operating costs at market prices of alternative A will be as shown in Table 8.1.

Table 8.1. Average annual operating costs for sawmilling alternative A at full production. (At 1977 market prices in 1,000 shs/year).

Type of costs	Logging and road transport		Sawmilling[a]		Admin. and sales[b]		Social infrastructure		Total	
	Total	Direct import	Total	Direct import	Total	Direct import	Total	Direct import	Total	Direct import
Depreciation[c]	837	416	1,037	769	191		155		2,200	1,185
Interest[d]										
On machinery/buildings	259	114	591	374	95		170		1,115	488
On stock of spare parts[e]	63	42	141	136	7				211	178
On working capital[e]	43		43		27		2		115	
Insurance	91		60		30		10		191	
Fixed machinery/building costs	1,293	572	1,872	1,279	350		337		3,852	1,851
Energy (diesel, oil)	256[f]		335		76				667	
Tyres	261[f]	90	70		83				414	90
Spare parts and consumables excl. tyres	410[f]	202	220	144	110				840	346
Other costs[g]	50		186	22	335		50		621	22
Total machinery/building costs	2,270	864	2,783	1,445	954		387		6,394	2,309
Salaries										
Un- and semiskilled pers.	415		432		60		(Included in sawmilling		907	
Skilled personnel	163		181		292		and administration)		636	
Total shs/year	2,848	864	3,396	1,445	1,306		387		7,937	2,309
Total shs/cu.m sawnwood	203	62	243	103	93		28		567	165

[a] Including trimming unit and loading of sawnwood.

[b] Includes the preoperational costs (980,000 shs), office building with assumed initial investments of 150,000 shs, one Landrover and one Scania LBT 111.

[c] Same write-off times are used as in Table 8.2.

[d] Calculated as described in Ch. 5.2.

[e] Working capital and stock of spare parts are:

	Working capital:	Stock of spare parts:
Logging and log transport	481,000 shs	691,000 shs
Sawmilling	475,000 "	1,564,000 "
Administration and sales	296,000 "	78,000 "
Social infrastructure	18,000 "	0 "

[f] Because of over-capacity the annual costs of spare parts, diesel and tyres for the two LBT 111 vehicles are reduced with 30 % compared with the costs reported in Ch. A 3.7.

[g] Includes travel and meeting costs, sales promotion, training, audit fees, etc. - cf. Table A 4.3.

8.2.3 Particular assumptions alternative B

Alternative B consists basically of the same technological components as alternative A. In FERGUS et al. (1977:10), it is concluded that the sawmill machinery chosen there is probably the best solution assuming one centrally located bigger sawmill. However, it is stated (op.cit.) that the present Sao Hill project does not in all respects represent an optimal solution. Based on the proposals (op. cit.) the following modifications are therefore made of the actual Sao Hill project to arrive at alternative B of this analysis:

- The location of the mill is assumed to be on site B of Map 5.5 (cf. FERGUS et al. op.cit.: 58-65).
- The main sawmill building is assumed simpler and to cost 1.2 mill. shs. instead of about 2.2 mill. shs. (cf. FERGUS et al. op.cit.: 70).
- The road improvement from site B (Map 5.5) to the Tan-Zam Highway is assumed to cost 330,000 shs. (cf. FERGUS et al. op.cit.: 63) - i.e. the same as the road constructed from the present mill site east of Irunda height (cf. Map 5.5). This latter road is not necessary when the mill is assumed to be located on site B.
- In clearfellings no forwarder is used, but three Ford 6600-2 agricultural tractors, and one Ford County 1164 for the more difficult terrain (cf. Ch. 7.2.3 and FERGUS et al. op.cit.: 64-65, 142-143). This equipment has an overcapacity of about 12 %.
- The road transport of logs is done by using three Scania LB 81 with 1-axle piggy-back trailer (cf. FERGUS et al. op.cit.: 146-146). This equipment has an overcapacity of about 23 %.[1]
- Caterpillar 930 is used as wheelloader instead of Volvo LM 841, as Caterpillar in 1977 had service and sales agent in Tanzania.
- Only 70 junior-staff houses are assumed necessary in alternative B, and water supply costs are lowered to 260,000 shs.

Consequently, the investment costs of alternative B will be as shown in Table 8.2.

Table 8.2. Investments in alternative B.

Type	Investment costs[a] (1,000 shs) Total	Direct imports	Assumed write-off time (years)
1. Sawmilling and administration			
Site preparation	520		20
Main sawmill building	1,200		20
Workshop and other buildings	560		20
Sawmill machinery	4,890	4,890	10
Green chain with dipping	450	450	10
Sawdoctor equipment	90	90	10
Trimming unit	370	370	10
Diesel power plant	800	800	10
Electricity installation	180		10
2 wheelloaders (Caterp. 930) excl. tyres	970		5
1 Scania Lorry LBT III with trailer excl. tyres	690		5
2 agric. tractors with trailers (excl. tyres)	320		5
1 landrover	90		5
Misc.	450		10
Roads[b]	330		20
Sum	11,910	6,600	
2. Logging and log transport			
3 Ford 6600 - 2 tractors excl. tyres	420		5
1 Ford County 1164 excl. tyres	230		5
Logging equipment for Ford 6600 and Ford County	200	200	5
3 Scania LB 81 excl. tyres	1,100		5
3 piggy-back trailers and hydraulic grapple loaders for the LB 81 lorries	770	770	5
1 Scania LB 81 Tipper excl. tyres	400		5
1 landrover excl. tyres	90		5
1 stone crusher	60		10
Access roads[c]	230		20
Misc.	200		10
Sum	3,700	970	
3. Social infrastructure			
20 senior-staff houses	1,400		20
70 junior-staff houses	1,050		20
Water supply	260		20
Misc.	240		20
Sum	2,950		
4. Preoperational costs[d]	980		20
Total	19,540	7,570	

[a] Not including stock of spare parts and working capital.

[b] Improvements of the main road from site B to site G. Map. 5.5 (cf. footnote 13 of Table A 4.1, and FERGUS et al. 1977:63).

[c] Cf. footnote 13 of Table A 4.1.

[d] Same as in alternative A.

The employment and salaries are as shown in Table A 4.2 and the other recurrent expenditures are assumed to be as described in Table A 4.3, however adjusted (by using the data in Appendix 3) for the fact that other vehicles are used (cf. above).

The average operating costs for alternative B assuming full production will then be as shown in Table 8.3.

8.2.4 Particular assumptions alternative C

Sawmilling machinery - type and costs

Each of the five sawmills of alternative C consists of two circular saws - one slabber and one resaw - driven by one diesel motor. The two saws are assumed to be of the type KA-RA YS 1/10 consisting of a steel frame in three sections. The central section is equipped with steel fundaments and telescopic legs, and the end section equipped with telescopic legs. The saws consist of a steel table 8 m long, rollers with ball bearings, hydraulic table feeding equipment, saw blade arbor and guiderods, size adjuster with roller, and tool box.[2] The cost for this at producer's place in 1977 was 8,100 $ not including package.[3] In addition the following accessoires are assumed per saw:

Type	Price ex producer s place
Hydraulic press roller[4]	1,600 US $
Sharpening machinery[5]	350 "
Sawblade[6]	350 "
TOTAL (rounded off)	2,300 US $

Packing, insurance and freight costs in 1977 for the transport from Helsinki to Dar es Salaam were respectively 540, 130 and 1,600 US $. Total costs per sawbench cif. Dar es Salaam would then be (rounded off) 12,700 US $ or 107,000 shs.

The sawbenches have a maximum load capacity of 2,080 kg. Maximum sawblade diameter is 1,200 mm.

Table 8.3. Average annual operating costs for sawmill alternative B at full production. (At 1977 market prices in 1,000 shs/year).

Type of costs	Logging and road transport		Sawmilling[a]		Admin. and sales[b]		Social infrastructure		Total	
	Total	Direct import	Total	Direct import	Total	Direct import	Total	Direct import	Total	Direct import
Depreciation[c]	613	175	993	594	191		133		1,930	769
Interest[c]										
On machinery/buildings	185	48	542	327	95		146		968	375
On stock of spare parts[d]	37	17	141	119	7				185	136
On working capital[d]	38		43		27		2		110	
Insurance	75		60		30		8		173	
Fixed machinery/building costs	948	240	1,779	1,040	350		289		3,366	1,280
Energy (diesel, oil)	235[e]		336[f]		76[e]				647	
Tyres	191[e]		70		83				344	
Spare parts and consumables excl. tyres	313[e]	148	320	144	110				743	292
Other costs	50		186	22	335		50		621	22
Total machinery/building costs	1,737	388	2,691	1,206	954		339		5,721	1,594
Salaries:										
Un- and semiskilled pers.	437		432		60		(Included in sawmilling and administration)		929	
Skilled personnel	152		181		292				625	
Total shs/year	2,326	388	3,304	1,206	1,306		339		7,275	1,594
Total shs/year cu.m(s)	166	28	236	86	93		24		520	114

[a] Including trimming unit and loading of sawnwood.

[b] Includes the preoperational costs, office building with assumed initial investment of 150,000 shs, one landrover and one Scania LBT III, altogether representing an investment amount of 1,910,000 shs.

[c] Calculated as described in Ch. 5.2.

[d] Working capital and stock of spare parts are:

	Working capital:	Stock of spare parts:
Logging and log transport	423,000 shs	410,000 shs (194,000 shs import)
Sawmilling	476,000 "	1,564,000 " (1,320,000 " ")
Administration and sales	296,000 "	78,000 "
Social infrastructure	18,000 "	0 "

[e] Because of over-capacity a 23 % reduction of the annual spare parts, diesel and tyre costs is assumed for the three Scania LB 81 used in the road transport of logs.

[f] Of this 231,000 shs is for diesel used by the diesel-generators (cf. Table 8.2), which also gives electricity for the administration office.

The model can be delivered with mechanical table feeder. However, a hydraulic table drive has many advantages as:

- steepless speed regulation of the table between 0 - 100 m/min.
- easy change of direction of the table movement
- easy handling of the levers
- easy movement of the table even with heavy load
- long life of the hydraulic motors (10-20 years)

All this implies less physical strain on the workers, and more accurate sawing. The only argument in favour of a mechanical drive is that repair of breakdowns might be easier. However, after discussions with the producer and with other sawmill experts, it was concluded that this factor was not decisive here as the hydraulic table feeding system used is robust and no more complicated than the hydraulic system on an agricultural tractor. Besides, the sawbench will be situated on the same spot most of the time - i.e. no breakdowns due to frequent transport will occur. Summa summarum hydraulic table feed is assumed in this analysis. If mechanical table feed is used, the investment costs will be 1,500 - 2,000 US $ lower per sawbench. As mentioned above this alternative will, however, give harder physical strain on the workers and less accurate sawing[7].

Each sawmill is assumed to be equipped with one crosscut saw for cutting shorts. The investment costs for this (including power transmission equipment) is estimated to 5,000 shs. per mill.

One Bedford 500 P diesel motor is assumed to run the two sawbenches and the crosscut-saw by using driving belts for power transmission. This is a 6-cylinder engine having a maximum power of 164 HP (SAE) at 2,800 rpm. Optimal fuel use is at 2,000 rpm giving about 130 HP (SAE) at a diesel consumption of 15 - 20 l per machine hour. Investment costs cif. Dar es Salaam for this in 1977, including starter, radiator and engine mounting feet was 44,000 shs.[8]

Driving belts, belt discs, and other power transmission devices are assumed to cost 1,500 US $ per set of two sawbenches, or 13,000 shs. rounded off.

The sawnwood is loaded on tractor trailers directly after being sawn. Thus, no storing shed is necessary except at the Central Unit. The sawmill buildings are assumed to be simple with cement floor (6 m x 20 m), eucalyptus poles and corrugated iron. Building and site preparation investments are assumed to be 70,000 shs. per sawmill, of which 40,000 shs. represents investments having a write-off time of 3.3 years (the mills are assumed to be moved every 3-4 years - cf. below).

Estimated total investments and corresponding write-off times, employment and recurrent expenditures for the sawmilling operation are shown in Tables 8.4, 8.5 and 8.6 respectively.

Table 8.4. Investment costs of sawmill operations, alternative C.

Type	Investment costs (shs)		Assumed write-off time (years)
	Total	Direct import	
Preparing of site (cement flour, timber intake), erection of building, building materials which cannot be reused	40,000		3.3
Building materials[b] which can be reused	30,000		10
Sawmill machinery	219,000	214,000	10
Diesel engine	44,000		5
Power transmission	13,000	13,000	5
Misc. items	35,000	20,000	10
Total - one mill	381,000	247,000	
Total - five mills	1,905,000	1,235,000	

[a]Not including stock of spare parts and working capital.

[b]Corrugated iron sheets, office equipment, etc.

Table 8.5. Employment in sawmill operations, alternative C.

Type of job	Nos. of workers	Gross salary[a] per person (shs/month)	Total annual salary[a]	
			Un- and semiskilled personnel	Skilled personnel
Log intake	3	390	16,200	
Sawyers	2	450		12,400
Sawyers assistants	2	410	11,300	
Sorting and loading on trailer	4	390	21,600	
Watchman	1	390	5,400	
Manager/clerk	1	1,200		16,600
Total - one mill	13 (of which 3 are skilled)		54,500	29,000
Total - five mills	65 (of which 15 are skilled)		273,000	145,000

[a]Gross salary plus 15 % social benefits.

Table 8.6. Recurrent expenditures (except personnel costs) sawmill operations, alternative C.

Type	Total costs (shs/year)	Direct import of this (shs/year)
Diesel, oil	45,000[a]	
Repair and maintenance	30,000[b]	28,000
Insurance	3,000	
Other costs	5,000	
Total - one mill	83,000	28,000
Total - five mills	415,000	140,000

[a]Based on an average diesel consumption of 90 l per working day.

[b]Based on the information given by the producer, increased with 30 %.

Production capacity

The five sawmills are assumed to have on the average an annual production of about 14,000 cu.m of sawnwood on one-shift, the four mills operating mainly in clearfellings each producing 2,900 cu.m and the one at the Central Unit for thinnings producing 2,300 cu.m per year.

A vital question here is how realistic these production estimates are. KOWERO et al. (1985) reports of an output volume of 2,420 cu.m of sawnwood for two mobile sawbenches at West-Kilimanjaro for 203 working days (after 1 year of operation). It is unclear how much of this was from softwood thinnings. NTI (1959) gives empirical data from Norway for the double circular sawmill - i.e. mills corresponding to alternative C in this analysis. In this type of mills the first saw normally makes two cuts on the log and the other makes the rest. The power comes from one diesel motor which runs the axle common for both saws. The data are based on an investigation in 1958 of four Norwegian sawmills. All mills investigated had mechanical press roller and table feed. The production obtained for a mill with hydraulic table feed and hydraulic press roller should be higher than for a mill with mechanical systems.

From NTI (1959:Bilag 3) it is seen that the production of the four sawmills investigated varied between 5.3 - 7.6 cu.m(r) per working hour (i.e. delay time included) for log top diameter 20 cm. This equals 41 - 46 cu.m per day assuming eight working hours per day, or 9,200 - 13,700 cu.m per year assuming 225 working days per year. According to NTI (1959:33) the delay time for the four mills studied varied between 16 - 19 % of workplace time.

As discussed above, more modern machinery is used in alternative C than what was available in 1959. It seems realistic to conclude that the assumed annual production of about 6,000 cu.m(r) per sawmill in Tanzania should be obtainable, assuming adequate repair, maintenance and log supply.

NTI (1959) covers also four sawmills of the double slabber type - i.e. mills corresponding to alternative A(B) in this analysis. It is found (op.cit.: Bilag 29) that for logs with top diameter of 20 cm the production of the four mills investigated varied between 14.8 - 19.5 cu.m(r) per working hour, with an average of about 17 cu.m(r)

per working hour corresponding to 136 cu.m(r) per 8 hours working day or 30,600 cu.m(r) per year assuming 225 working days per year. It is here noteworthy that the production of alternative A (alternative B) and alternative C assumed in this analysis for Tanzania in 1977 are respectively about 100 % and 52 % of the actual production reported in NTI (1959) for corresponding technologies in 1958 in Norway[9]. At the same time the delay time reported op.cit. are 21 - 37 % and 6 - 19 % for respectively alternative A and alternative C, indicating the somewhat higher technological complexity in 1958 of alternative A (cf. op.cit.:33, 50). It should here be noted that the study from Norway in 1959 refers to machinery of a less modern type than the one assumed in Tanzania. Lacking more recent studies of this kind, however, the Norwegian study gives useful information. In my opinion, taking into account the technology development which the KA-RA saw represents, the productivity figures assumed in this analysis for alternative C relative to alternatives A and B are probably underestimated rather than overestimated, if repair and maintenance are done properly.

Logging and log road transport

The assumed sawnwood production and sawnwood recovery percentages imply an annual sawlog supply of 6,200 cu.m u.b. for the four mills getting timber from clearfellings only, and 5,200 cu.m u.b. for the mill at the Central Unit taking thinnings only. The felling, bucking and limbing are assumed to be done with manual saws as for the alternatives A and B.

In thinnings the sulky method described in Ch. 6.2.4 is used.

Assuming that clearfellings give an average utilizable volume of about 400 cu.m u.b. per ha (cf. Table 5.18), each of the four sawmills taking mainly timber from clearfellings will require that about 15 ha be clearcut per year[10]. If each mill is situated on one site for about 3 years, and then moved to the center of the next 3 year logging area, the average skidding distance from stump to mill site will be 150 - 250 m depending on the shape and distribution of the compartments and on where the sawmill can be placed. This implies that the logs can be skidded directly from stump to the mill site. For the easy terrain (about 90 % of the area) the equipment described in Ch. 7.2.3. is used - i.e. one

Ford 6600 tractor with 2-drum winch per sawmill. For the more difficult terrain the use of one Ford County 1164 is assumed which can be shared by the four mills according to need.

Each Ford 6600 tractor is assumed to have a logging productivity of 7,500 cu.m u.b. per year (cf. Ch 7.2.3). Assuming that 4,500 cu.m u.b. of sawlogs are skidded by the Ford 1164 in the difficult terrain taking 70 % of the available skidding time of this machine, and that its capacity in the easy terrain corresponds to 10,000 cu.m u.b. per year, this skidding system for clearfellings will have on the whole an overcapacity of about 51 %.

For the sawmill at the Central Unit the logging is assumed to be done by 9 two-men crews equipped with sulkies as described in Ch. 6.2.2. The road transport here is assumed to be done by using one Ford 6600 agricultural tractor and two trailers, and the loading directly on the waiting trailers by two workers. The tractors necessary for this will be employed only one third of the total time on this work (3 trips per day, each of about 6 km both ways). The rest of the time this tractor is assumed to do various jobs at the Central Unit.

The cutting, delimbing and bucking of clearfellings is assumed to be done manually as practiced today at Sao Hill. 8 cutters are necessary per sawmill in addition to one headman and one part-time cook.

The transport of sawnwood from the sawmills to the Central Unit is done with Ford County 1167 tractors with 2-axle trailers. The trailers are equipped with breaks, and can take loads up to 9 - 10 tons. Each sawmill produces about 13 cu.m sawnwood per day. The sawnwood is loaded on a waiting trailer by hand directly from the sawbench. In addition about 1.3 cu.m of the best slabs and offcuts is assumed taken per trailer load to the Central Unit for boxboard production (5 % recovery percentage for boxboard - cf. above). This means that each mill will have to be visited twice a day by a tractor for road transport of sawnwood, slabs and off-cuts.

The average transport speed (both ways) by the tractor is about 15 km per hour. This implies that one tractor from the Central Unit daily will manage two trips to the sawmill in Mninga Forest Reserve

(one way distance 13 km), two trips to the sawmill in Irunda Forest Reserve (one way distance 6 km) and one trip to one of the sawmills in Msiwasi Forest Reserve (one way distance 15 km). The second tractor will manage three trips per day to the sawmills in Msiwasi Forest Reserve. To secure this transport, however, it is assumed that one additional Ford County 1167 is bought and kept in reserve, thus giving an overcapacity of about 35 %.

In addition one landrover, one Scania LB 81 Tipper for road work, one stone crusher, and access roads as in alternative B are necessary, as well as tool maintenance personnel, workshop manager and mechanics.

The vehicle costs are analysed in Appendix 3. The estimated employment, investments and other costs for logging and road transport in alternative C are shown in Tables 8.7, 8.8 and 8.9 respectively.

Table 8.7. Employment and personnel costs of logging and road transport in alternative C.

Type of job	Employment (manyears per year)	Amount paid (shs/month per person)	Total salaries[a] (shs/year)	
		Gross salary	Un- and semiskilled personnel	Skilled personnel
Logging Central Unit mill				
Felling, sulky-pulling	18	390	97,000	
Loading trailer	2	390	10,800	
Headman	2	430	11,900	
Ford 6600 driver	1/3	500		2,300
Cook (1 half-time employed)	1/2	390	2,700	
Logging other mills				
Felling, delimbing, bucking	32	390	172,400	
Headman	4	430	23,800	
Ford 6600 drivers	4	500		27,600
Ford County 1164 driver	1	520		7,200
Tractor helpers (loading)	5	390	26,900	
Cooks (4 half-time employed)	2	390	10,800	
Logging all mills				
Tool maintenance - head	1	470		6,500
" " - assistant	1	390	5,400	
Workshop manager	1	2,000		27,600
Mechanics - chief	2	800		22,100
" - assistants	2	480	13,200	
Landrover driver	1	530		7,300
Road transport of sawnwood to Central Unit				
Ford County drivers	2	520		14,400
Road workers[b]	5	390	26,900	
Sum (rounded off)	86 (of whom 12 represent skilled personnel)		402,000	115,000

[a]Gross salary plus 15 % social benefits.

[b]Less feeder and branch roads are necessary in alt. C than in alt. A.

Table 8.8. Investment costs of logging and road transport of sawnwood in alternative C.

Type	Investment costs (1,000 shs) Total	Direct import	Assumed write-off time (years)
Logging			
4 1/3 Ford 6600-2 excl. tyres	600		5
2 tractor trailers with brakes	60		5
1 Ford County 1164	230		5
5 sets of skidding equipment for tractors	200	200	5
1 Scania LB 81 Tipper excl. tyres	390		5
1 Landrover 109" excl. tyres	90		5
9 sulkies, various equipment, etc.	40		5
1 stone crusher	60		10
Misch. items	160		10
Sum	1,830	200	
Road transport of sawnwood to Central Unit			
3 Ford County 1164 tractors excl. tyres	700		5
8 tractor trailers with brakes	240		5
Access roads	230		20
Sum	1,166		
Total	3,005	200	

Table 8.9. Recurrent expenditures (exclusive personnel costs) of logging and road transport in alternative C for all sawmills.[a]

Type	Total annual costs (shs/year)	Direct import of this (shs/year)
Logging		
Spare parts vehicles	164,000	
Fuel, oil	231,000	
Tyres	90,000	
Insurance	28,000	
Handtools, boots etc.	5,000	2,000
Misc.	30,000	
Sum	548,000	2,000
Road transport of sawnwood to Central Unit		
Spare parts	44,000	
Fuel, oil	42,000	
Tyres	29,000	
Insurance	5,000	
Other costs	25,000	
Sum	145,000	
Total	693,000	2,000

[a]Because of low capacity utilization the costs of the Ford County 1164 used for logging are reduced by 50 % compared with the data given in Ch. A 3.2.

Central Unit

The Central Unit is assumed to have the following tasks:

- collect the sawnwood from the sawmills
- do the sorting, preservation, drying and trimming of the sawnwood, and the sales and marketing
- provide workshop for repair and maintenance for all logging and sawmilling in the project.
- administer the project.

The Central Unit is assumed to be situated on site B on Map 5.5, and to have the sawmill which utilizes the thinnings from Sao Hill Forest Reserve.

The investments, employment and recurrent expenditures of the Central Unit are shown in Table 8.10, Table 8.11 and Table 8.12 respectively, broadly following the corresponding components of alternative B. Only one wheelloader (Cat. 930) is assumed necessary, as there at the Central Unit will be no unloading or transport of sawlogs from clearfellings. Because more workers can stay at home, only 50 junior-staff houses are assumed necessary in alternative C.

Table 8.10. Central Unit investment costs alternative C.

Type	Investment costs (1,000 shs)		Assumed write-off time (years)
	Total	Direct import	
Central Unit			
Site preparation	200		20
Buildings (3 sheds with 1,000 sq. m office, workshop)[a]	600		20
Sorting and dipping arrangement	150		20
Sawdoctor equipment	90	90	10
Trimming unit	370	370	10
2 diesel motors 60 HP[b]	75		5
1 wheelloader	485		5
2 Ford 6600-2 tractors excl. tyres[c]	232		5
2 tractor trailers without brakes	40		5
1 Landrover	90		5
1 Scania lorry LBT III with trailer[d]	690		5
Roads	330		20
Pre-operational costs[e]	980		20
Misc.[f]	360		10
Total (rounded off)	4,690	460	

[a] The sawmill is not included. The equipment for the mechanical workshop is included in Table 8.7.

[b] Ford Bedford 230 P diesel motor for trimming unit and production of electricity light.

[c] 2 tractors for misc. jobs. One of these tractors is 2/3 of the time doing misc. minor jobs at the Central Unit and 1/3 of the time collecting sawlogs from thinnings.

[d] For transport of sawnwood to customer or nearest railway station, and of goods for the sawmill project.

[e] Same amount as for alternatives A and B.

[f] Mainly harbour handling costs in Tanzania and transport costs of machinery and equipment from Dar es Salaam to Sao Hill (cf. Table A 4.1), but also including furniture investments and various installations.

Table 8.11. Employment and salaries at Central Unit alternative C.

Type of job	Nos. of employees	Total salary[a] (shs/month per person) Total[a]	Total salary (shs/year) Un- and semiskilled personnel	Skilled personnel
Unloading, sorting, dipping	30	460	165,600	
Trimming unit - foreman	1	736		8,800
" " - others	12	460	66,200	
Delivery	12	449	64,700	
Wheelloader operator	1	552		6,600
Ford 6600 drivers	1 2/3	575		11,500
Workshop - mechanic	1	1,127		13,500
" - assistants	3	529		19,000
" - store clerk	1	621		7,500
Sawdoctor	1	1,380		16,600
" - assistant	1	805		9,700
" - helper	1	483	5,800	
Watchmen	5	449	26,900	
Administration and sales[b]	29 (of whom 17 are skilled personnel)		60,000	320,000
Total (rounded off)	100 (of whom 28 are skilled)		389,000	413,000

[a]Including social benefit corresponding to 15 % of gross salary.

[b]As given in Table A 4.2. In addition because of more difficult control in alternative C, one highly qualified person is assumed employed for only controlling the operation of the sawmills, having a gross salary of 2,000 shs/month.

Table 8.12. Recurrent expenditures (excl. personnel costs) for Central Unit alternative C.

Cost classification	Total annual cost (shs/year)	Direct import (shs/year)
Non-mobile equipment		
Spare parts and consumables - trimming unit	12,000	12,000
Spare parts and consumables - workshop	42,000	22,000
Spare parts and consumables - central store	12,000	
Spare parts and consumables - 2 diesel motors (Bedford 220 P)	10,000	
Spare parts and consumables - buildings	6,000	
Blue stain preservation	22,000	22,000
Package etc.	101,000	
Working clothes	20,000	
Insurance	20,000	
Diesel - 2 Bedford 220 P motors[a]	66,000	
Other costs	20,000	
Sum	331,000	56,000
Mobile equipment (vehicles)[b]		
Spare parts	155,000	
Fuel, oil	139,000	
Tyres	125,000	
Insurance	36,000	
Sum	455,000	
Administration		
Office equipment and consumables	35,000	
Postage, telephone	22,000	
Sales promotion, training and education	42,000	
Bank charges	15,000	
Litterature, entertainment, etc.	20,000	
Mileage compensation	50,000	
Travel and meeting costs	130,000	
Audit fees	40,000	
Other costs	16,000	
Sum	370,000	
Total	1,156,000	56,000

[a]Diesel consumption of 67 l per day per motor is assumed, with a diesel cost of 2.20 shs per l.

[b]1 landrover and 1 Scania LBT 111 is for administration and sales.

Social infrastructure

The social infrastructure investments are assumed to be as shown in Table 8.13.

Table 8.13. Investment costs in social infrastructure, alternative C.

	Investment costs (1,000 shs)		Assumed write-off time
	Total	Direct import	(Years)
20 senior staff houses	1,400		20
50 junior staff houses	750		20
Water supply	250		20
Misc.	240		20
Total	2,640		

Personnel costs for repair and maintenance are included in Central Unit costs presented in Table 8.11. In addition 55,000 shs./year (of which 7,000 shs. is insurance) is assumed as misc. items for the houses in addition to the house rents paid by the dwellers.

The total annual operation costs of alternative C at full production are shown in Table 8.14.

8.3 Calculation of direct and indirect economic effects

8.3.1 Direct economic effect

Based on the assumptions in Ch. 8.2 the following calculations of the direct economic effects of the three alternatives of technology are presented.

Tables 8.1, 8.3 and 8.14 give the annual and per cu.m costs of the three methods assuming 9 % p.a. calculation rate of interest.

Tables 8.15, 8.16 and 8.17 give the resource flow of the three alternatives. Based on these, Tables 8.18, 8.19 and 8.20 give, as described in Ch. 5.2.3 and 5.2.4, a sensitivity analysis of the discounted net present costs of the three methods at various shadow prices (un/semiskilled labour, skilled labour, import), relative annual pri-

Table 8.14. Average annual operating costs for sawmill alternative C at full production. (At 1977 market prices in 1,000 shs/year).

Type of costs	Logging		Sawmilling		Road transport of sawnwood to Central Unit		Central Unit except.admin.. and sales		Administration and sales[a]		Social infrastructure		Total	
	Total	Direct import	Total	Direct import	Total	Direct import	Total	Direct import	Total	Direct import	Total	Direct import	Total	Direct import
Depreciation	310	36	226	117	178		274	41	191		119		1,298	194
Interests[b]														
on machinery/buildings	91	10	94	61	56		137	23	95		131		604	94
on stock of spare parts[c]	18	4	25	22	8		17	8	7				75	34
on working capital[c]	29		23		5		25		27		2		111	
Insurance	28		15		5		26		30		7		111	
Fixed machinery/building costs	476	50	383	200	252		479	72	350		259		2,199	322
Energy (diesel, oil)	231[d]		225		42		129		76				703	
Tyres	90[d]				29		42		83				244	
Spare parts and consumables excl. tyres	169[d]	2	150	112	44		162	34	110				635	148
Other costs	30		25		25		163	22	335		48		626	22
Total machinery/building costs	996	52	783	312	392		975	128	954		307		4,407	492
Salaries:														
Un- and semiskilled pers.	402		273		27		329		60		(Included in		1,091	
Skilled personnel	115		145		14		93		320		Central Unit costs)		687	
Total - shs/year	1,513	52	1,201	312	433		1,397	128	1,334		307		6,185	492
Total - shs/cu.m(s)	108	4	86	22	31		100	9	95		22		442	35

[a] Same costs are assumed as in alt. A and alt. B, except that one person more is employed for control reasons in alt. C.

[b] Calculated as described in Ch. 5.2.

[c] Stock of spare parts and working capital are:

	Working capital:	Stock of spare parts:
Logging	320,000 shs	204,000 shs (40,000 shs is import)
Sawmilling	250,000 "	279,000 " (247,000 " is import)
Road transport of sawnwood	56,000 "	90,000 "
Central Unit except administration	283,000 "	190,000 " (92,000 shs is import)
Administration and sales	296,000 "	78,000 "
Social infrastructure	17,000 "	0 "

[d] Because of over-capacity the skidding costs are reduced with an amount corresponding to 50 % of the annual recurrent expenditures of one Ford County 1167 with two-axle trailers.

ce increases (labour, energy, import, other costs), total price increases (labour, energy import, other costs, investment costs, and recurrent expenditures), and rates of interest (3, 6, 9, and 12 % p.a.). For example it is seen from the first and second line of Table 8.18 that if the total labour costs are increased by 10 % above the estimate given in the first line, the net discounted costs of alternative A at 3 % p.a. calculation rate of interests (and shadow prices 1.0) is increased from 59.2 mill. shs. to 60.7 mill. shs. (rounded off).

When all shadow prices are 1.0, Tables 8.18 - 8.20 give the discounted net present costs at market prices, the first 35 lines of Tables 8.18 - 8.20 thus giving a sensitivity analysis of financial cost efficiencies. As stated in Ch. 5.2.3 most probable shadow prices of un/semiskilled labour, skilled labour and import are assumed to be respectively 0.7, 1.3 and 1.6, the last 46 lines of Tables 8.18 - 8.20 thus giving a sensitivity analysis of the economic cost efficiencies of the three alternatives of technology.

8.3.2 Indirect economic effects

The indirect economic effects of the three alternatives of technology are calculated using the input/output table for Tanzania as described in Ch. 5.2.5. As vector y_T are used the columns in Table 8.21. The results are presented in Table 8.22.

Table 8.15. Resource flow sawmill alternative A.
At 1977 market prices (1,000 shs per year).

	Year 0	1	2	3	4	5	6	7	8	9	10
1. Investments[a]											
1.1 Un- and semiskilled labour	1,994[b]										- 1,097
1.2 Skilled labour	963[b]										- 530
1.3 Energy (fuel, oil)	275[b]										- 151
1.4 Other domestic inputs	11,035[b]					2,891					- 4,957
1.5 Imports	12,216		4			3,222		4			- 3,054
2. Recurrent expenditures[c]											
2.1 Un- and semiskilled labour		647	907	Same for all years							
2.2 Skilled labour		477	636	Same for all years							
2.3 Energy (fuel, oil)		334	667	Same for all years							
2.4 Other domestic inputs		804	1,608	Same for all years							
2.5 Imports		229	458	Same for all years							

[a]Including working capital and stock of spare parts.

[b]Includes preoperational costs (980,000 shs), site preparation, roads investments separated into the cost component for roads given in footnote 13 of Table A 4.1, and the social infrastructure investment separated into the cost components given in footnote 15 of Table A 4.1.

[c]It is assumed that full production is gained after 2 years and that labour costs and other recurrent expenditures the first year are respectively 75 % and 50 % of corresponding costs at full production.

Table 8.16. Resource flow sawmill alternative B.
At 1977 market prices (1,000 shs per year).

	Year 0	1	2	3	4	5	6	7	8	9	10
1. Investments[a]											
1.1 Un- and semiskilled labour	1,798[b]										- 989
1.2 Skilled labour	841[b]										- 463
1.3 Energy (fuel, oil)	250[b]										- 138
1.4 Other domestic inputs	10,832[b]					3,881					- 4,407
1.5 Imports	9,084		4			873		4			- 2,271
2. Recurrent expenditures[c]											
2.1 Un- and semiskilled labour		697	929	Same for all years							
2.2 Skilled labour		469	625	Same for all years							
2.3 Energy (fuel, oil)		324	647	Same for all years							
2.4 Other domestic inputs		784	1,567	Same for all years							
2.5 Imports		157	314	Same for all years							

[a]As for Table 8.15.

b --- " ---

c --- " ---

Table 8.17. Resource flow sawmill alternative C. At 1977 market prices (1,000 shs/year).

	Year 0	1	2	3	4	5	6	7	8	9	10
1. Investments[a]											
1.1 Un- and semiskilled labour	1,578[b]										- 868
1.2 Skilled labour	747[b]										- 411
1.3 Energy (fuel, oil)	219[b]										- 120
1.4 Other domestic inputs	9,487[b]					3,912					- 3,630
1.5 Imports	2,274		4			329					- 569
2. Recurrent expenditures[c]											
2.1 Un- and semiskilled labour		818	1,091	Same for all years							
2.2 Skilled labour		515	687								
2.3 Energy (fuel, oil)		352	703								
2.4 Other domestic inputs		723	1,446								
2.5 Imports		128	170								

[a] As for Table 8.15.

[b] --- " ---

[c] --- " ---

Table 8.18. Discounted net present costs of sawmill alternative A (1,000 shs).

SHADOW PRICES LABOUR US&SS	SK	IMP CRT	REL.PRICE INCR. (% P.A.) LAB OUR	ENE RGY	IMP CRT	OTH ER	TOTAL PRICE INCREASE (%) LAB OUR	ENE RGY	IMP ORT	OTH ER	INV EST	REC UR.	CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.) 3.	6.	9.	12.
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59221	55378	52130	49371
1.0	1.0	1.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	60671	56679	53309	50449
1.0	1.0	1.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	62121	57980	54488	51526
1.0	1.0	1.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	63571	59261	55667	52604
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	59774	55857	52549	49741
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	60327	56335	52968	50110
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	60879	56814	53386	50480
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	60862	56966	53706	50916
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	62504	58594	55281	52461
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	64145	60202	56857	54006
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	61498	57529	54171	51316
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	63776	59679	56211	53260
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	66053	61829	58251	55205
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	61669	57937	54763	52051
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	64116	60497	57396	54732
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	66564	63055	60028	57412
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	62695	58357	54711	51628
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	66169	61336	57291	53884
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	69643	64314	59872	56141
1.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60415	56379	52976	50092
1.0	1.0	1.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61739	57486	53909	50885
1.0	1.0	1.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63208	58709	54938	51757
1.0	1.0	1.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64835	60063	56073	52717
1.0	1.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59824	55876	52544	49719
1.0	1.0	1.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60501	56432	53006	50105
1.0	1.0	1.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61260	57054	53520	50535
1.0	1.0	1.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62112	57749	54094	51013
1.0	1.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59444	55610	52360	49592
1.0	1.0	1.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59649	55833	52588	49816
1.0	1.0	1.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59827	56042	52809	50039
1.0	1.0	1.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59969	56229	53019	50257
1.0	1.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	60186	56240	52899	50056
1.0	1.0	1.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	61206	57154	53716	50787
1.0	1.0	1.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	62278	58119	54582	51563
1.0	1.0	1.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	63401	59135	55498	52385

Continues ...

Table 8.18 continued.

SHADOW PRICES			REL.PRICE INCR. (% P.A.)				TOTAL PRICE INCREASE (%)						CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.)			
LABOUR US&SS	SK	IMP ORT	LAB OUR	ENE RGY	IMP ORT	OTH ER	LAB OUR	ENE RGY	IMP ORT	OTH ER	INV EST	REC UR.	3.	6.	9.	12.
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68222	64242	60852	57954
0.7	1.3	1.6	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	69587	65464	61957	58963
0.7	1.3	1.6	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	70953	66687	63063	59972
0.7	1.3	1.6	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	72318	67909	64169	60981
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	68775	64720	61270	58323
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	69328	65199	61689	58693
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	69881	65677	62108	59063
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	70848	66814	63372	60425
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	73474	69387	65893	62897
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	76101	71959	68414	65369
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	70500	66392	62892	59898
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	72777	68542	64932	61843
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	75055	70692	66972	63788
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	71415	67554	64242	61393
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	74608	70867	67632	64831
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	77802	74180	71022	68270
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	71851	67353	63547	60310
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	75480	70463	66241	62666
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	79108	73574	68936	65023
0.7	1.3	1.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69367	65200	61661	58643
0.7	1.3	1.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70638	66261	62554	59401
0.7	1.3	1.6	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72049	67435	63540	60236
0.7	1.3	1.6	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73614	68734	64629	61156
0.7	1.3	1.6	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68825	64739	61266	58301
0.7	1.3	1.6	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69502	65295	61727	58688
0.7	1.3	1.6	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70262	65917	62242	59118
0.7	1.3	1.6	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71113	66612	62815	59595
0.7	1.3	1.6	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68579	64612	61219	58308
0.7	1.3	1.6	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68907	64969	61583	58666
0.7	1.3	1.6	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69192	65303	61937	59022
0.7	1.3	1.6	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69420	65603	62274	59372
0.7	1.3	1.6	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	69187	65103	61620	58639
0.7	1.3	1.6	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	70207	66017	62438	59369
0.7	1.3	1.6	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	71279	66982	63304	60145
0.7	1.3	1.6	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	72402	67998	64219	60968
0.5	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66490	62675	59429	56647
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68222	64242	60852	57954
0.9	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69954	65804	62274	59260
1.1	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71687	67366	63697	60567
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68222	64242	60852	57954
0.7	1.5	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69390	65281	61787	58802
0.7	1.7	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70558	66321	62722	59651
0.7	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64939	61026	57701	54864
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68222	64242	60852	57954
0.7	1.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71505	67457	64003	61043
0.7	1.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	74787	70673	67153	64133

Table 8.19. Discounted net present costs of sawmill alternative B (1,000 shs).

SHADOW PRICES			REL.PRICE INCR. (% P.A.)				TOTAL PRICE INCREASE (%)						CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.)			
LABOUR US&SS	SK	IMP ORT	LAB OUR	ENE RGY	IMP ORT	OTH ER	LAB OUR	ENE RGY	IMP ORT	OTH ER	INV EST	REC UR.	3.	6.	9.	12.
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53977	50233	47090	44435
1.0	1.0	1.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	55421	51523	48254	45496
1.0	1.0	1.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	56865	52813	49418	46556
1.0	1.0	1.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	58309	54103	50582	47617
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	54513	50696	47494	44792
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	55048	51159	47899	45150
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	55583	51622	48304	45507
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	55046	51296	48146	45484
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	56114	52360	49203	46532
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	57182	53424	50260	47581
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	56328	52439	49173	46412
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	58679	54646	51256	48389
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	61030	56852	53339	50366
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	56054	52407	49330	46720
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	58130	54582	51571	49004
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	60206	56757	53812	51289
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	57299	53081	49558	46594
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	60621	55930	52026	48753
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	63943	58779	54494	50912
1.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55211	51264	47959	45175
1.0	1.0	1.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56582	52406	48920	45990
1.0	1.0	1.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58105	53672	49982	46888
1.0	1.0	1.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59795	55074	51154	47877
1.0	1.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54564	50716	47492	44773
1.0	1.0	1.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55222	51257	47940	45149
1.0	1.0	1.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55961	51861	48441	45566
1.0	1.0	1.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56790	52538	48998	46031
1.0	1.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53982	50266	47140	44496
1.0	1.0	1.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53959	50281	47179	44549
1.0	1.0	1.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53900	50272	47202	44592
1.0	1.0	1.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53798	50234	47205	44621
1.0	1.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	55083	51207	47950	45196
1.0	1.0	1.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	56262	52249	48871	46011
1.0	1.0	1.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	57517	53360	49854	46883
1.0	1.0	1.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	58847	54541	50903	47814

Continues ...

Table 8.19 continued.

SHADOW PRICES			REL.PRICE INCR. (% P.A.)				TOTAL PRICE INCREASE (%)						CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.)			
LABOUR US&SS	SK	IMP ORT	LAB OUR	ENE RGY	IMP ORT	OTH ER	LAB OUR	ENE RGY	IMP ORT	OTH ER	INV EST	REC UR.	3.	6.	9.	12.
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59460	55766	52646	49996
0.7	1.3	1.6	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	60811	56971	53732	50983
0.7	1.3	1.6	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	62163	58177	54818	51971
0.7	1.3	1.6	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	63514	59382	55903	52958
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	59995	56229	53051	50353
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	60531	56692	53455	50711
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	61066	57155	53860	51068
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	61169	57468	54337	51674
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	62878	59170	56028	53352
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	64586	60872	57719	55030
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	61811	57973	54729	51973
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	64161	60180	56812	53950
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	66512	62386	58895	55927
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	62008	58430	55367	52788
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	64557	61093	58127	55580
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	67105	63756	60868	58372
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	62858	58680	55170	52204
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	66255	61593	57694	54411
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	69653	64507	60218	56619
0.7	1.3	1.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60633	56746	53471	50698
0.7	1.3	1.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61938	57832	54384	51471
0.7	1.3	1.6	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63388	59036	55393	52323
0.7	1.3	1.6	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64999	60370	56508	53263
0.7	1.3	1.6	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60047	56250	53048	50334
0.7	1.3	1.6	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60705	56790	53497	50710
0.7	1.3	1.6	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61444	57395	53997	51127
0.7	1.3	1.6	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62272	58072	54555	51592
0.7	1.3	1.6	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59467	55820	52727	50093
0.7	1.3	1.6	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59430	55844	52789	50178
0.7	1.3	1.6	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59336	55830	52826	50247
0.7	1.3	1.6	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59173	55768	52831	50294
0.7	1.3	1.6	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	60566	56741	53506	50757
0.7	1.3	1.6	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	61745	57783	54427	51572
0.7	1.3	1.6	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	62999	58894	55411	52444
0.7	1.3	1.6	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	64329	60075	56459	53375
0.5	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57708	54194	51220	48692
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59460	55766	52646	49996
0.9	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61212	57339	54072	51300
1.1	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62965	58912	55498	52605
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59460	55766	52646	49996
0.7	1.5	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60595	56773	53549	50813
0.7	1.7	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61731	57781	54451	51630
0.7	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57324	53639	50532	47899
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59460	55766	52646	49996
0.7	1.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61596	57894	54760	52093
0.7	1.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63732	60021	56873	54191

Table 8.20. Discounted net present costs of sawmill alternative C (1,000 shs).

SHADOW PRICES			REL.PRICE INCR. (% P.A.)				TOTAL PRICE INCREASE (%)						CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.)			
LABOUR US&SS	SK	IMP ORT	LAB OUR	ENE RGY	IMP ORT	OTH ER	LAB OUR	ENE RGY	IMP ORT	OTH ER	INV EST	REC UR.	3.	6.	9.	12.
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47237	43036	39563	36669
1.0	1.0	1.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	48848	44463	40841	37825
1.0	1.0	1.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	50459	45891	42120	38981
1.0	1.0	1.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	52069	47319	43399	40137
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	47816	43535	39999	37053
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	48394	44035	40434	37436
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	48973	44534	40870	37820
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	47592	43378	39893	36985
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	47947	43720	40224	37310
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	48302	44062	40554	37630
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	49416	45070	41474	38475
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	51596	47104	43385	40281
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	53775	49139	45297	42087
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	48618	44471	41033	38160
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	49998	45906	42503	39651
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	51378	47342	43973	41143
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	50580	45904	42049	38844
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	53924	48772	44535	41020
1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	57267	51640	47021	43195
1.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48711	44262	40593	37542
1.0	1.0	1.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50354	45625	41735	38507
1.0	1.0	1.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52184	47139	42999	39572
1.0	1.0	1.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54223	48822	44400	40750
1.0	1.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47879	43564	40003	37038
1.0	1.0	1.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48600	44156	40493	37449
1.0	1.0	1.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49410	44819	41041	37906
1.0	1.0	1.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50318	45560	41652	38414
1.0	1.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47335	43124	39643	36741
1.0	1.0	1.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47438	43218	39727	36817
1.0	1.0	1.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47545	43316	39816	36897
1.0	1.0	1.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47656	43418	39909	36982
1.0	1.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	48358	44014	40419	37421
1.0	1.0	1.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	49563	45067	41341	38231
1.0	1.0	1.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	50857	46198	42333	39102
1.0	1.0	1.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	52241	47410	43396	40037

Continues ...

Table 8.20 continued.

SHADOW PRICES LABOUR US&SS	SK	IMP CRT	REL.PRICE INCR. (% P.A.) LAB OUR	ENE RGY	IMP ORT	OTH ER	TOTAL PRICE INCREASE (%) LAB OUR	ENE RGY	IMP ORT	OTH ER	INV EST	REC UR.	CALCULATED DISCOUNTED COSTS DISCOUNT FACTORS (% P.A.) 3.	6.	9.	12.
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48216	44051	40605	37729
0.7	1.3	1.6	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	49711	45375	41789	38759
0.7	1.3	1.6	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	0.0	51207	46699	42974	39869
0.7	1.3	1.6	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	52703	48024	44158	40939
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0	48794	44551	41040	38113
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0	49373	45050	41476	38497
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	49951	45550	41912	38881
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	48784	44598	41134	38242
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	49352	45146	41662	38755
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	49920	45693	42191	39268
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	50395	46086	42516	39535
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	52574	48120	44427	41342
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	54754	50154	46338	43148
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	49710	45602	42191	39337
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	51204	47153	43777	40945
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	52699	48703	45363	42553
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	51543	46906	43079	39894
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	54871	49760	45553	42059
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	58198	52615	48027	44224
0.7	1.3	1.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49597	45200	41569	38546
0.7	1.3	1.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51138	46478	42639	39450
0.7	1.3	1.6	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52855	47897	43824	40448
0.7	1.3	1.6	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54769	49475	45137	41551
0.7	1.3	1.6	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48858	44580	41045	38098
0.7	1.3	1.6	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49579	45172	41535	38509
0.7	1.3	1.6	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50389	45834	42083	38966
0.7	1.3	1.6	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51297	46575	42693	39474
0.7	1.3	1.6	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48373	44193	40733	37844
0.7	1.3	1.6	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48538	44343	40868	37966
0.7	1.3	1.6	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48709	44499	41010	38094
0.7	1.3	1.6	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48886	44663	41159	38230
0.7	1.3	1.6	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	49337	45030	41461	38481
0.7	1.3	1.6	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	50542	46082	42383	39292
0.7	1.3	1.6	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	51835	47213	43374	40163
0.7	1.3	1.6	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	53220	48426	44438	41098
0.5	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46221	42278	39012	36285
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48216	44051	40605	37729
0.9	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50211	45824	42197	39173
1.1	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52205	47598	43790	40617
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48216	44051	40605	37729
0.7	1.5	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49443	45134	41570	38598
0.7	1.7	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50670	46216	42534	39466
0.7	1.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47506	43367	39944	37088
0.7	1.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48216	44051	40605	37729
0.7	1.3	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48926	44735	41266	38370
0.7	1.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49636	45419	41927	39011

Table 8.21. Recurrent expenditures[a] used in estimating indirect economic effects of different sawmill alternatives (1,000 shs/year).

Sector in input/output table			Sawmill technology alternative Alt. A	Alt. B	Alt. C
Sector	20	Textiles	38	39	45
"	23	Printing and paper	122	122	130
"	24	Chemicals and petroleum	667	647	703
"	25	Metallic and non-metallic products	10	10	10
"	27	Automobile repair	411	377	348
"	28	Other manufacturing	30	30	30
"	32	Electricity and water supply	6	6	5
"	33	Construction[b]	90	81	75
"	34	Commerce	108	108	108
"	36	Transport	130	130	130
"	38	Banking and insurance	216	216	216
"	46	Unspecified	447	448	349
Domestic goods total			2,275	2,214	2,149
Sector	47	Wages & salaries	1,543	1,554	1,778
Imports			458	314	170
Depreciation[c]			2,220	1,930	1,298
Gross domestic product			3,763	3,484	3,076
Gross output (not including profit)			6,496	6,012	5,395

[a]Based on Table 8.1, Table 8.3 and Table 8.14.

[b]Building and road repairance.

[c]Including depreciation of imported investment goods.

Table 8.22. Direct and indirect economic effects of alternative sawmill technologies for producing 14,000 cu.m of sawnwood ('000 shs/year).

Variables	Alternative A			Alternative B			Alternative C		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
1. Marginal consumption propensity is 0									
Domestic inputs*	2,275	843	3,118	2,214	816	3,030	2,149	820	2,969
Imports	458	701	1,159	314	674	988	170	672	842
Subsidies, custom duties, other indirect taxes	0	339	339	0	344	344	0	319	319
Wages and salaries	1,543	682	2,225	1,554	683	2,237	1,778	684	2,462
Operating surplus	0	438	438	0	420	420	0	416	416
Depreciation	2,220	283	2,503	1,930	271	2,201	1,298	207	1,505
Net value added	1,543	1,120	2,663	1,554	1,103	2,657	1,778	1,100	2,878
Gross value added	3,763	1,403	5,166	3,484	1,374	4,858	3,076	1,307	4,383
Total (gross) production	6,496	3,286	9,782	6,012	3,208	9,220	5,395	3,118	8,513
2. Marginal consumption propensity is 0.5									
Domestic inputs*	2,275	2,177	4,452	2,214	2,158	4,372	2,149	2,296	4,445
Imports	458	911	1,369	314	884	1,198	170	904	1,074
Subsidies, custom duties, other indirect taxes	0	459	459	0	465	465	0	452	452
Wages and salaries	1,543	860	2,403	1,554	862	2,416	1,778	880	2,658
Operating surplus	0	1,075	1,075	0	1,060	1,060	0	1,120	1,120
Depreciation	2,220	340	2,560	1,930	329	2,259	1,298	270	1,568
Net value added	1,543	1,935	3,478	1,554	1,921	3,475	1,778	2,000	3,778
Gross value added	3,763	2,274	6,037	3,484	2,250	5,734	3,076	2,271	5,347
Total (gross) production	6,496	5,882	12,318	6,012	5,757	11,769	5,395	5,923	11,318
3. Marginal consumption propensity is 0.9									
Domestic inputs*	2,275	3,244	5,519	2,214	3,232	5,446	2,149	3,477	5,626
Imports	458	1,079	1,537	314	1,052	1,366	170	1,090	1,260
Subsidies, custom duties, other indirect taxes	0	557	557	0	562	562	0	558	558
Wages and salaries	1,543	1,002	2,545	1,554	1,004	2,558	1,778	1,037	2,815
Operating surplus	0	1,585	1,585	0	1,572	1,572	0	1,683	1,683
Depreciation	2,220	386	2,606	1,930	375	2,305	1,298	321	1,619
Net value added	1,543	2,586	4,129	1,554	2,575	4,129	1,778	2,720	4,498
Gross value added	3,763	2,971	6,734	3,484	2,951	6,435	3,076	3,042	6,118
Total (gross) production	6,496	7,851	14,347	6,012	7,796	13,808	5,395	8,167	13,562

* Not including wages and salaries and operating surplus.

8.4 Discussion of effects on different criteria of development

The discussion below is based on the assumptions and calculations in preceding chapters and concerns appraisal of the three technological alternatives according to the criteria mentioned in Ch. 4.3.2.

8.4.1 Production efficiency from a national economic point of view

Direct economic effects

The Tables 8.18, 8.19 and 8.20 show that alternative C is significantly more favourable from a national economic point of view than alternative B, which again is more favourable than alternative A. At 9 % p.a. rate of interest, most probable shadow prices (0.7, 1.3 and 1.6 for respectively un/semiskilled labour, skilled labour and import) and zero relative price changes, the discounted present costs are:

Alternative	A	60.9	mill. shs.
"	B	52.6	" "
"	C	40.6	" "

With these assumptions alternative A and alternative B are respectively 50 % and 30 % more expensive than alternative C from a national economic point of view. These relative cost differences are fairly constant, but decrease slightly with increased price of labour and energy because alternative C is more labour intensive and demands rather more diesel and oil than the two other alternatives. The relative cost differences increase with increasing prices of investments, imports and other domestic resources (exclusive of labour and diesel/oil) and with increasing rate of interests. The reason is that the alternatives A and B are more capital intensive and demand more import and domestic resources than alternative C.

The above mentioned cost differences for alternatives A and B relative to alternative C correspond to respectively 3.17 and 1.97 mill. shs. per year or about 226 and 140 shs. per cu.m of sawnwood produced, during the project's assumed life-time of 10 years and assuming 9 % p.a. rate of interest.

The main reason for the relatively large difference between the alternatives is the low investment costs of alternative C. From Tables 8.15, 8.16 and 8.17 it is seen that the initial investment amounts (i.e. investments at year zero) are 26.4 mill. shs., 22.8 mill. shs. and 14.3 mill. shs. for the alternatives A, B and C respectively.

From Tables A 4.1, 8.2 and 8.8 it is seen that the initial investment amount for logging and road transport equipment in alternatives A and B are respectively 1.4 mill. shs. and 0.7 mill. shs. higher than in alternative C. Tables A 4.1, 8.2, 8.4 and Table 8.10 show that the initial investment amount for sawmilling and administration in alternatives A and B are respectively about 6.8 and 5.3 mill. shs. higher than in alternative C. These differences are mainly caused by higher investment costs in alternatives A and B of sawmill machinery (including green chain and power supply) and buildings.

Indirect economic effects

Table 8.22 shows that the indirect use of economic resources, at zero marginal propensity to consume, is highest for alternative A and lowest for alternative C. The differences between alternatives A and C are about 5 % regarding total (gross) production, and about 3 % between alternatives B and C. The greatest difference occurs regarding depreciation, where alternative C has an indirect effect of 27 and 24 % less than respectively alternatives A and B. The main reason for this is that alternative C demands less from the sectors "Automobil repair" (sector nos. 27), "Construction" (sector nos. 33) and "Unspecified" (sector nos. 46) than the other two alternatives - cf. Table 8.21.

When the marginal propensity to consume is changed to 0.9, Table 8.20 shows that alternative C results in about 4 % and 5 % higher indirect total (gross) production than respectively alternative A and alternative B. The main rason for this is that alternative C is the most labour intensive technology of the three alternatives analysed. Regarding depreciation the same picture emerges as described above for marginal consumption propensity 0. Regarding import alternative B has the lowest indirect use, but only about 3 % lower than alternatives A and C. Regarding indirect operating surplus alternative C is 6-7 % higher than the other two alternatives.

All alternatives, but in particular alternative C, have a high indirect import usage compared with the direct import component. The main reason for this is that the agricultural tractors used in all alternatives are assembled in Tanzania, thus giving a low direct import, but a high indirect import of assembly parts.

Adjusting for the indirect operating surplus and taking account of the indirect import effects, it seems fair to conclude that if the marginal consumption propensity is about 0.9, the indirect economic effects of alternative C are preferable to those of alternatives A and B, and that alternative B is preferable to alternative A in this respect. However, it should be pointed out that the differences here between the alternatives are not great, in particular considering the uncertainty regarding the input/output table used, as discussed in Appendix 1.

8.4.2 Employment

Direct employment

Table 8.23 shows the most probable direct employment effects of the three alternatives of technology.

Table 8.23. Direct employment effects of producing 14,000 cu.m of sawnwood per year.

Type of personnel employed	Direct employment generated (man-years per year)		
	Alt. A[a]	Alt. B[b]	Alt. C[c]
Un-/semi-skilled	167	171	196
Skilled	57	56	55

[a]As stated in Appendix 4.

[b]As alternative A, adjusted for other vehicles being used- cf. Ch. 8.2.3

[c]Based on Table 8.5, Table 8.7 and Table 8.11.

It is seen that alternativ C has about 11 % higher direct total employment effect than the other two alternatives. The employment of skilled personnel is about equal in the three alternatives, but for un/semiskilled personnel alternative C gives about 17 % higher employment than alternatives A and B.

Indirect employment effects

Wages and salaries in Table 8.22 may be a reasonably good indication of indirect employment effects, assuming approximately similar wage and salary levels in the various economic sectors. It is seen, then, that the indirect employment effects of the three technological alternatives are about equal. For marginal consumption propensity equalling 0.5 and 0.9, the indirect employment effect is in the size of respectively 110 and 125 manyears per year assuming 8,000 shs. per manyear and realistic input-output coefficients (cf. Ch. 5.2.5).

8.4.3 Working conditions

Alternative C will probably give higher physical strain for the employees than the other two alternatives in the handling of sawlogs at mill site and in loading sawnwood on tractor trailers. With proper planning, however, it should be fairly easy to keep this strain below a harmful level.

Regarding psychological strain and risks of personnel accidents, I see no significant difference between the alternatives. It might be argued, however, that in alternative C more workers will be able of living at home in already existing villages.

Regarding workers' influence on their own working situation, the three alternatives seem to be approximately equal, although it might be argued for example that alternative C represents smaller production units where each worker might have more influence than in larger production units.

The three technological alternatives are in my opinion about equal with respect to working conditions.

8.4.4 Integration

Table 8.22 shows that alternatives A and B compared to alternative C have a higher import usage (particularly direct import) an about the same indirect operating surplus. From the Tables 8.15, 8.16 and 8.17 it is seen that alternative C has a considerably lower import investment costs than the other two alternatives. It may therefore be argued that alternative C is more integrated in the present economic structure of Tanzania.

Regarding integration with the present social structure and the future economic and social development of Tanzania, it may be argued that alternative C is easier to integrate in the existing social infrastructure than alternatives A and B, and thus gives a higher positive spin-off effect. In the actual case at Sao Hill Sawmill SKJØNSBERG (1983:38) writes:

> "The building of the sawmill on (forest) reserve land has far reaching consequences. The advantage lies in the social control that can be exerted, but the disadvantages are many. The most serious is the total lack of permanency in the settlement, as every worker who leaves the job also leave the enclave. The inability of the enclave to provide for the next generation is another serious effect".

Regarding skill formation, it may be argued that alternative C gives employment to about 30 more persons and therefore creates a higher skill formation than alternatives A and B.

Based on the above mentioned arguments, I conclude that with respect to integration alternative C is preferable to alternatives A and B.

8.4.5 Independency

Regarding independency on micro level - i.e. financial profitability (cf. Ch. 4.3.2.5) - it is seen from the Tables 8.16, 8.17 and 8.18 that alternative C is significantly better than alternative B, which again is better than alternative A. At shadow prices 1.0, 9 % p.a. calculation rate of interest and most probable estimate on all prices, the discounted present values of costs of the three alternatives are:

Alternative A 52.1 mill. shs.
" B 47.1 " "
" C 39.6 " "

This means that alternatives A and B are respectively 32 % and 19 % more expensive from a business economic point of view than alternative C. The above mentioned cost differences for alternatives A and B relative to alternative C correspond to respectively 1.95 and 1.17 mill. shs. per year, or 139 and 84 shs. per cu.m of sawnwood produced. These differences are considerable considering that the sales price ex mill in 1977 was on average 586 shs. per cu.m of sawnwood.

It is seen from the Tables 8.16, 8.17 and 8.18 that the cost differences between alternative C and alternatives A and B decrease some with increasing cost of labour and energy, and increase with increasing import and other costs.

The main reasons for these cost differences are as discussed in Ch. 8.4.1.

It is worth noticing that the estimates given in the Tables 8.1, 8.3 and 8.14 give relatively smaller differences between alternative C and alternatives A and B than the corresponding estimates (for shadow prices 1.0) in the Tables 8.18, 8.19 and 8.20. The reason is of course that the calculation procedure represented by the former three tables does not reflect adequately the true financial (and economic) costs of getting high investments at an early stage of a project. The discounted net present value procedure used in estimating the figures of the latter three tables, is a more correct method for adequately reflecting the time profile of investments and recurrent expenditures.

Regarding independency on macro level indicated as direct and indirect import usage, Table 8.22 indicates the same results as emerged above regarding micro level indenpendency.

8.4.6 Ecological effects

None of the three technological alternatives is ecologically damaging. Although alternatives A and B have a slightly lower diesel and

oil consumption than alternative C (5-8 % lower), the three alternatives are regarded approximately equal with respect to ecological effects in Tanzania.

8.4.7 Distributional aspects other than personal income

The most important distributional effects, apart from personal income, is in this case regional income. Here, the alternatives A and B are about equal, whereas alternative C, having about 18 % higher employment of un-/semi-skilled personnel (cf. Table 8.23), is likely to have a greater indirect effect in Iringa region and Mufindi District.

8.4.8 Risks

As alternatives A and B consist of only one sawmill unit, they are more vulnerable for breakdowns, changes in production output etc. than alternative C, consisting of five smaller units. These units, on the other side, might be more difficult to administer although one extra person per unit is assumed assigned for this purpose.

Alternative C has not been tried at Sao Hill and its assumed productivity is therefore more uncertain than alternatives A and B. However, as discussed in Ch. 8.2.4, the assumed productivity for alternative C probably represents rather an underestimate than an overestimate.

The productivity estimates assumed in the analysis are empirically proved to be realistic at Sao Hill for alternatives A and B. In fact the annual production has been higher than 14,000 cu.m of sawnwood, mainly because of more than one shift production (BAVU et al. 1983:18). A central question regarding uncertainty is then the possibilities of alternative C increasing its production in the same way as alternative A has empirically shown it can.

The possibilities for control represent another uncertainty factor. Alternatives A and B have proven to be controllable at Sao Hill. Five smaller mills spread out in the forest reserves are, however, probably more difficult to control. Lack of control could imply either (a) decreased total production of sawnwood; (b) no decrease in production, but increased production costs; (c) no decrease in production and no increased costs, but decrease in official sales; or a combination of these factors. From a national economic point of view situations (a) and (b) represent the worst cases. However, also situation (c) could be vital for the project's existence, as a necessary condition for an industrial project in most LIC is financial self-reliance. The experience so far in a mobile sawmill project in Tanzania, indicates that small sawmill units are controllable in environments similar to that of Sao Hill (BARKLUND pers. comm., KOWERO et al. 1985).

Alternatives A and B are more vulnerable for import shortages and changes in import prices than alternative C, which, on the other hand, is some more vulnerable for changes in energy (oil, and diesel) prices.

Another risk factor is the assumed life-time of particularly the transport equipment. Experiences at Sao Hill Sawmill seem to indicate that a five year life-time, as assumed in the analysis, probably is more on the higher than the lower side, as 3-4 years might be more realistic. Because of heavier investment in transport equipment in alternatives A and B than in alternative C, a lower life-time will favour the latter relative to the other two alternatives. A lowering of the life-time from 5 to 3.5 years, all other factors assumed equal, will increase the depreciation costs by about 30 %. From Tables 8.1, 8.3 and 8.14 it is seen that this will increase the logging and road transport costs by 13-17 shs. per cu.m sawnwood produced.

It is also uncertain whether economies of scale exist regarding factors like e.g. possible steam power plant for energy production, concentration of welfare goods and capacity utilization of internal (on mill site) transport machinery. It may be that alternatives A and B here have a comparative advantage to alternative C. But this is not obvious - for example ROOS (1983) says that the costs of steam power plants are proportional to power generation from a production of 150 kW and upwards.

If profitable further utilization of slabs and off-cuts is possible at mill site to a larger extent than assumed in this analysis, it is quite clear that the alternatives A and B here have an advantage compared to alternative C. In the case of Sao Hill, this was in fact

one argument for choosing alternative A. However, time has shown that such productions have not materialized at Sao Hill Sawmill. Ex ante it was not possible to know that for sure.

Summa summarum, regarding risks, I rank the three technological alternatives equal.

8.4.9 Other main factors

The three technological alternatives are in my opinion not significantly different on other major development factors.

8.5 Discussion and conclusions

Table 8.24 presents the ranking of the three alternatives of technology on each of the criteria discussed above. It is seen that alternative C is superior to alternatives A and B in a Pareto-optimal sense. In particular it is seen that the economic and employment factors strongly favour alternative C. In my opinion, alternative C represents the best technological choice, under the assumptions made.

If the skidding operations in alternative C were assumed to be done by using oxen instead of agricultural tractors, the analyses in Ch. 7 show that the preferability of sawmill alternative C would be even higher than shown above.

Table 8.24 also shows that alternative B is superior to alternative A in a Pareto-optimal sense.

One should be careful in drawing general conclusions from this study Particularly three factors favour alternative C at Sao Hill. First, that the timber supply areas were relatively widely scattered. At higher timber supply concentrations near the bigger sawmill, alternative A and B are likely to be relatively more attractive than shown in this analysis. Secondly, no electricity is yet available at Sao Hill, which means that all three sawmill alternatives have to use diesel or steam as power supply. If public electricity were available at prices below diesel or steam, the costs of alternatives A and B would probably have been lowered relative to the costs of alternative C. Thirdly, alternative C results in lower costs regarding social

Table 8.24. Ranking[a] of the sawmill alternatives of technology.

Criteria	Alternative A		Alternative B		Alternative C	
1 Economic efficiency (production costs in shs per cu.m of sawnwood at 9 % p.a. rate of interest[b])	3	(678)	2	(592)	1	(452)
2 Employment						
2.1 Direct employment - un- and semiskilled personnel (manyears per year)	3	(167)	2	(171)	1	(196)
- total personnel (manyears per year)	3	(224)	2	(227)	1	(251)
2.2 Indirect employment - total personnel (manyears per year)[c,d]	1	(125)	1	(126)	1	(130)
3 Working conditions	1		1		1	
4 Integration	2		2		1	
5 Independency - financial profitability (production costs in shs per cu.m of sawnwood at market prices and 9 % p.a. rate of interest)	3	(579)	2	(524)	1	(442)
- import need (1,000 shs per year direct and indirect)[c,e]	3	(1,537)	2	(1,366)	1	(1,260)
6 Ecological effects	1		1		1	
7 Distributional aspects except personal income	2		2		1	
8 Risks	1		1		1	
9 Other factors	1		1		1	

[a] In brackets is presented most probable estimate of criterion indicated.

[b] Shadow prices 0.7, 1.3 and 1.6 for respectively un-/semi-skilled labour, skilled labour and foreign exchange.

[c] Marginal consumption propensity is 0.9.

[d] 8,000 shs per manyear is assumed.

[e] Not including capital costs.

infrastructure than alternatives A and B, because alternative C is more decentralized and more of the workers can live in their existing homes.

For projects having physical and socio-economic conditions similar to the Sao Hill project, however, the result of this study should be of interest.

Finally, also this study shows that labour intensive technologies exist which are highly compatible with modern capital intensive methods both from a financial and a socio-economic point of view.

NOTES TO CHAPTER 8

[1] 4 trips per day per unit (15 km average road transport distance - cf. Map 5.5) and 14 cu.m (r) payload per trip.

[2] Produced by the company Kallion Konepaja OY, Raisio, Finland.

[3] Information given by the producer, based on the prices medio 1979 reduced by 10 % to correspond to 1977 price level.

[4] The sawbench can be delivered with mechanical press roller costing only 125 US $. However, the hydraulic system gives more accurate sawing. Regarding repair and maintenance the situation seems to be as reported below for the hydraulic table drive.

[5] The saw is equipped with a machine which makes sharpening possible without removing the blade. The sharpening machine is driven by the oil pressure from an agricultural tractor. It is here assumed that one sharpener per sawmill (i.e. two sawbenches) is enough as the sharpening machine can easily be moved. The price includes oil pressure hoses with couplings.

[6] The slabber is assumed to have 1,200 mm blade costing 400 US $ and the resaw a 900 mm blade costing 300 US $.

[7] 2-4 % less recovery percentage according to NAGODA (pers. comm.)

[8] Based on information given by Berner & Larsen A/S, Oslo, the agent for this motor type in Norway.

[9] Note that alternative A in addition has one circular sawbench which is not included in the above estimate of 100 % for alternative A. Assuming that this sawbench's production is 3,000 cu.m (r) per year, the above figure will be about 91 %.

[10] The average size of the compartments at Sao Hill is about 50 ha (FOREST DEPARTMENT 1972).

PART IV MORE GENERAL DISCUSSIONS AND CONCLUSIONS

9 DISCUSSIONS AND CONCLUSIONS

9.1 Introduction

This chapter aims at discussing more generally the content of the previous chapters in relation to the objectives of the study specified in Ch. 1.2. Several of the points discussed below are interrelated and should be viewed together.

9.2 Literature review

It is clear from Ch. 2 that the choice of technology in LIC is a complicated issue involving technical, biological, socio-economic and institutional aspects which are difficult to overlook.

In the empirical studies of technological matters the implicit or explicit assumptions which the studies are based upon, often are violated by the prevailing socio-economic conditions (far from perfect competition, limited substitutability, distorted prices, etc.).

Many different methods have been used for analyzing the technological choice, and it is hard to compare the results from different studies.

Only a few of the existing studies compare alternative choices of technology. This is the case particularly regarding forestry and forest industry studies. When alternatives are compared, most often only one or two criteria are considered: profitability (or cost efficiency) from a business economic point of view, and employment.

It is worth noticing that except for the study by MICSKI & STRIDSBERG (1981) of using powersaw instead of two-man raker saw, these analyses of technology in forestry and forest industry projects indicate that labour intensive technologies seem promising compared to more capital intensive alternatives.

9.3 Some theoretical aspects regarding the concept and role of technology

The definition of technology arrived at in Ch. 3.1 is wide. It is, however, difficult to find better definitions as, in my opinion, it is important to include both the hardware and software components of the concept.

The various types of technological changes defined in Ch. 3.2 (labour-saving, capital-saving, neutral technological changes, etc) are in my opinion useful for understanding vital links between the technological choice on micro level and its macroeconomic effects.

Although burdened with severe simplifications compared to reality, the neoclassical growth model applied in Ch. 3.2.2 illustrates the importance of the technological choice in LIC. In my opinion, the differences regarding contribution to economic growth per capita between the three technological alternatives in sawmilling that are analysed, are striking, not least when knowing that alternative C probably not is the optimal solution (cf. Ch. 9.5.1), and that alternative A - the technology actually chosen - is recognized as being one of the most successfull forest industry projects in Tanzania.

The neoclassical growth model does not give other results than the cost efficiency analysis in Ch. 8.4.1, but the strength of the model is that it focuses on one important variable in most LIC, the growth in consumption per capita. However, such a model would not, in most cases, be sufficient for choosing technology on the project level, because other development criteria than economic efficiency, for example those described in Ch. 8.4, then would not be considered.

9.4 Methods for socio-economic project analysis

The method proposed in Ch. 4.3 proved to be operational in the case studies in Ch. 6 - Ch. 8 and capable of distinguishing between, and ranking the technological alternatives analysed, according to the pre-established criteria. None of the other methods proposed in Ch.

4.2 would, in my opinion, have made more correct technological choices with the given criteria, and the other methods would be considerably more resource demanding.

As mentioned in Ch. 4.3 it is important to realize that if none of the technological alternatives are significantly better regarding one or more of the criteria used, it is not important which of the technological alternatives that is chosen. The main emphasis should be to exclude those alternatives which are clearly unfavourable according to the criteria used. This argument is further strengthened when taking into consideration the risk factors mentioned in Ch. 4.3.2.8, which always will exist in this kind of problems.

The size and significance of the project should be considered when choosing degree of efforts in the analysis. All other factors equal it is more important to use limited analytical capacity on a large project than on a small one.

It is a considerable strength of the proposed method, that it allows for starting the analysis at a relatively aggregated level and then proceed towards more detailness according to the need and wants of the decision makers. For example, the analysis could in theory be expanded to integrate most of the criteria originally treated separately in the economic efficiency criterion, if the decision makers would accept increased costs and involvement from their side regarding stating their preferences.

As mentioned in Ch. 4.3.1 perhaps the most severe problem in practice is to define the realistic set of technological alternatives. In most projects the set of realistic alternatives is not obvious, and special care should be devoted to this stage of the analysis.

9.5 Empirical results from the Sao Hill Sawmill

9.5.1 Evaluation of the actual technological choice at the Sao Hill Sawmill

Assuming the development criteria used in Ch. 6 - Ch. 8 are relevant for Tanzania, the analyses generally suggest that the actual choice of technology that was made in the initial phase of the Sao Hill Sawmill project seemsto be:

(i) Close to optimal when choosing the use of sulkies in the thinning operations.

(ii) Far from optimal in the skidding from clearfellings, when choosing the Volvo TC 860 forwarder.[1]

(iii) Far from optimal when choosing one centrally located sawmill (alternative A in Ch. 8) instead of 5 decentralized mills with a common central unit (alternative C in Ch. 8).

The differences between the technologies actually chosen and the optimal ones of the alternatives analyzed in Ch. 7 and Ch. 8 are so significant that the conclusions above can hardly be questioned, although the analyses are based on many assumptions burdened with considerable risks. Also, several factors suggest that the differences between the optimal choices and the technologies actually chosen are greater than estimated:

* It is assumed that all workers are permanently employed. In practice, however, many causal labourers having a considerably lower salary than the permanently employed workers, are engaged in the project.

* It could be argued that the 5-year write-off time for vehicles assumed is too long under the rough conditions at Sao Hill, and that probably 3 years would be a more realistic estimate (together with some higher scrap value). This would, all other factors assumed equal, increase the costs of the capital intensive alternatives relative to the more labour intensive ones.

* The analyses are based on only three technological alternatives. One may ask whether other alternatives existed, which could have been more preferable than those analysed. In my opinion, the skidding alternatives analysed in Ch. 6 and Ch. 7 represent the best ones of the set of possible alternatives. Regarding the sawmilling analysed in Ch. 8 it is quite clear from the conclusions in Ch. 7 and Ch. 8 that 5 decentralized mills using oxen instead of agricultural tractors for skidding, would have been a better choice than alternative C, for all criteria used in Ch. 8. Also other sawmilling technologies exist, which could be of interest at Sao Hill, for

example pitsawing in the forest and mechanized resawing or planing at a central unit. This alternative would have been physically harder for the pitsawyers than any work operations in the other sawmilling methods mentioned. However, as quoted in Ch. 2.3.3 from FERGUS et al. (1977) and KIJOTI & WHITE (1981), the pitsawing alternative would probably have been highly competitive on most of the other criteria used in Ch. 8.

The development in relative prices since 1977 is shown in Appendix 2. It is seen that the labour costs have increased considerably less than the other main production costs at the Sao Hill Sawmill, and that particularly the petrol, diesel and capital costs have increased strongly. This implies that the conclusions above regarding the priorities in 1977 between the technological alternatives analyzed in Ch. 6 - Ch. 8, were even stronger in 1982 and 1986, i.e. the labour-intensive alternatives were even more favourable in 1982 and 1986 than in 1977.

The Sao Hill Sawmill Projet is by NORAD as well as Tanzanian authorities considered to be a successfull industry project (BAVU et al. 1983). The analyses in Ch. 3.2.2.2 and Ch. 8 indicate that if the choice of technology in other projects in Tanzania is equally far from optimum as in that project, the social opportunity cost, regarding economic growth per capita as well as regarding other important development criteria, is of a considerable magnitude.

9.5.2 More general results from the Sao Hill study

Factor endowments and type of production

One main reason for the results in Ch. 6 and Ch. 8 favouring labour intensive technologies is the low labour costs in Tanzania relative to the capital costs, in particular when considering the shadow prices on labour and foreign exchange. This effect is shown in Fig. 3.1.

Another reason of a more general character could be that transport operations are essential in all of the three analyses. Generally, the transport costs tend to be high in LIC among other things because of poor roads, difficulties with spares, repair and maintenance of vehicles etc. Technologies which are lowering the transport costs, could, ceteris paribus, have a comparative advantage. This could particularly be the case in short distance transport with low speed for all alternative technologies, as in skidding of logs.

Type of employment

As mentioned in Ch. 4.3.2.2 it is important to evaluate the effect on employment of different technologies, in particular the employment of un- and semiskilled workers. In this study all labour intensive technological alternatives give employment to significantly more workers classified as un- and semiskilled, compared to the capital intensive alternatives.[2]

The analyses in Ch. 6 - Ch. 8 do not support the hypothesis by HIRSCHMAN (1958) that mechanization is an efficient substitute for management supervisory skill. In the skidding operations analysed in Ch. 6 and Ch. 7 the labour intensive methods do not require more skilled supervision than the capital intensive alternatives.[3]
In the sawmill operations analysed in Ch. 8 it is seen from Tables 8.5, 8.7, 8.11 and A 4.2 that the most labour-intensive alternative (alternative C) demands 6 manyears per year (i.e. about 12 %) more skilled management personnel than the capital intensive alternative. The additional personnel are the managers of the five semi-mobile sawmills and one person for overall supervision. However, this substitute can hardly be regarded as inefficient, given the much lower total production costs of alternative C relative to the other two technologies analysed.

Working capital

Several studies, for example SEN (1968) and BHALLA (1975), have pointed at the importance of including working capital in the analyses of technological choice on project level, as the labour intensive technologies most often would demand a higher use of working capital. The analyses in Ch. 6 - Ch. 8 support this hypothesis. However, in all the three analyses the working capital costs are less than 10 % of all total costs, and does not influence the overall ranking of the technological alternatives.

Use of other production inputs than labour and capital
In the skidding operations analysed in Ch. 6 and Ch. 7 it is seen that the most capital intensive alternatives (forwarders and agricultural tractors) used considerably more energy as well as spare parts and imported goods than the labour intensive methods.

In the sawmilling operations analysed in Ch. 8 it is seen that the labour intensive alternative (alternative C) had 6-8 % higher use of energy than the two more capital intensive alternatives. The latter, on the other hand, had respectively 17 % and 33 % higher use of spare parts than the most labour intensive alternative. The utilization of timber is the same in the three sawmill alternatives.

Except for the greater use of energy in the sawmilling operations, the analyses show that the labout intensive alternatives used the same amount or less of none-labour and none-capital production inputs compared to the capital intensive methods.

Surplus generation. Contribution to economic growth
Much of the literature on choice of technology pays considerable attention to surplus generation and the ratio of surplus generated per unit of investment (SEN 1968, UNIDO 1972, LITTLE & MIRRLEES 1974). Surplus is most often defined as the difference between net value added and wages, and is important to the economy as far as it is reinvested. Factors like type of ownership (foreign versus domestic companies), possibilities of enforcing savings through taxation, differences in propensities to consume between workers and capital owners, etc., are in general vital factors to consider here, as shown e.g. in STEWART (1978) and UNIDO (1972).

In the analyses in Ch. 6 - Ch. 8 no premium is given to investment relative to consumption, i.e. it is assumed that the rate of savings in Tanzania is as warranted by the Government. However, even if this assumption were relaxed assuming most of the wages will be consumed, it is seen from Ch. 6 - Ch. 8 that the labour intensive alternatives because of lower total costs, will have a significantly higher surplus generation measured as difference in total production costs, compared to the capital intensive alternatives.

In addition comes the difference in surplus generated by any savings of wages, assuming the marginal propensity to consume being less than one.

As such, the analyses in Ch. 6 - Ch. 8 show that labour intensive alternatives exist which give higher contribution to economic growth than the more capital intensive technologies actually chosen.

Income distribution
The differences regarding income distribution between the technological alternatives analysed in Ch. 6 - Ch. 8 are striking. The labour intensive alternatives give higher income to un- and semi-skilled workers and use more resources provided in the Iringa region, and Tanzania, than the other alternatives.

Economies of scale
The analyses in Ch. 6 - Ch. 8 assume optimal capacity utilization and the same total production output for all the technological alternatives. It is, therefore, difficult to draw clear conclusions from these studies about possible economies of scale. However, a few comments can be given: First, the above assumption of optimal capacity utilization implies that if production is to be expanded (or decreased) the more capital intensive technologies will have greater production intervals in which capacity utlization is lower than the optimal, and therefore the highest unit costs assuming a given change in output.

Second, in skidding, economies of scale is to be found only regarding repair and maintenance of machinery. In sawmilling, economies of scale are possible regarding repair and maintenance, management, and marketing, whereas diseconomies of scale would exist regarding long-distance transport of timber. In the present study the repair and maintenance work is assumed combined for the skidding and sawmilling activities, and it would, in my opinion, be difficult to lower these unit costs by increasing the scale of output. It seems to me therefore, that economies of scale hardly exist beyond the output level assumed in Ch. 6 - Ch. 8, as long as one shift operation is practiced.

If multi-shift operations are allowed, the possibilities of economies of scale would, in my opinion, be about equal for all technological alternatives, except for the use of animal skidding, where only one shift operations are possible.

Existence of alternatives. Choice of product and quality

As discussed in Ch. 2 neoclassical analysis of choice of technology is based on the existence of a wide range of technologies of varying labour and capital intensities. Critics (e.g. KALDOR 1965 , AMIN 1969) have denied that such choices exist for LIC. The analyses in Ch. 6 - Ch. 8 support the neoclassical view for the skidding and sawmilling operations in Tanzania at the present state of development, particularly when considering that different combinations of skidding equipment and sawmilling methods can be used. The analyses show that a greater labour intensity than what was actually chosen in the Sao Hill Sawmill Project would have been both feasible and economically efficient.

The analyses in Ch. 6 - Ch. 8 underline the importance of, and connections between, the choice of type of output and the choice of technology. If tree length skidding were assumed instead of log skidding, both the use of sulkies and oxen would be nearly impossible.

In the initial phase of the project neither skidding with oxen nor decentralized sawmilling were considered, implying that one here lost superior technological choices. This illustrates the importance to keep a wide spectrum of alternatives open when choosing technology, holding open alternative output levels and alternative technologies.

The quality of the products produced by the technologies analysed in Ch. 6 - Ch. 8 was the same and independent of their capital intensity. This could be a general characteristic of forestry and forest industry operations because of their bulky and intermediate-oriented products compared to several other lines of production. However, further empirical studies need to be done before generalizations are made.

Competition and the influence of relative prices

The results in Ch. 7 - Ch. 8 do not support the neoclassical view that relative prices determine the choice of technology. This is not surprising, because the technology in the project analysed (as in most other Government based projects in Tanzania) was chosen in an economic environment which was far from the neoclassical assumptions of perfect competition. In fact, the results in Ch. 7 - Ch. 8 support the hypothesis of WELLS (1975) reported in Ch. 2.2.1, that when price competition is not the rule, the goals of the "engineering man" is likely to override the arguments of the "economic man".

Flexibility

All studies in Ch. 6 -Ch. 8 show that the labour intensive alternatives have greater flexibility than the more capital intensive ones regarding break downs, lack of spare parts, foreign exchange savings, availability of service facilities, changes in outputs, etc. This might be only incidental, but could also be a general tendency, which should be studied more thoroughly.

Generality of the results

The results in Ch. 6 - Ch. 8 show that large changes in the relative prices of labour and investment would be necessary to change the priority arrived at with the given criteria. In fact, as mentioned in Ch. 9.5.1, the relative price development in Tanzania since 1977 implies that the labour intensive technologies in Ch. 6 - Ch. 8 have increased their preferability with respect to cost efficiency during the last 10 years in Tanzania.

As previously mentioned, one should be careful in generalizing the results in Ch. 6 - Ch. 8 to other LIC, because both the socio-economic and technological environment may vary considerably among countries. The findings in SOLBERG & SKAAR (1986) show the same pattern as in the present study, indicating that ox-skidding could be of considerable interest for several other countries in East-Africa. Only more empirical studies, from different countries, would make it possible to reject - or not - any hypothesis of the generality of the results in the present study.

9.6 Proposals for more appropriate choices of technology

The following section aims at describing some factors which I think are important in securing appropriate choices of technology in development projects, with particular reference to forestry based projects. The proposals do not relate directly to the studies in Ch. 6 - Ch. 8, but draw on the author's more general experiences from development projects in LIC.

9.6.1 The objective

One part already mentioned in Ch. 4.3, is that instead of trying to find the optimal technological alternative, it may be easier and more realistic to try to exclude the wrong choices. In most practical cases there will then at the end be a choice between a few alternative technologies which, particularly when considering the risks always involved in such decisions, are about equally good. Often, it will then not make a great difference which one of the alternatives that is actually chosen.

9.6.2 Increased empirical knowledge

Studies should be done to increase the information about technical performances, costs, employment effects, etc. of various types of technologies. This has to be based on case-studies, e.g. as shown in Ch. 6 - Ch. 8. It is important to study a wide range of technologies in different relevant situations. The method outlined in Ch. 4.3.2 represents in my opinion a useful approach for such studies.

Equally important it is to disseminate information from these studies to consultants, decision makers, teachers and other people directly or indirectly influencing the choice of technology in LIC.

Both the collection and dissemination of information should be coordinated by an international organization, e.g. FAO, in cooperation with national aid organisations like NORAD, SIDA, DANIDA, etc.

Detailed knowledge and expertise are necessary for this kind of work, and working groups consisting of specialists should be established with the main aim of being informed and inform others about the relevant technological alternatives available for LIC in their fields. Regarding forestry and forest industries I would recommend groups at least on the following type of subjects:[4]

a. Agro-forestry
b. Silviculture
c. Bioenergy
d. Logging and long distance transport of timber
e. Sawmilling (including combinations with pitsawing)
f. Other forest industries

Each group should consist of technical specialists who have broad experiences from LIC and are independent of machinery producers and ordinary consultants. The group members could preferably be only parttime employed for this work, having their main professional activities elsewhere.

9.6.3 Use of the knowledge

Given that a certain project in a certain country is to be established, the main task of the specialist groups proposed in the previous section should be to provide information about the feasible set of technological alternatives for that project. This information, then, should be the starting point for socio-economic and ecological pre-analyses aiming at excluding inferior technologies at an early stage of the planning. Let us call this the stage 1 of the analysis.

In the next phase, stage 2, the remaining set of technological alternatives should be analysed in detail, for example as proposed in Ch. 4.3.2, preferably in a continous dialog between technical/-biological expertise, social scientists, donor agency, and political authorities at different levels.

In my experience it is important that different types of consultants are used in stage 1 compared to stage 2. In stage 1 the proposed independent groups of specialists together with social scientists should be used, whereas in stage 2 one could hire ordinary professional consultants. The aim of this two-stage process is to obtain a wider range of possible alternative technologies.

The same procedure should in my opinion also be followed regarding decision to change/modify existing technologies, or regarding starting research and development of new, mor appropriate technologies. Such activities are investments and their justification should be analysed as ordinary projects.

The identification of suitable alternatives is necessary, but not sufficient. Equally important is that ways and means are found of implementing the preferable tecnologies. The responsibility for action here lies, in my opinion, primarily at the governments of the LIC in the public policy pursued, and at the donor agencies.

The governments can take action directly and indirectly regarding the choice of technology. Directly, they can influence the technological choices by making proper analyses of projects owned or controlled by the government. Governments could also provide advisory services which would draw attention of private managers and producers to technologies that are considered more appropriate to development needs than those introduced by machinery salesmen, foreign consultants, and investors or other current sources. Such services may be particularly valuable to smaller and informal sector producers for example in the sawmill and wood working industries. The recommendations from SUNDBERG (1974) quoted in Ch. 2.3.1 and from LAARMAN et al. (1981) quoted in Ch. 2.3.2 are highly relevant.

Indirectly, the governments of LIC can play a major role in influencing the private investment decision through a wide variety of instruments, for example their influence on the decisions of private investors through fiscal, credit, price, wage and other policies and incentives to encourage or discourage the adoption of certain technologies; the nature of public infrastructure; their policies regarding import substitution and export promotion; the operation of foreign exchange controls, licensing and permit systems.
The effects of the various policy instruments on the technological choice will depend on the nature and functioning of the particular economic systems.[5]

As mentioned in Ch. 2 there exist many obstacles against introducing labour intensive technologies. For example if more mechanized skidding methods like agricultural tractors have already been introduced in an area, it is realistic to expect a negative attitude among the employed workers towards introducing oxen skidding.[6]
In such circumstances one should be careful and take due time in trying to convince decision makers and workers about the advantages of using animal skidding. Economic incentives could also be important. The salaries of the oxen handlers could for example be increased to the same level as - or even higher than - the salaries of the tractor drivers, thus directly giving the handlers a part of the economic benefits of the "new" technology. Indirectly, this would also indicate the importance of the technological change and of the oxen handlers.

The governments should encourage development of competent management, and skill for socio-economic appraisal and implementation of existing appropriate technologies. When choosing from the available menu of technologies it is important to adapt the existing technologies to the particular conditions prevailing in the LIC, and - if desirable - develop new and more appropriate technologies for particular situations. In practice this is not an easy task. Resources devoted to such efforts will give a prototype only after some time. This machinery will have to be tested and usually a period of adjustment is necessary. The gain, if any, will often accrue only after years, and considerable risks are involved. In several occasions it may be an advantage just to use or slightly modify already existing alternatives instead of trying to develop completely new ones. This will, of course, depend heavily on the issue at hand, and on the prevailing technical and socio-economic conditions.

Both adaption of existing technologies and development of new ones more appropriate for LIC, demand investments in research and prodution. In these activities it is likely to be considerable economies of scale, and if they are to be done commercially, a rather large market must exist. Another factor to consider is that such activities are a rather uncertain business in IC as firms in the larger LIC probably would start producing themselvels some of the technology found successful. Thus, a producer in IC cannot count on a

LIC market being open very long. At the same time it is not likely that within the IC themselves there will be a market for such kind of equipment. It seems, therefore, that production of new technology more appropriate for LIC will have to be done within larger LIC themselves or within regionally integrated groups of these countries.

Regarding R & D for adaption of the skidding operations in Ch. 6 and Ch. 7 I give the same recommendations as in SOLBERG & SKAAR (1986:73-74). Regarding the sawmill operations analysed in Ch. 8 I similarily believe the main challenge is to adapt the existing technologies in an appropriate management/organizational context. One important issue here would be to analyse the preferability of establishing a power source supply based on wood waste from the sawmills. Another important issue would be to combine the semi-mobile sawmills analysed in Ch. 8 with the oxen skidding method view in Ch. 7.

This latter issue is in my opinion a typical example of many important technological adaptions - that methods with different capital intensities are combined to give a more appropriate technology than what existed before. The question is to find the optimal mix of technology in a project. The technological alternatives analysed in Ch. 6 - Ch. 8 are more or less chosen by chance and do not give a complete picture of all existing, realistic technological alternatives in that particular project. Examples of operations which are not considered in this respect are timber cutting by powersaws contra using manual saws and axes, the loading of timber at road side, the log road transport (including road construction), the handling of timber and sawnwood at the sawmill yard, the drying of sawnwood, and the power supply issue for the sawmills. This indicates, as already mentioned in Ch. 9.5.1, that the study in Ch. 8 probably gives just a lower estimate of what could be gained by using a more appropriate technological mix than the one actually chosen.

The role of the donor agencies in the technological choice on project level is vital. They should, first, realize the importance of the issue. Secondly, they should have sufficient expertise available - either as own staff or as uncommitted consultants for example as the groups of specialists mentioned above - to make their own

judgements about what are the best choices of technology. Thus, one could easier avoid that outside technically oriented interests with relatively low experience from LIC, decide the technological choice.

9.7 Some concluding remarks

The question of technological determinism mentioned in for example STEWART (1978:278-279) remains open: Is the situation in LIC technologically determined, not because there are no alternative technologies to choose from, but because of the complex social, political and economic links between the selection mechanisms and the technologies chosen. This question is actually a hypothesis which can be rejected or not only by empirical studies and field action. Thus, the research in this field should not only be occupied with mapping the technical and socio-economic performance of alternative technologies, but also with analysis of which factors (political, social, economic) are decisive in the actual choices of technology, to get a better understanding of the possibilities of arriving at more rational choices. This would be a challenging interdisciplinary task for disciplines like engineering, economics, political science, sociology, social anthropology and psychology.

It should be emphasized that the choice of technology should be viewed as a dynamic process, changing over time according to changes in the technical, socio-economic and political structure it operates within, and at the same time influences. Thus, as development is gradually achieved by means of appropriate technology, the meaning of what is "appropriate", will change because of this development.

Technology cannot be viewed in isolation from the society it is intended to benefit, since it is just one segment of the total environmental, technical, social and political structure in which societies function. All social processes are complex, and the choice of technology alone cannot solve the development problems of third world countries. However, as indicated by this study, there are for these countries considerable benefits to be gained by choosing the appropriate technology at the project level.

NOTES CHAPTER 9

[1]It should be noted that the Volvo TC 860 forwarders were chosen mainly because they were intended to bring the logs without dirt directly to the sawmill (TWICO 1972). As discussed in FERGUS et al. (1977) this was a serious mistake as the machines were not constructed for terrain transport, and the distance to the sawmill was too long. In the later stage of the project agricultural tractors were used in the skidding of clearfellings. Skidding with oxen was, however, never seriously considered, according to the project reports available.

[2]It should be noted that the classification in various skills are not obvious - for example are the ox-drivers classified as skilled in Ch. 6 and Ch. 7. However, this classification underestimates rather than overestimates the employment of un- and semiskilled labour.

[3]Some more employment is required for feeding and caretaking of the oxen, but that is not classified as skilled management.

[4]Each group could according to need be devided in subgroups - e.g. group f. could be devided in particleboard, fibreboard, pulp and paper.

[5]ILO (1972) gives a more complete presentation of various policy means available for LIC in this respect.

[6]The unemployed would most likely have another view, but they have limited possibilities of getting their viewpoints through.

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APPENDIX 1: INPUT-OUTPUT TABLE FOR TANZANIA

For estimating indirect economic effects of the various technological alternatives analysed in this paper, the input-output table for Tanzania given in UNDP (1975) and shown in Table A 1.1 has been used. The following sections give a brief outline of the main assumptions underlying this input-output matrix. The outline is mainly based on TANZANIA (1973:1-9).

The input-output table relates to Tanzania mainland only. The classification of the production sectors used follows closely the industrial classification of the national accounts series. The estimates of gross domestic product by account series cover 9 major industries. These 9 industry groups have for purposes of the input-output table been divided into 44 production sectors. The 45th production sector (viz. Unspecified, see Table A 1.1) covers the residual items which cannot be allocated to any other sectors.

Compilation of an input-output table requires a large body of primary data pertaining mainly to the purchases and disposals of each production sector. The annual survey of manufacturing industries forms the basis for the industry part of the input-output table. In addition to the data thus obtained, samples of 4 or 5 factory establishments from each industry sub-group were contacted and information on their source of supply and origin of input-items obtained. For export crops and other agriculture sub-sectors, the main data has been national account studies from the various commodity boards and different farm studies.

The methods used for compiling input-output tables in most countries follow roughly either or both the input or output approach. The output approach consists in first establishing the totals of output for each of the production sectors distinguished, followed by an allocation of the total output to the using industries and final demand categories. The input approach consists in building up the cost structure of industrial sectors, sector by sector. In the input-output analysis for Tanzania, mainly the input (or cost structure) approach has been adopted. Private consumption expenditure by sector of origin has been obtained in most cases as a residue. Fixed capital formation and stock figures are consistent with the estimates presented in the national accounts series. The consumption expenditures and fixed capital formation figures are inclusive of the distribution costs. Direct taxes are not distinguished in the input-output table since the value of services before taxation are entered in the table. Indirect taxes and subsidies are entered as three separate rows as primary inputs against the purchasing industry.

The input-output table is valued in producer's prices for the intermediate flows (valued f.o.b. plant excluding marketing costs and commodity taxes) and the marketing costs (delivery expenditures, insurance, indirect taxes, etc.) are counted only once in the system (TANZANIA 1973:7). The estimates of consumption expenditure, capital formation and exports are taken inclusive of the marketing costs element, which is considered as input of the producing industry from the marketing cost sectors, and are, therefore, valued at purchaser's prices.

Neither TANZANIA (1973) nor UNDP (1975) discuss the uncertainty elements involved in compilation of the Tanzanian input-output tables. However, TANZANIA (1973) mentions (p. 3) that for export crops and agricultural sub-sectors the available data are often incomplete and allocations or approximations have had to be made. In regard to international trade data it is stated (op.cit.:4) that the main gap in the context of input-output studies relates to the destination of import merchandise, and allocation has been made to a certain extent on the basis of ad-hoc enquires and in a large number of cases on relatively insufficient basis. Regarding the input-output coefficients it is stated (op.cit.:8) that substitution between imported goods and domestically produced goods may often cause a drastic change in the domestic input coefficients, and this is particularly true in developing countries of Tanzania's size and stage of development. UNDP (1975) gives no estimate of the uncertainty involved in the input-output table for Tanzania, but gives a list of what improvements should be done regarding the statistical data. It says (op.cit.:6) that highest priority should be given to improvements of data related to agriculture, small-scale industries, transport and internal trade.

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Table A 1.1. Input-output table for Tanzania mainland in 1970 (million shs)*

(From: UNDP 1975)

No.	Sector	Seed cotton 1	Sisal 2	Tea leaf 3	Coffee 4	Sugar-cane 5	Tobacco 6	Cashewnut 7	Pyrethrum 8	Food grains 9	Other crops 10	Livestock 11	Fishing 12	Forestry and hunting 13	Diamond mining 14	Other mining 15	Food manufacturing 16	Beverage industries 17	Tobacco manufactures 18	Cotton ginning 19	Textiles 20	Leather and footwear 21	Sawmilling and carpentry 22	Printing and paper 23	Chemicals and petroleum 24	Metallic and non-metallic products 25	Railway workshops 26	Automobile assembling and repairs 27	Other manufacturing 28	Wine industries 29	Tailoring 30	Other small-scale industries 31	Electricity and water supply 32	Construction 33	Commerce 34	Hotels and restaurants 35	Transport 36	Communications 37	Banking and insurance 38	Real estate 39	Business services 40	Public administration 41	Education 42	Health 43	Other services 44	Unspecified 45	Subtotal	Fixed capital formation	Private consumption expenditure	Government consumption expenditure	Exports (FOB)	Increase in stocks	Grand total	No.
1	Seed cotton																			246.8																											246.8						246.8	1
2	Sisal																				17.4				0.4																						17.8				179.8	-25.7	171.9	2
3	Tea leaf																27.0																														27.0						27.0	3
4	Coffee				2.0												3.2																														5.2		16.3		312.8	0.8	335.1	4
5	Sugar-cane					0.7											33.8																														34.5		1.7				36.2	5
6	Tobacco						1.9												13.5																												15.4				59.5	-4.9	70.0	6
7	Cashewnut							2.0									16.0																														18.0		10.2		115.2	15.0	158.4	7
8	Pyrethrum																								7.6																						7.6				1.5		9.1	8
9	Food grains									31.4		10.9					93.2	1.2												2.2		1.0				2.6						19.4	1.4	0.8			164.1		587.4		23.2	30.0	804.7	9
10	Other crops										27.2	10.7					12.6				0.6				0.9					2.5		11.5		50.7		2.6						9.1	1.3	0.8			130.5		734.4		85.3	8.0	958.2	10
11	Livestock																48.2					24.2														4.6						17.8	2.5	1.6			98.9	24.0	651.2		9.1	20.4	803.6	11
12	Fishing																																			1.4						5.7	0.3	0.1			7.5		131.6		28.3		167.3	12
13	Forestry and hunting						1.4		2.5			3.4				0.2	1.4	0.1					2.9		3.2	0.4		0.4	0.4	4.2		11.3		61.5								3.4					96.7		175.3		51.9		323.9	13
14	Diamond mining																																																		112.3	-4.5	107.8	14
15	Other mining											0.6	0.4			0.5	0.2					0.1				3.3			1.6			4.8		21.7													33.2		7.6		13.9		54.7	15
16	Food manufacturing											21.6					20.5	7.7							1.9					7.8		1.7				2.8						11.1	2.8	[illegible]	3.8		83.5		421.5		160.9	-3.9	662.0	16
17	Beverage industries																																			10.0							2.8				12.8		145.6		1.0		159.4	17
18	Tobacco manufactures																																																196.0		9.0	-0.2	204.8	18
19	Cotton ginning																42.2				38.5																										80.7				251.6	0.3	332.6	19
20	Textiles		0.4							1.8	1.2		7.3	1.8		1.4	0.7	0.3	0.2	4.7	37.5	[illegible]	0.8	0.1	0.3	0.1			0.1		3.2	0.8		0.8	14.2	0.2	0.5		0.2			13.5		0.1	0.1		95.0		286.3		-44.6	7.4	433.3	20
21	Leather and footwear																					1.2							0.3			0.8															2.3		34.0		28.7	0.6	65.6	21
22	Sawmilling and carpentry																1.0	1.0	2.4					0.3	0.7	0.4		0.3	0.1					30.9	8.4		0.4					3.8	0.1	0.1	1.3		51.2		27.9		7.8		86.9	22
23	Printing and paper		0.6	0.4												0.4	0.4	0.7	0.2	0.5	0.5	0.7	0.3	0.4	0.7	0.2		0.4	0.4				0.4	3.8	1.0	1.2	2.6	1.0	3.3		0.6	16.1	2.9	0.9	2.7		43.1		22.4		2.4		67.9	23
24	Chemicals and petroleum		1.0							0.6	2.1	2.4	3.2		3.0	1.3	2.1	0.2	0.4	0.9	2.5	0.2	3.4	0.2	1.0	2.0	0.6	4.7	0.4			2.3	8.0	0.7	9.0	1.3	13.7		0.7		0.3	5.7	0.1	1.4	1.8		77.2		66.9		145.8	1.0	290.9	24
25	Metallic and non-metallic products		5.0	1.0		1.0					1.7	3.0			1.2	0.9	8.6	0.1	0.7	2.3	1.0	0.7	5.5	0.5	1.8	4.4	0.9	1.8	2.8			0.8		78.1	14.0		4.0					3.6	0.2	0.1			145.7		11.9		23.2	1.6	182.4	25
26	Railway workshops																																				19.2										19.2						19.2	26
27	Automobile assembling and repairs		2.1	0.6		0.3					1.0	1.4			0.5	0.5	1.4	0.8		0.3	0.3	0.1	0.7	0.1	0.3	0.5		13.7	0.2				3.0	9.7	11.0	0.4	33.2		0.9		0.4	15.9	0.7	2.2	1.9		104.1	11.0	40.7		0.3		156.1	27
28	Other manufacturing		3.1			1.4											6.3	2.6	3.4	0.8	4.3		1.1	0.7	2.3	2.4		1.6	1.0				3.6	11.1	5.0		3.7		0.7		0.2			0.7			56.0	0.6	8.3		12.0	3.0	79.9	28
29	Wine industries																																																106.0				106.0	29
30	Tailoring																																																24.4				24.4	30
31	Other small-scale industries	3.6	1.9	1.5	1.6		0.3	1.3	1.0	2.4	4.8	6.2	1.0	1.8																					7.6												33.1		138.4		19.7		191.2	31
32	Electricity and water supply		3.1	1.1		0.6									1.5	0.8	5.5	0.9	0.5	1.0	5.6	0.4	1.4	0.6	1.1	3.8	0.7	0.9	2.8	0.5			0.3	4.6	8.1	4.8	4.2	4.0	2.4		0.6	11.8	2.2	3.3	3.4		82.5		33.1				115.6	32
33	Construction		1.0	1.1							2.0	3.9				2.5	3.7	0.4	0.4	0.8	1.1	0.8	0.4	0.2	0.8	1.6		0.8	0.5				4.0	0.3	8.4	2.1	15.3		2.6	77.1	0.2	57.4	0.8	0.6	2.3		193.1	1 008.2				13.4	1 214.7	33
34	Commerce	1.5	16.5	1.5	25.0	1.9	15.7	31.5	0.9	39.8	39.0	41.5	24.1	25.5	3.9	13.2	70.8	13.8	17.1	33.0	34.7	7.3	13.1	8.9	44.1	21.0	1.1	19.5	13.4	5.7	2.6	16.8	4.5	155.9	8.4	7.1	34.3	1.2	3.2		0.4	33.0	4.5	6.6	4.6		868.1	75.2	289.9			126.8	1 360.0	34
35	Hotels and restaurants														2.0	0.7	3.7	0.4	0.4	0.8	1.1	0.8	0.4	0.2	0.8	1.6		0.8	0.5					5.7	8.4		1.8		1.0		0.3	26.5	4.7	1.0	0.4		64.0		34.3		19.4		117.7	35
36	Transport	3.3	22.9	0.8	14.1	4.7	5.8	11.7	0.7	14.6	14.8	37.4	9.0	25.7	3.3	5.9	33.2	9.8	7.9	12.4	15.4	5.1	8.3	3.7	19.6	9.0	0.4	8.2	5.7	2.1	1.0	6.3	4.0	91.8	129.2	4.1	45.3	6.8	6.3		2.3	62.7	6.6	5.8	7.9		697.6	49.9	126.6		302.5		1 176.6	36
37	Communications		0.6	0.4											0.6	0.7	2.5	1.7	2.2	0.1	1.8	0.2	0.5	0.4	1.2	0.8		0.7	0.4				0.5	3.5	11.3	0.7	3.4		2.7		0.6	14.7	0.2	0.6	0.9		53.9		16.9				70.8	37
38	Banking and insurance		0.7						0.1						0.8	0.8	4.3	1.3	1.6	0.7	1.9	0.8	0.6	0.4	1.3	1.7		1.0	0.7				0.3	4.8	32.7	0.8	11.8		2.9		0.3	1.0		0.1	0.2		75.6		10.3		4.4		88.3	38
39	Real estate																																									10.5	0.4				10.9		747.8				758.7	39
40	Business services			0.7							0.3					1.1	2.1	1.4	1.8	0.1	1.5	0.2	0.4	0.3	0.9	0.7		0.6	0.4				1.2	5.4	8.4	0.5	3.0		1.0		0.1	4.6	0.4	0.2	1.0		38.3						38.3	40
41	Public administration																																																	968.4			968.4	41
42	Education										4.8				2.0																		1.1		1.7			1.8	0.7	0.7					0.2		12.5		56.0	165.3			233.6	42
43	Health														1.0																			0.4	1.7		0.1		0.2		0.1						3.5		31.3	106.5			141.3	43
44	Other services										0.1				3.9																			0.6	8.4	2.4	0.4		1.6			8.8			4.2		30.4		99.7		29.2		159.3	44
45	Unspecified																	0.2				0.2	0.1	0.1	1.0				2.6						2.0							16.6			1.0		23.8		1.4		129.2		154.4	45
	SUBTOTAL	10.4	57.0	9.1	42.7	10.6	25.1	46.5	5.2	90.6	99.0	145.0	45.0	54.8	23.7	30.9	444.6	44.6	52.7	305.2	165.5	43.7	39.9	17.1	91.9	53.9	3.7	53.4	34.3	25.0	8.8	58.1	30.9	542.0	298.9	49.6	196.9	14.8	30.4	77.1	6.4	372.7	34.9	28.8	37.7		3 859.1	1 168.9	3 293.3	1 240.2	2 184.4	169.1	13 935.0	
	Imports	4.0	6.2	4.0	9.0	4.0	4.0			7.9	2.4	4.2	0.5	0.2	2.4		27.8	7.7	6.2	1.7	62.2	9.9	14.1	10.6	[illegible]	[illegible]	-3.9	35.8	29.5		0.3	-7.9	11.5	340.3	21.7	7.1	195.5	7.9	25.4			48.0	21.0	27.7	9.7	150.6	1 217.3	636.7	737.4		-6.6		2 607.0	
	Customs duties		2.8		24.7			9.0			0.6	1.5		0.6			7.6	2.8	1.0	12.5	10.2	0.5	0.8	0.9	1.9	2.6		7.9	3.6		0.1		0.2	17.2	19.6	5.4	64.6								1.1	3.7	203.4	55.5	166.2				425.1	
	Other indirect taxes	0.5	4.1	0.5	0.5	0.5	0.5	0.5		0.5	0.5	0.8		10.0		0.6	62.0	60.9	96.9	0.2	59.4	1.5	4.1	10.3	20.6	7.9		1.6	4.3	14.8	2.1	4.2	3.3	4.8	26.8	2.4	56.9		1.0	9.2			0.1		5.6	0.1	473.5	16.8	76.3				568.6	
	Less subsidies										-11.2													-3.9									-14.7				-2.5								-3.4		-33.7						-33.7	
	Wages and salaries	19.7	85.9	11.4	56.9	17.4	13.5	4.3	2.1	34.3	59.8	28.0	12.0	10.0	28.3	9.0	60.6	6.3	15.9	6.9	68.6	3.6	16.2	12.3	24.0	24.6	10.3	7.1	8.8	3.4	1.6	20.0	30.7	316.7	462.0	19.5	365.0	325.0	45.7	-5.7	14.6	546.0	173.6	77.8	93.0		2 852.0						2 852.0	
	Depreciation	2.5	13.3	1.2	5.6	2.9	1.4	1.1	0.3	7.5	6.7	7.7	1.7	6.3	10.1	1.5	21.6	3.0	3.0	0.1	27.2	0.9	2.2	2.1	12.0	15.8	1.1	3.5	1.7	1.3	0.3	2.6	13.9	19.7	41.0	4.7	119.0	9.4	3.0	128.3	1.2	1.7					512.1						512.1	
	Operating surplus	208.9	2.7		199.7		24.7	97.0	1.5	663.9	798.4	618.4	108.3	242.0	43.3	12.7	37.8	34.7	29.1	6.0	40.2	5.5	9.6	10.5	25.0	18.5		45.3	-2.3	61.5	11.2	106.3	39.8	68.6	490.0	29.0	181.2	13.7	-18.2	544.1	16.1		4.0	7.0	15.6		4 851.3						4 851.3	
	GRAND TOTAL	246.8	272.9	27.0	335.1	36.2	70.0	158.4	9.1	804.7	958.2	803.6	167.3	323.9	107.8	54.7	662.0	159.4	204.8	332.6	433.3	65.6	86.9	67.9	290.9	182.4	19.2	156.1	79.9	106.0	24.4	121.2	115.6	1 214.7	1 360.0	117.7	1 176.6	70.8	88.3	758.7	38.3	968.4	233.6	141.3	159.3	154.4	13 935.0	[illegible]	[illegible]	[illegible]	2 200.0	169.1	[illegible]	
	GDP at factor cost	231.1	101.9	12.6	262.2	20.3	39.6	102.4	3.9	705.7	866.9	654.1	122.0	258.3	81.7	23.2	120.0	44.0	48.0	13.0	136.0	10.0	28.0	24.9	61.0	58.9	11.6	53.9	8.2	66.2	13.1	128.9	84.4	404.4	993.0	53.2	665.2	48.1	30.5	672.4	31.9	547.7	177.6	84.8	108.6		8 215.4						8 215.4	
	GDP at market prices	231.6	108.8	13.1	287.4	20.8	40.1	111.9	3.9	706.2	856.8	656.4	122.0	268.9	81.7	23.8	189.6	107.7	145.9	25.7	205.6	12.0	32.9	32.2	83.5	64.4	11.6	55.4	16.1	81.0	15.3	133.1	73.2	426.4	1 039.4	91.0	784.2	48.1	31.5	681.6	31.9	547.7	177.7	84.8	111.9		8 858.6	72.3	242.5				9 173.4	

*The valuation is at factor cost for intermediate inputs and purchaser's values for final deliveries.

APPENDIX 2: PRICE-INDICES AND EXCHANGE RATES USED IN THE ANALYSES

This appendix gives the price changes and exchange rates used in the analysis in Ch. 6 - Ch. 8.

A 1 Price indices

A 1.1 Consumer price index for Tanzania

Various price indices for Tanzania are available. By contacting Tanzania's Ministry of Finance and Economic Planning I was adviced to use for my purpose the National Consumer Price Index shown in Table A 2.1.

Table A 2.1. The National Consumer Price Index for Tanzania. (Base: 1970 = 100).

Year	1974	1975	1976	1977	1973	1979	1980	1981	1982	1983	1984	1985	1986
Index	148	188	201	224	249	283	369	464	599	760	1035	1438	2567

(Source: EIU (1983, 1987).

A 1.2 Price development since 1977 on certain important items

The following gives the price developments from medio 1977 to January 1982 and January 1987 of specific factors which are particularly important for the relative cost development of the technological alternatives analysed in Ch. 6 - Ch. 8.

The estimates are based on data from the respective selling/importing agencies in Tanzania, and accountancy data at Sao Hill Sawmill. Regarding spare parts and tyres, the figures given represent a weighted average of the most common items used.

Table A 2.2. Price index development in Tanzania of specific production inputs from medio 1977 to January 1982. Base: Medio 1977 = 100).

Item	Index	
	Jan. 1982	Jan. 1987
Salaries		
Unskilled permanent employed	154	332
Skilled - vehicle operator	154	272
" - sawmill manager, workshop managers, etc.	164	236
Investments - vehicles		
Ford 6600-2	201	701
Landrover 109"	214	1,343
Scania LB 81	205	1,436
Scania LBT 111	200	865
Investments- sawmill machinery		
Br. Lindqvist,Sweden Ka-Ra YS, Finland	} 150	} 1,150
Spare parts		
Scania vehicles		
Landrover 9"	230	1,510
Ford 6600-2		
Sawmill machinery Br. Lindqvist Ka-Ra	} 160	} 1,160
Tyres		
Agricultural tractor	271	} 1,130
Others (Scania and Landrover)	204	
Oil products		
Diesel	189	641
Petrol	208	697
General consumer price index[x]	265	1,146
Rough sawnwood	235	639

[a]Based on own data collection.

[b]From Table A 2.1.

A 1.3 Price index of machinery export from Sweden

Most of the imported machinery used at Sao Hill Sawmill comes from Sweden. Table A 2.3 gives export price index for machinery (except electrical products) from this country.

Table 2.3. Export price index for machinery from Sweden. (Base: 1968 = 100).

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Index	146	173	192	204	222	239	265	288	329	373	381	396	406

Source: SWEDEN (1982:237, 1986:219).

A 2 Exchange rates

Table A 2.4 gives the exchange rates for US $, SEK and NOK.

Table A 2.4. Exchange rates[a] between shs and US$, SEK and NOK

Source: EIU (1983, 1987)

Currency	Unit	Year									
		1974	1975	1976	1977	1978	1979	1980	1981	1982	1987[b]
US $	shs/US $	7.18	7.18	8.31	8.42	7.99	8.29	8.21	8.18	9.20	54.48
SEK	shs/100 SEK	151.0	179.3	189.7	191.3[1]	171.8[1]	189.3	197.1	178.2	146.8	824.2
NOK	shs/100 NOK	119.0	137.8	148.8	162.1	154.9	162.2	167.6	149.6	141.4	760.1

[a] Average selling rates

[b]January 1987

APPENDIX 3: INVESTMENT AND OPERATING COSTS OF VEHICLES

This appendix gives the assumptions underlying the investment and operating costs of vehicles for the alternatives of technology discussed in Ch. 6 - Ch. 8.

If nothing else is stated in the text, the data and calculations are based on the assumptions in Ch. 5.2.3.

A 3.1 Ford 6600-2 agricultural tractor

The following estimates are based on FERGUS et al. (1977:142) and on information given by the Logging Manager at Sao Hill Sawmill.

<u>Investments</u>

Tractor excl. tyres	139,000 shs
Igland skidding equipment (2-drum Igland Compact 5000 winch, logging shield, front blade and protecting equipment)	50,000 " (dir. imp.)
A 2-axle trailer costs excl. tyres 20,000 shs. without breaks and 30,000 shs. with breaks.	

<u>Recurrent expenditures</u>

Diesel 4.5 l per machine hour	2.20 shs. per l
Oil 160 l per year	8.00 shs. per l
Tyres 10,000 shs. per set, life-time 2,000 machine hours per set.	
Spare parts, repair and maintenance (incl. wire, chokers, and spare parts for winch, at 1,500 machine hours operation time per year. 2,000 shs. is assumed to be direct import)	23,000 shs. per year
Insurance	1,500 " " "
Driver's salary (incl. 15 % social benefits)	7,200 " " "

<u>Operating costs</u>

Based on above assumptions, 1,500 machine hours per year, 5 years write-off time, 10 % cast-off value, and 9 % p.a. interest rate, the operating costs will be:

	shs/year	shs/machine hour
Depreciation:		
Tractor	25,000	16.70
Igland equipment	9,000	6.00
Interest:		
Machinery	9,400	6.30
Stock of spare parts	2,200	1.50
Working capital (working capital is 17,000 shs.)	1,500	1.00
Insurance	1,500	1.00
Fixed machinery costs	48,600	32.50
Diesel	14,900	9.90
Oil	1,300	0.90
Tyres	7,500	5.00
Spare parts	23,000	15.30
Total machinery costs	95,300	63.60
Driver's salary	7,200	4.80
Total (rounded off)	103,000	68.00

For a tractor with a 2-axle trailer and no skidding equipment the spare part component is reduced by 6,000 shs. per year, and the tyre cost increased by 2,500 shs. per year for the whole unit. Diesel and oil costs will be about the same, whereas depreciation cost is lowered respectively 4,000 shs. and 5,000 shs. per year, depending on breaks or not on the trailer. Spare parts for trailer are valued at 4,000 and 3,000 shs. per year for trailer with respectively breaks or not.

A 3.2 Ford County 1164

The following is based on information given by the Logging Manager at Sao Hill and FERGUS et al. (1977:143).

<u>Investments</u>

Machinery (excl. tyres)	232,000 shs.
Igland skidding equipment (2-drum Igland Compact 5000 winch, logging shield, front blade and protecting equipment)	50,000 " (direct import)

Recurrent expenditures

Diesel 6 l per machine hour 2.20 shs. per l

Oil 180 l per year 8.00 shs. per l

Tyres 16,000 shs. per set (assumed life-time corresponding to 2,000 machine hours)

Repair & maintenance (incl. wire, chokers and spare parts for winch) 28,000 shs. per year

Driver's salary 520 shs per month plus 15 % social benefits.

Operating costs

Based on this, assuming 1,500 machine hours per year, 9 % p.a. rate of interest, 5 years write-off time on the tractor and 10 % cast-off value of machinery, the operating costs will be:

	shs/year	shs/machine hour
Depreciation	50,800	33.90
Interest:		
Machinery	14,000	9.30
Stock of spare parts	3,000	2.00
Working capital (working capital is 21,000 shs.)	1,900	1.30
Insurance	2,500	1.70
Fixed machinery costs	72,200	48.20
Diesel	19,800	13.20
Oil	1,400	0.90
Tyres	12,000	8.00
Spare parts	28,000	18.70
Total machinery costs	133,400	89.00
Driver's salary	7,200	4.80
Total (rounded off)	141,000	94.00

For a Ford County with a 2-axle trailer same cost adjusments should be done as for Ford 6600-2 in Ch. A 3.1.

A 3.3 Volvo TC 860 forwarder

The following estimates are based on accountancy data from Sao Hill Sawmill and information given by the project's Logging Manager. The investment amounts are based on an offer dated June 1976 from

Volvo Sweden to Sao Hill Sawmill giving a price of 1,500,000 shs. per forwarder (inclusive tyres) c.i.f. Dar es Salaam. Based on the data in Appendix 2, this price is increased by 5 % to arrive at the (medio) 1977-price.

Investments

	With trailer	Without trailer
Tractor with crane excl. tyres	950,000	810,000
Tyres - one set (life time 5,000 machine hours)	150,000	120,000

All is direct import.

Recurrent expenditure

Diesel 11 l per machine hour 2.20 shs. per l

Oil 900 l per year 8.00 shs. per l

Repair and maintenance (spare parts, all direct import) 100,000 shs. per year

Insurance 8,100 shs. per year with trailer, 6,000 shs. per year without trailer

Driver's salary 650 shs per month plus 15 % social benefits.

Crane operator's salary 500 shs per month plus 15 % social benefits.

Operating costs for forwarder with trailer

Based on the above given data and assuming 1,500 machine hours per year[1], 9 % p.a. rate of interest, 10 % cast-off value, and 5 years write-off time, the operating costs will be:

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[1]The average for the two Volvo TC 860 forwarders at Sao Hill for the year 1977 was 1,450 machine hours per tractor (SAO HILL 1978 b).

	shs/year	shs/machine hour
Depreciation - machine	171,000x	114.00
Interest:		
Machine	47,000	31.30
Stock of spare parts (not including tyres)	17,100	11.40
Working capital (working capital is 64,000 shs.)	5,800	3.90
Insurance	8,100	5.40
Fixed machinery costs	249,000	166.00
Diesel	36,300	24.20
Oil	7,200	4.80
Tyres	45,000x	30.00
Repair and maintenance (spare parts)	100,000x	66.70
Total machinery costs	437,500	291.70
1 driver	9,000	6.00
1 crane operator	6,900	4.60
Total (rounded off)	453,000	302.00

[x]Direct import.

If the forwarder operates in terrain transport only, the trailer will not be used and the annual costs corresponding to the above given estimates will be about 55,000 shs lower, totalling 398,000 shs/year or 265 shs/machine hour.

A 3.4 Forwarder Rottne Blondin 750 model 600

The Volvo TC 860 forwarder is constructed for doing both terrain and road transport and is therefore not a specialized terrain forwarder (cf. FERGUS et al. 1977:32). To get a more realistic picture of the costs involved in using forwarders at Sao Hill, Rottne Blondin 750 is chosen mainly because of its chassis being similar to the Ford 6600 agricultural tractor, which has a relatively good service network in Iringa region. This machine is also one of the smaller forwarders with relatively low investment costs, which implies that the costs due to time out of production are relatively less than bigger forwarders like e.g. Volvo BM 969.

Rottne Blondin 750 is a framesteered forwarder with boogie, having a 75 HK DIN (58 kW at 2,100 r/min) Ford diesel motor. Weight is 9,950 kg and maximum terrain load weight is 10,000 kg. It is equipped with hydraulic grapple loader Rottne Grip 70, with maximum reach 5.3 m and lift moment 3,600 kpm. Length, with and height of the forwarder are respectively 8.90 m, 2.49 m and 3.0 m.

No empirical cost data from Tanzania exist for this machine. The following estimates are therefore based on empirical data from Norway and Sweden as given by SA (1978) and STATENS SKOGER (1977). In addition the data available at Sao Hill Sawmill from using the TC 860 forwarder have been used.

Investments

Price per forwarder in June 1977 f.o.b. Oslo (excl. sales tax) was according to Norwegian sales agent 430,000 Nkr equalling 697,000 shs (cf. Appendix 2), of which the tyre costs amount to 40,000 Nkr or 65,000 shs with assumed life time corresponding to 5,000 machine hour. Freight, insurance and port-handling costs for the transport Oslo-Dar es Salaam are calculated to be 90,000 shs. Based on this the investment costs c.i.f. Dar es Salaam are assumed to be:

Forwarder excl. tyres	722,000 shs
Tyres (1 set)	65,000 shs

Recurrent expenditures

Diesel 7 l per machine hour	2.20 shs per l
Oil 600 l per year	8.00 shs per l
Repair and maintenance (spare parts)	60,000 shs per year
Insurance	4,100 " " "
Driver (650 shs/month plus 15 % social benefits)	9,000 " " "

Operating costs

Based on the data given above and assuming 1,500 machine hours per year, 9 % p.a. rate of interest, 5 years write-off time, and 10 % cast-off value of machine, the operating costs will be:

	shs/year	shs/machinehour
Depreciation machine (dir. import)	130,000	86.70
Interest:		
Machine	35,700	23.80
Stock of spare parts (stock of spare parts is 108,000 shs of which 72,000 is direct import)	9,700	6.50
Working capital (working capital is 36,000 shs)	3,200	2.10
Insurance	4,100	2.70
Fixed costs	182,700	121.80
Diesel	23,100	15.40
Oil	4,800	3.20
Tyres (direct import)	19,500	13.00
Repair and maintenance (spare parts, half is direct import)	60,000	6.00
Total machine costs	290,100	193.40
Driver's salary	9,000	6.00
Total (rounded off)	300,000	200.00

A 3.5 Wheelloader Volvo LM 841/Caterpillar 930

The following is based on information given by the Logging Manager at Sao Hill Sawmill. The figures refer to Volvo LM 841, which was directly imported by the project. Caterpillar had in 1977 its own sales-agency in Dar es Salaam, and the prices given below can with reasonable accuracy also be used for the wheelloader Caterpillar 930, which is of the same capacity as Volvo LM 841.

Investment

Machine(excl. tyres) with grapple or forklift 485,000 shs

Recurrent expenditure

Diesel 9 l per machine hour 2.20 shs per l

Oil 550 l per year 8.00 shs per l

Tyres 39,000 shs per set, with assumed life-time corresponding to 2,500 machine hours

Repair and maintenance: 52,000 shs per year

Insurance 3,500 " " "

Driver's salary 480 shs/month plus 15 % social benefits

Operating costs

Based on this, assuming 1,600 machine hours per year, 9 % p.a. rate of interest, 5 years write-off time and 10 % cast-off value of machinery, the operating costs will be:

	shs/year	shs/machine hour
Depreciation	87,300	54.60
Interest:		
Machinery	24,000	15.00
Stock of spare parts[1]	4,400	2.80
Working capital (working capital 37,000 shs)	3,300	2.10
Insurance	3,500	2.20
Fixed machinery costs	122,500	76.60
Diesel	31,700	19.80
Oil	4,400	2.80
Tyres	25,000	15.60
Repair and maintenance	52,000	32.50
Total machinery costs	235,600	147.30
Driver's salary	6,600	4.10
Total (rounded off)	242,000	151.00

A 3.6 Scania lorry LB 81 with crane and 1-axle piggy-back trailer

The following estimates are based on FERGUS et al. (1976:146), accountancy data from Sao Hill Sawmill and information given by the Logging Manager at Sao Hill Sawmill.

Investments

Vehicle (without tyres)	365,000 shs
Hydraulic grapple loader	180 000 shs (direct import)
1-axle piggy back trailer (including stakes, excluding tyres)	75,000 shs (direct import)
Total	620,000 shs

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[1]Stock of spare parts is 49,000 shs for Caterpillar 930 and 97,000 shs for Volvo LM 841. Here, 49,000 shs are assumed.

Recurrent expenditure

Diesel 0,40 l per km	2.20 shs per l
Oil 400 l per year	8.00 shs per l, plus

2,000 shs/year for hydraulic oil for the grapple loader

Tyres 24,000 shs per set with average life-time corresponding to 20,000 km

Service and maintenance:

Vehicle	40,000 shs per year
Grapple loader[1] and trailer	29,000 " " "
Insurance	16,000 " " "

Driver 600 shs per month plus 15 % social benefits

Operating costs

Based on the above given data, and assuming 38,000 km driving distance per year, 9 % p.a. rate of interest, 5 years write-off time, and 10 % cast-off value of machinery, the operating costs will be:

	shs/year	shs/km
Depreciation	111,600	2.94
Interests:		
Machinery	30,700	0.81
Stock of spare parts	7,900	0.21
Working capital (working capital 53,000 shs)	4,800	0.31
Insurance	16,000	0.42
Fixed machinery costs	171,000	4.50
Diesel	33,400	0.88
Oil	5,200	0.14
Tyres	45,600	1.20
Repairs and maintenance:		
Scania vehicle	40,000	1.05
Grapple loader and trailer	29,000	0.76
Total machinery costs	324,200	8.53
Driver's salary	8,300	0.22
Total (rounded off)	333,000	8.80

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[1]Regarding grapple loader costs see Ch. A 3.7.

For a LB 81 Tipper the total investment costs are assumed to be 410,000 shs, of which tyre costs are 16,000 shs.

A 3.7 Scania lorry LBT 111

The following is based on FERGUS et al. (1977:146) and on information given by the Logging Manager at Sao Hill Sawmill.

Investments

Vehicle (without tyres)	490,000 shs
Hydraulic grapple loader (e.g. Hiab 670)	180,000 shs (direct import)
Two-axle trailer (with stakes, excl. tyres)	200,000 shs
	870,000 shs

Recurrent expenditures

Diesel 0.72 l per km	2.20 shs per l
Oil 600 l per year	8.00 shs per l, plus

2,000 shs/year for hydraulic oil for the grapple loader

Tyres 55,000 shs per set, with assumed life-time corresponding to 20,000 km

Repair and maintenance	89,000 shs per year
Insurance	26,000 " " "

Driver's salary 650 shs/month plus 15 % social benefit

Operating costs

Based on this, and assuming 28,000 km driving distance per year, 9 % p.a. rate of interest, 5 years write-off time, and 10 % cast-off value, the operating costs will be:

	shs/year	shs/km
Depreciation	156,600	5.59
Interest:		
Machinery	43,100	1.54
Stock of spare parts	9,500	0.34
Working capital (working capital 76,000 shs)	6,800	0.24
Insurance	26,000	0.93
Fixed machinery costs	242,000	8.64
Diesel	44,400	1.59
Oil	6,800	0.24
Tyres	77,000	2.75
Repair and maintenance	89,000	3.18
Total machinery costs	459,200	16.40
Driver	9,000	0.32
Total (rounded off)	468,000	16.70

Without hydraulic grapple loader the above annual costs would be reduced by about 66,000 shs:

Depreciation	32,000 shs/year
Interest	13,000 "
Rep. and maintenance	19,000 "
Oil	2,000 "
Sum	66,000 shs/year

The grapple loader annual costs are based on data for 9 Hiab 970 cranes as given by the Norwegian company Nedre Glommen Skogeierforening for the years 1977-79.

A 3.8 Landrover 109"

The following estimates are based on information from the Logging Manager at Sao Hill Sawmill.

Investments

Vehicle (excl. tyres) 91,000 shs

Recurrent expenditures

Petrol 2 l per 10 km	3.60 per l
Oil 60 l per year	8.00 shs per l

Tyres 2,400 shs per set (assumed life-time corresponding to 15,000 km)

Repair and maintenance(spare parts)	5,000 shs per year
Insurance	3,900 " " "

Driver's salary 530 shs/month plus 15 % social benefits

Operating costs

Based on this, assuming 36,000 km driving distance per year, 9 % p.a. rate of interest, 5 years write-off time and 10 % cast-off value of machinery, the operating costs will be:

	shs/year	shs/km
Depreciation	16,400	0.46
Interest:		
Vehicle	4,500	0.13
Stock of spare parts	800	0.02
Working capital (working capital 15,000 shs)	1,400	0.04
Insurance	3,900	0.11
Fixed machinery costs	27,000	0.75
Petrol	25,900	0.72
Oil	500	0.01
Tyres	5,800	0.16
Repair and maintenance	5,000	0.14
Total machinery costs	64,200	1.78
Driver	7,300	0.20
Total (rounded off)	72,000	2.00

APPENDIX 4: ACTUAL INVESTMENT AND OPERATIONAL COSTS OF THE SAO HILL SAWMILL PROJECT

The following gives the investment and operational costs of the Sao Hill Sawmill Project assuming an annual sawlog input quantity of 30,000 cu.m u.b. The costs include the sawmilling and logging operations only - i.e. the planing, boxboard and impregnation plants are not included (cf. Ch. 8.3.2). The sawmill consists of one double slabber, one circular split saw, two circular resaws and one circular double edger, arranged as described in TWICO (1972). For the bigger logs there is an additional circular sawbenche, which can be operated as a separate unit or in combination with the resaws.

Because the project's accountancy system was not satisfactory in the first stage of the project, different information sources as mentioned below have been used to arrive at as correct estimates as possible.

A 4.1 Investment costs

Table A4.1 gives the investment costs of the Sao Hill Sawmill Project, rounded off to the nearest 10,000 shs. When nothing else is stated the investment amounts are taken from the project's own balance sheet, assetts account. Machinery installation and mounting costs are, if nothing else is stated, included in the costs. Stock of spare parts and working capital are not included.

A 4.2 Salaries and wages

Based on Sao Hill Sawmill's own wage records for 1977, Table A4.2 gives the number of employees and corresponding salaries (at 1977 price-level) necessary for producing about 14,000 cu.m of sawnwood per year at Sao Hill.

To avoid any bias in favour of the more labour intensive techniques, based on an employment/wage policy which may be judged unfair, I have in this analysis assumed that all workers are permanently employed (cf. Ch. 5.2.5). Based on BRANDSNES (1977:71-4) it is assumed that the employer in addition to the workers' gross salary has to pay 15 % of the gross salary as social benefits for the workers:

Workmen compensation	4.8 %
National Provisional Fund	5.0 %
Housing levy	2.0 %
Pensions	2.0 %
Misc.	1.2 %
Sum	15.0 %

The workers are paid somewhat differently for the same job in accordance with how long experience they have. The amounts given in Table A4.2 are based on the average payments at Sao Hill. The salaries of foreign technical assistance personnel are not included.

A 4.3 Operating costs exclusive personnel costs

Table A4.3 gives the operating costs exclusive personnel renumerations. The estimates are based on BRANDSNES (1977), SAO HILL (1981), and the vehicle cost estimates in Appendix 3. The estimates in BRANDSNES (1977) and SAO HILL (1981) are adjusted for the fact that this analysis does include neither the planing and boxboard activities nor the impregnation plant, and that a sawlog input of 30,000 cu.m u.b. is assumed. The costs given by BRANDSNES op.cit. are budget figures. However, they are based on empirical production data from Sao Hill Sawmill up to June 1977 and worked out in close cooperation with the logging and sawmill managers as well as the general manager of the project. These data are checked with the accountancy data for 1977 (SAO HILL 1978). The figures arrived at therefore represent in my opinion the best estimates available for realistic calculation of the operating costs of Sao Hill Sawmill. The log royalty paid to the Forest Department is not included below. For 30,000 cu.m u.b./year this amounts to 1,482,000 shs/year at 1977 prices.

TABLE A4.1: ACTUAL INVESTMENT COSTS OF THE PRESENT SAO HILL SAWMILL PROJECT.[1]

Item	Investment amount in recurrent prices (1,000 shs.)	Place and time investment amount refers to	Investment costs estimated in (medio) 1977-prices (1,000 shs.)[1]	Adjustment percentage used[1] (%)
1. Sawmill and administration				
Site preparation	440	Sao Hill, medio 1975	520	19
Main sawmill building	2,100[2]	Sao Hill, October 1975	2,480	18
Workshop building, one shed for storing sawntimber (1,000 sq.m), one shed for trimming unit, petrol station, office building	500[2]	Sao Hill, medio 1976	560	12[17]
Sawmill Machinery[3]	x 3,620[4]	C.i.f. Dar es Salaam, Febr. 1975	x 4,890	35[17]
Green chain	x 330[4]	C.i.f. Dar es Salaam " "	x 450	35[18]
Sawdoctor equipment[5]	x 65[4]	C.i.f. Dar es Salaam " "	x 90	35[18]
Trimming unit	x 350[4]	C.i.f. Dar es Salaam, early 1976	x 370	7
Diesel power plant[6]	x 750[4]	C.i.f. Dar es Salaam, early 1976	x 800	7[20]
Electricity installations	160	Sao Hill, early 1976	180	15
2 wheel loaders (Volvo LM 841)	x 820	C.i.f. Dar es Salaam, Jan. 1975	x 1,050	28[21]
1 Scania lorry LBT III with 2-axle trailer[8]	740[7]	Sales price, Dar es Salaam, medio 1977	740	0
2 agric. tractors Ford 6600-2 with trailer	340[7]	Sales price, Dar es Salaam, medio 1977	340	0
1 landrover 109"	90[7]	Sales price, Dar es Salaam, medio 1977	90	0
Misc. items	450[9]	Sales price, Dar es Salaam, medio 1977	450	0
2. Logging and road transport of logs				
2 Volvo TC 860 forwarders with trailers	x 1,300[10]	C.i.f. Dar es Salaam, late 1974	x 2,200	69[22]
1 Ford County 1164[11]	250	Sales price, Dar es Salaam, medio 1977	250	0
Logging equipment for Ford County	x 50	C.i.f. Dar es Salaam, medio 1977	x 50	0
2 Scania LBT III lorries with trailer[11] for timber transport	1,490	Sales price, Dar es Salaam, medio 1977	1,490	0
2 hydraulic grapple loaders for the two LBT111	x 360	C.i.f. Dar es Salaam, medio 1977	x 360	0
1 landrover 109"	90	Sales price, Dar es Salaam, medio 1977	90	0
1 Scania LB 81 Tipper[12]	410	Sales price, Dar es Salaam, medio 1977	410	0
Roads	500[13]	Sao Hill, medio 1976	560	12
1 stone crusher	50	Sao Hill, medio 1975	60	19
Misc. items	200[14]	Sao Hill, medio 1977	200	0
3. Social infrastructure				
20 senior-staff houses[15]	1,400	Sao Hill, medio 1977	1,400	0
100 junior-staff houses[15]	1,500	Sao Hill, medio 1977	1,500	0
Water supply	270	Sao Hill, medio 1976	300	12
Misc. items[16]	210	Sao Hill, medio 1976	240	12
4. Preoperational costs	820[23]	Sao Hill, medio 1975	980	19

[x]Imported directly by the project.

[1]When nothing else is stated, the adjustment from investment amount at purchase-time to corresponding cost at 1977-price level is done by applying the price indeces given in Appendix 2.

[2]Estimated by using data from the project's accountancy and calculations done by the project's building officer.

[3]Equipment from the company Bröderna Lindqvist AB, Sweden: Log intake (log haul 70x60 m, log turner, kick-off device), double log edger (slabber) LE 512, log saw bench J 52, split-saw type SS 8, 3 resaws KL 70, 1 double board edger type K 71, electric motors, conveyors, trolley wheels, sawdust transport equipment

[4]The amount is taken from original TWICO-invoice. It includes mounting costs.

[5]Includes automatic sharpener Lorock JL M 36, 1 hand sharpener, grinding wheels, set gauge, etc.

[6]3 diesel generators, each giving 150 kW (According to FERGUS et al. (1978:72) two generators ought to be enough for the saw-mill and trimming unit only, but one unit is kept as reserve).

[7]Bought in Dar es Salaam through Tanzanian agency.

[8]For transport of sawntimber to nearest reailway station, and of machinery and equipment in the construction period.

[9]Mainly harbour handling costs, and transport costs of machinery and equipment from Dar es Salaam to Sao Hill.

[10]Of this the freight Sweden - Dar es Salaam amounts to 236,000 shs and port handling etc. to 12,000 shs.

[11]The two Volvo TC 860 forwarders were supposed to do all the log transport from stump to mill site. However, this did not work out and here I have assumed, based on Fergus et al. (1978:144-148) and on the Project's actual investment, that one Ford County 1164 in the terrain transport and two Scania LBT III with 2-axle trailer and hydraulic grapple loader in the road transport are necessary in addition to the two Volvo TC 860.

[12]Mainly for road maintenance and construction work.

[13]200,000 shs of this refers to access roads in the forest, and 300,000 refers to the road from site A to site I, east of Irunda Height (see Map.5.5) about 10 km long. This is the only road considered here because all other roads neccessary for the mill situated at site A, will be neccessary also for the other allocation of the mill (or central unit) discussed in this paper. According to the project's accountancy record and information given by the logging manager of the project, the road construction costs can be devided into the following components (1976-prices):

Planing (grader)	4.50	shs pr m
Bridges, culverts	3.00	-- " --
Gravel	25.00	-- " --
Total	32.50	shs pr m

	Percent of total costs
Unskilled & semiskilled labour	30
Skilled labour	5
Diesel,oil	5
Other domestic inputs	60
Total	100 %

Annual maintenance costs was estimated to about 5 % of construction costs.

The Sao Hill Sawmill Project has bought its own grader. However, it is assumed here that the project rents (from the Forest Department or one of the tea-companies) a grader necessary for the road construction work. This assumption is done to avoid unreliable estimates of the annual costs of the grader caused by unreliable statements about how long time the project's grader will be rented out to other projects (cf. Fergus et al. 1977:145).

[14] Workshop equipment, 9 skidding sulkies, etc.

[15] Per May 1977 it was built 16 senior-staff houses and 52 junior-staff houses at Sao Hill. By then it was assumed that in addition to this at least 10 new senior-staff houses and 50 junior-staff houses must be built in the near future to secure the necessary key-staff for one shift production.

The houses are as described in FERGUS et al. (1977:42). The costs are assumed to be (price level medio 1977):

15,000 shs per junior staff house (38 sq.m)
60,000 shs per senior staff house (90 sq.m)
80,000 shs per senior staff house (120 sq.m)

(On average each senior-staff house is assumed to cost 70,000 shs).

Based on information given by the project's Maintenance Officer the cost components are estimated to be:

Unskilled and semiskilled labour	40 %	of total costs
Skilled labour	25 %	- " -
Diesel, oil	5 %	- " -
Other domestic inputs	30 %	- " -
Sum	100 %	of total costs

[16] Roads, transmission lines, electricity installations, furniture.

[17] The producers of the sawmill machinery (Bröderna Lindqvist AB, Sweden) reports that the prices of their machinery increased with 30-35 % from early 1975 to medio 1977. Table A2-2 gives a cost increase of 18 % from 1975 to 1977. Table A2-3 gives a cost increase of 6.6 % due to changes in exchange rates. Based on this I have assumed a price increase of 35 % altogether.

[18] Same price increase is assumed as for the sawmill machinery (cf. footnote 17).

[19] The trimming unit is produced in Norway. Same price increase is assumed as in footnote 20.

[20] The generators are produced in Sweden. Table A2-2 gives a cost increase of 6.3 % from 1976 to 1977. Table A2-3 gives a cost increase in shs due to changes of the exchange rate, corresponding to 0.8 %. Altogether a cost increase of 7 % is assumed.

[21] Volvo (Sweden) AB informs that the prices ex factory in Sweden of the LM 841 wheelloader increased by 21 % from January 1975 to June 1977. Table A2-3 gives a change in exchange rates between Sw.kr and shs. of 7-8 % for the same period. Altogether a cost increase (in shs.) of 28 % is assumed.

[22] Based on the information in Ch. A3.3. Volvo (Sweden) AB informs that the prices ex factory in Sweden of the TC 860 machine increased with 21 % from Nov. 1974 to June 1977.

[23] Salaries in the initial stage of the project, house rent, hotel accomodation, travel expenditures, legal fees, etc.

TABLE A4.2: PERSONNEL REMUNERATION AT SAO HILL SAWMILL
(1977-PRICE LEVEL)

Type of job	Nos. of employees	Remuneration paid (shs/month per pers.)		Ann. remuneration (shs/year)[1]	
		Gross salary	Total[1]	Un- and semiskilled personnel	Skilled personnel
1. Logging and road transport					
Logging in thinnings	18	390	449	97,000	
Felling, delimbing, bucking in clearcut operations	32	390	449	172,000	
Headmen	6	430	495	36,000	
Tool maintenance - head	1	470	541		6,500
" " - assistant	1	390	449	5,400	
Ford County driver	1	520	598		7,200
" " helpers	2	390	449	11,000	
Volvo TC 860 drivers	4	650	748		36,000
" crane operators	2	500	575		14,000
" helpers (loading	2	390	449	11,000	
Scania LBT 111 drivers	4	650	748		36,000
Landrover driver	1	530	610		7,300
Log volume clerk	1	430	495		5,900
Workshop manager	1	2,000	2,300		28,000
Mechanics - chief	2	800	920		22,000
" - assistant	2	480	552	13,000	
Road workers	8	390	449	43,000	
Cook	2	390	449	11,000	
Watchmen	3	390	449	16,000	
Sum[x]	93 (of which 17 are skilled personnel)			415,000	163,000
2. Sawmilling					
Log haul	9	390	449	48,000	
Saw operators	10[2]	430	495		59,000
Slab belt attendant	6	390	449	32,000	
Timber yeard foreman	1	670	771		9,300
Timber yard and green chain	30	400	460	166,000	
Trimming unit foreman	1	640	736		8,800
" " others	12	400	460	66,000	
Delivery (sorting, packing, etc.)	12	390	449	65,000	
Wheelloader operators	2	480	552		13,000
Agric. tractor drivers	2	450	518		12,000
Electrician	1	800	920		11,000
" assistants	3	400	460	17,000	
Workshop & central store mechanic	1	980	1,127		14,000
" " " assistant	3	460	529		19,000
" " " store clerk	1	540	621		7,500
Sawdoctor	1	1,200	1,380		17,000
" assistant	1	700	805		10,000
" helper	1	420	483	5,800	
Watchmen	6	390	449	32,000	
Sum[x]	103 (of which 24 are skilled personnel)			432,000	181,000

Type of job	Nos. of employees	Gross salary	Total	Un- and semiskilled personnel	Skilled personnel
3. Administration and sales					
General manager	1	3,700	4,255		51,000
Sawmill "	1	1,700	1,955		23,000
" " assistant	1	1,200	1,380		17,000
Logging manager	1	2,100	2,415		29,000
" " assistant	1	1,200	1,380		17,000
Personnel manager	1	1,600	1,840		22,000
Accountant-chief	1	1,900	2,185		26,000
" -assistant	1	1,200	1,380		17,000
" "	2	750	863		21,000
Sales-manager	1	1,700	1,955		23,000
" -clerk	1	550	633		7,600
Tally clerk	1	450	518	6,200	
Scania driver	1	650	748		9,000
Landrover driver	1	530	610		7,300
Camp overseer	1	600	690		8,300
Copy typist	2	510	587		14,000
Misc. personnel[3]	10	390	449	54,000	
Sum[x]	28 (of whom 16 are skilled personnel)			60,000	292,000
Total	224 (of whom 57 are skilled personnel)			907,000	636,000

[x] Rounded off.

[1] Including social benefit remunerations corresponding to 15 % of gross salary - see above.

[2] 2 saw operators are assumed to be "in reserve".

[3] Gatekeepers, sweepers, office messenger, etc.

TABLE A4.3: RECURRENT EXPENDITURES (EXCLUSIVE OF PERSONNEL COSTS) OF SAO HILL SAWMILL

Cost classification	Total annual cost (price level medio 1977) (shs/year)	Direct import of this (shs/year)
1. Logging		
Vehicles[1]		
Spare parts	398,000	200,000
Fuel, oil	243,000	
Tyres[2]	261,000	90,000
Insurance	91,000	
Handtools, boots, etc.	5,000	2,000
Road works	30,000[3]	
Stone crusher: Diesel	13,000	
Spare parts	7,000	
Other costs	20,000	
2. Sawmilling		
Spare parts - sawmilling machinery	110,000	110,000
" " - workshop	7,000	7,000
Consumables sawmill machinery[4]	12,000	12,000
" workshop	35,000	15,000
" central store	12,000	
" electricity installation	6,000	
Building maintenance	10,000	
Blue stain preservation	22,000	22,000
Package etc.	101,000	
Working clothes	33,000	
Diesel - powerplant[5]	231,000	
Insurance - sawmill	50,000	
Cost for vehicles not used by logging[6]		
Spare parts	213,000	
Fuel, oil	180,000	
Tyres	153,000	
Insurance	40,000	
Other costs	20,000	
3. Administration		
Office equipment and consumables	35,000	
Postage, telephone	22,000	
Sales promotion, training and education	42,000	
Bank charges	15,000	
Litterature, entertainment, etc.	20,000	
Mileage compensation	50,000	
Travel and meeting costs	130,000	
Audit fee	40,000	
Other costs	16,000	
4. Social infrastructure		
Repair and maintenance	50,000[7]	
Insurance	10,000[7]	

[1] 2 Volvo TC 860 forwarders with trailers
1 Ford County 1164
2 Scania LBT 111 with 2-axle trailer and hydraulic grapple loader
1 Scania LB 81 Tipper
1 Landrover
The costs for these vehicles are taken from Appendix 3. Because of overcapacity, the annual costs of spare parts, diesel and tyres for the two LBT 111 vehicles are reduced with 30 % compared with the estimates given in Appendix 3.

[2] Note that the tyre costs are included in the investment amounts in Table A4.1.

[3] Includes renting of grader.

[4] Mainly sawblades.

[5] Reduced 10 % for private electricity consumption at evenings.

[6] 2 Wheel-loaders Volvo LM 841
1 Scania LBT 111 with 2-axle trailer
2 Agric. tractors (Ford 6600) with trailer
1 Landrover

[7] This amount is based on information given by the Project's Building Officer.

APPENDIX 5: ESTIMATES OF OPTIMAL BRANCH ROAD SPACING

Road costs, and consequently road spacing, play an important role when analysing skidding methods.

The following gives estimates regarding optimal branch road spacing at Sao Hill for the various skidding alternatives discussed in Ch. 6 and Ch. 7.

The optimal road spacing model used represents a simplification of reality. The model is static as it assumes that the road costs and logging quantities are directly related in time - i.e. it is assumed that the road costs in one period do not influence the logging costs in later periods. Also, factors like erosion, skidding and road alignment possibilities, distance between landings etc. are not considered.

It should be noted that the optimal road spacing figures arrived at are meant to be guiding estimates only, and adjustments due to local terrain and soil conditions in practice will have to be made. However, the terrain at Sao Hill is rather flat and the soil quite homogenous. One should also remember that in most cases the area around the optimal road spacing points will be fairly flat, and smaller deviations from the optimal points do not significantly influence the total logging costs. Hence, the estimates of optimal road spacing arrived at should, on average, correspond quite well to the real situation at Sao Hill.

A 5.1 Basic assumptions and definitions

The logging conditions are as described in Ch. 5.1.3 and Ch. 5.2.2, with no serious obstacles for road alignment.

The branch roads are assumed to be layed at right angles to the access roads as shown in Figure A5.1. Dotted lines (----) indicate the logging area.

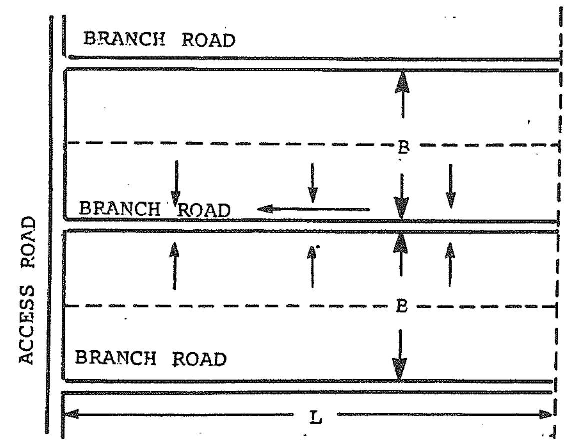

Figure A5.1. Forest road network model.

The following symbols are used (cf. Figure A5.1):

- B is the average distance (in km) between the branch roads
- L is the length (in km) of the branch roads
- C is the annual road construction and maintenance costs (in shs per km per year)
- M is the average volume extracted per year (in cu.m per sq.km per year)
- a_t is the terrain transport costs (in shs per cu.m) independent of B
- b_t is the terrain transport costs (in shs per cu.m per km) dependent of B

- a_r is the cost (in shs per cu.m) of the transport on the branch roads independent of L

- b_r is the cost (in shs per cu.m per km) of the transport on the branch roads dependent of L

- E is the total terrain- and road transport costs (in shs per cu.m)

From this one has:

$$E = a_t + b_t \cdot \frac{B}{4} + a_r + b_r \cdot \frac{L}{2} + \frac{C \cdot L}{M \cdot B \cdot L} \qquad (A5.1)$$

Derivating Eq. (A5.1) gives:

$$\frac{\partial E}{\partial B} = \frac{b_t}{4} - \frac{C}{MB^2} \qquad (A5.2)$$

Since E is defined for all B > 0, and $\frac{\partial^2 E}{\partial B^2} > 0$ for all B > 0, the size of B which minimizes E, B_{opt}, is determined by: $\frac{\partial E}{\partial B} = 0$, which gives from Eq. (A5.2):

$$B_{opt} = \sqrt{\frac{4C}{M \cdot b_t}} \qquad (A5.3)$$

Based on information from the Logging Manager at Sao Hill Sawmill I have assumed that a branch road is used only one cutting season, in the year of construction. After that the road is not used for forest management purposes until 6-8 years later. All log transport from the branch road's neighbouring areas is assumed to go on the access roads, which are the same for the three methods analysed. An eventual lower road construction cost after 6-8 years is not taken into account in the calculation - i.e. it is assumed that the construction cost of the new branch road will not be significantly lowered due to the construction work having been done 6-8 years before.

Also based on information given by the Logging Manager at Sao Hill Sawmill, the road construction costs including maintenance during the one year in use, are assumed to be on averge 1,500 shs/km for logging of 2nd thinnings and 10,000 shs/km for logging of clearfellings, the direct costs components being (in per cent of total costs):

	In thinnings	In clearfellings
Un- and semiskilled labour	35 %	25 %
Skilled labour	5 %	5 %
Direct import	0 %	0 %
Other costs	60 %	70 %

The extraction volume is assumed to be 60 and 435 cu.m o.b. per ha for respectively 2nd thinning and clearfelling (cf. Ch. 5.2.2).

A 5.2 Optimal branch road spacing in 2nd thinning of P. patula

This section estimates the optimal branch road spacing of the skidding methods described in Ch. 6.

A 5.2.1 Skidding with agricultural tractor

Based on ARVESEN (1970), HAARLAA (1973), OLE-MEILUDIE (1980) and OLE-MEILUDIE & DYKSTRA (1982) and adjusting for the conditions at Sao Hill I have assumed a terrain speed (average for skidding and return) of 3.8 km/h. Average load size is assumed to be 1.2 cu.m o.b. (i.e. about 12 logs per load - cf. Table 5.17). Running costs per machine hour is in Appendix 3 (Ch. A3.1) estimated to 68 shs. This implies:

$$b_t = \frac{2 \cdot 68}{1.6 \cdot 3.8} \text{ shs/cu.m \& km} = \underline{29.80 \text{ shs/cu.m \& km}}$$

Eq. (A5.3) then gives:

$$B_{opt} = \sqrt{\frac{4 \cdot 1,500}{6,000 \cdot 22.40}} \text{ km} = \underline{0.183 \text{ km}}$$

This corresponds to a road density of 55 m/ha, which is assumed in the analysis.

A 5.2.2 Ox-skidding

The following assumptions are here made (cf. Ch. 6.2.3):

- 3.3 km/h as terrain transport speed (average for skidding and return)
- 0.21 cu.m o.b. per load
- 15.20 shs per hour as terrain transport costs.

This implies:

$$b_t = \frac{2 \cdot 15.20}{0.21 \cdot 3.3} \text{ shs/cu.m \& km} = \underline{43.90 \text{ shs/cu.m \& km}}$$

Eq. (A5.3) then gives:

$$B_{opt} = \sqrt{\frac{4.1,500}{6,000 \cdot 43.90}} \text{ km} = \underline{0.151 \text{ km}}$$

This corresponds to a road density of 66 m/ha. In the analysis in Ch. 6 65 m/ha is assumed.

A 5.2.3 Sulky-skidding

Based on OLE-MEILUDIE & OMNES (1979) an average terrain speed of 1.4 km/hour is assumed.

Running costs per machine hour for the sulky is assumed to be 7.00 shs, based on the estimates given in Table 6.5, assuming 225 working days per year and 6 hours use of the sulky per working day.

Average load size is assumed to be 0.12 cu.m o.b. (OLE-MEILUDIE & OMNES 1979).

This implies:

$$b_t = \frac{2 \cdot 7.00}{0.12 \cdot 1.4} = \underline{83.30 \text{ shs/cu.m \& km}}$$

Eq. (A5.3) then gives:

$$B_{opt} = \sqrt{\frac{4 \cdot 1,500}{6,000 \cdot 83.30}} \text{ km} = \underline{0.110 \text{ km}}$$

This corresponds to a road density of 91 m/ha. In the analysis 90 m/ha is assumed.

A 5.3 Optimal road spacing in clearfellings

This section estimates the optimal branch road spacing of the skidding methods described in Ch. 7.

A 5.3.1 Using Rottne Blondin forwarder

This section deals with the method defined in Ch. 7.2.2.. Based on ARVESEN (1970) and HAARLAA (1970) and adjusting for the conditions at Sao Hill, I have assumed an average terrain transport speed (skidding and return) of 3.0 km/h. Average load size is assumed to be 8.5 cu.m o.b. Running costs per machine hour are assumed to be 200 shs (cf. Appendix 3 - Ch. A 3.4).

This implies:

$$b_t = \frac{2 \cdot 200}{8.5 \cdot 3.0} \text{ shs/cu.m \& km} = \underline{15.70 \text{ shs/cu. m \& km}}$$

Eq. (A5.3) then gives:

$$B_{opt} = \sqrt{\frac{4 \cdot 10.000}{43,500 \cdot 15.70}} \text{ km} = \underline{0,242 \text{ km}}$$

This corresponds to a road density of 41 m/ha. In the analysis 40 m/ha is assumed.

A 5.3.2 Using Ford 6600-2 agricultural tractor

This section deals with the method described in Ch. 7.2.3. Based on ARVESEN (1970), HAARLAA (1973), OLE-MEILUDIE (1980) and OLE-MEILUDIE & DYKSTRA (1982), I have assumed an average terrain transport speed of 4.0 km/h. Average load size is assumed to be 1.6 cu.m o.b. (OLE-MEILUDIE 1980). Running costs per machine hour are assumed to be 68 shs (cf. Appendix 3 - Ch. A 3.1).

This implies:

$$b_t = \frac{2 \cdot 68}{1.6 \cdot 4.0} \text{ shs/cu.m \& km} = \underline{21.25 \text{ shs/cu.m \& km}}$$

Eq. (A5.3) then gives:

$$B_{opt} = \sqrt{\frac{4 \cdot 10{,}000}{43{,}500 \cdot 21.25}} \text{ km} = \underline{0.208 \text{ km}}$$

This corresponds to a road density of 48 m/ha. In the analysis 50 m/ha is assumed.

A 5.3.3 Using oxen

This section deals with the method described in Ch. 7.2.4.

Based on the discussion and estimates given there, I have chosen as most probable estimates:

- 0.250 cu.m o.b. as average load size
- 3.3 km/h as average terrain transport and return speed
- 15.20 shs/h as cost of the method in the terrain transport

This implies:

$$b_t = \frac{2 \cdot 15.20}{0.250 \cdot 3.3} \text{ shs/cu.m \& km} = \underline{36.80 \text{ shs/cu.m \& km}}$$

Eq. (A5.3) then gives:

$$B_{opt} = \sqrt{\frac{4 \cdot 10{,}000}{43{,}500 \cdot 30.80}} \text{ km} = \underline{0.158 \text{ km}}$$

This corresponds to a road density of 63 m/ha. In the analysis 65 m/ha is assumed.

APPENDIX 6: YIELD TABLE FOR PINUS PATULA - SITE CLASS III

As argued in Ch. 5.2.2 it seems that the Sao Hill plantations of *Pinus patula* belong on average to site class III- i.e. having a dominant height at the age of 20 years in the interval 24-28 m.

Table A6.1 gives the yield of this site class III for *Pinus patula* as estimated by KLITGAARD & MIKKELSEN (1976:34).

Table A6.1. Yield of *Pinus patula* - site class III*

	Standing crop after thinning			Yield from thinnings		Total production	Increment	
Age (Years)	N_1	H_{dom}	V_{st}	N_2	V_{th}	V_t	MAI	CAI
6	1500	8.3	75			75	12.5	
7								30.5
8	1500	12.0				136	17.0	
9								32.0
10	1500	15.1				200	20.0	
11								33.5
12	900	18.0	237	600	30	267	22.3	
13								34.0
14	900	20.3				335	24.0	
15								35.0
16	900	22.6				405	25.3	
17								36.0
18	550	24.4	352	350	95	477	26.5	
19								33.5
20	550	26.1				544	27.2	
21								25.5
22	550	27.4				595	27.0	
23								18.5
24	400	28.3	437	150	70	632	26.4	
25								13.0
26	400	28.8				658	25.3	
27								10.5
28	400	29.5				679	24.2	
29								8.5
30	400	30.0	501			696	23.2	

* N = Number of stems.
H_{dom} = Dominant height (top height) in m.
V = Volume in cu.m. (total volume over bark).
MAI = Mean annual increment in cu. m.
CAI = Current annual increment in cu. m.

All figures are per hectare.

When used under normal conditions it is recommended op. cit. that all volume figures should be reduced by 10 to 25%, a reduction based on the number of stems prior to the first thinning, or the yield will be overestimated.

APPENDIX 7: LENGTHS, DIAMETERS AND VOLUMES OG LOGS AT SAO HILL

Table A7.1 gives length, diameter and volume distribution of logs delivered at Sao Hill Sawmill. The data is based on the project's measurement accounts for 1977, and are supposed to reflect fairly accurately the distribution of logs coming from the softwood plantations around Sao Hill, given the age of plantations and assuming same bucking policy as in 1977.

Table A7.1: DISTRIBUTION OF LENGTH; DIAMETER AND VOLUME OF LOGS AT SAO HILL.

Variable	Mid-point diameter	Nos. of logs											% of total[1,2]		Average log volume[2] (cu.m o.b.)
		Log length (m)										All logs	Nos of logs	Volume[2]	
		3.0	3.3	3.6	3.9	4.2	4.5	4.8	5.1	5.4	5.7				
1. Logs from clearcut in Msiwasi F.R.	45-50 cm	1		1			1	1	1			5	0.2	0.9	0.74
	40-45 "	1	8	2	1	6	8	8	7	3		47	2.1	6.2	0.58
	All logs	498	197	291	264	432	296	135	98	34	30	2,275	100	100	0.19
(P. patula planted 1951 measured April-June 1977)															
2. Logs from Msiwasi F.R.	45-50 cm			2		1						3	0.1	0.6	0.69
	40-45 "	1	3	1	2	8	7	4	7		3	36	1.8	6.6	0.64
	All logs	345	161	277	212	450	244	152	150	35	24	2,050	100	100	0.17
(Cup. lusit. planted 1951 measured Jan.-March 1977)															
3. Logs from thinnings Mninga F.R.	45-50 cm														
	40-45 "	1			1	1			2	1		6	1.5	5.0	0.62
	All logs	95	32	53	54	81	42	48	16	11	11	413	100	100	0.18
(P. patula thinnings, planted 1954, measured Dec. 1974)															
4. Logs from thinnings Irunda F.R.	45-50 cm														
	40-45 "						1					1	0	0.5	0.62
	All logs	361	176	267	130	131	47	26	18	5		1,161	100	100	0.10
(P. patula planted 1958 measured April-March 1977)															

1 Total volume is calculated by multiplying the log average volume with the total Nos. of logs.

2 Calculated as the volume of the log with average mid diameter and average length of the class.