LONG TERM REGIONAL PLANNING FOR FOREST INDUSTRIAL DEVELOPMENT IN AN AREA OF NORTH-EAST SCOTLAND

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CONTENTS

PREFACE

At the time this study commenced in October, 1967, ~~a lot of~~ discussion on forest industrial development and integration was taking place, between the forest growers and the timber merchants of the region studied. A steering committee had already been constituted to investigate the idea of a forest industries consortium. The interests this committee represented, included: most of the private forest estates, especially the larger ones; the Forestry Commission; the timber merchants and the Scottish Council for Development and Industry.

By January, 1968, my supervisor, Dr. W.E.S. Mutch had introduced me to the Steering Committee, and gave me several valuable contacts with forestry people in the area. Later the P.E. Consulting Group Ltd., was commissioned to undertake a Consortium Feasibility Study. Owing to my early association with the region; much of the basic information on the forest resources was available to me through the Steering Committee and P.E. Consultants.

The principal aim of this study has been the presentation of a thesis. In addition, the intention from the start was to make a practical contribution to the utilization of the region's resources. Looking back, this intention seems to have been rather too ambitious. It is hoped the study~~, however,~~ makes at least a small contribution to the region; brings a greater awareness of the problems involved and perhaps draws out some planning methods and ideas with application there.

I formally certify the work and composition of this thesis to be my own.

ACKNOWLEDGEMENTS

Particular thanks ~~is~~ are due to my supervisor, Dr. W.E.S. Mutch who read the manuscripts and contributed many helpful suggestions and criticisms. Thanks are also due to Dr. C.J. Taylor for his comments on Chapter V and Appendix A; to Mr. A.D. Ross and Mr. A.D. Alistair of P.E. Consultants, and to Mr. G.M.L. Locke for data on the region's growing stock.

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1 Hoppus ft ≙ 0·036' m³

SUMMARY

In Great Britain the availability of raw wood resources is the most important limiting factor in the development of forest processing industries. Consequently, it is of great importance for management to seek suitable strategies in order to determine the optimal use of wood resources, particularly at national and regional levels.

The forest resources of a region in North-East Scotland (including the counties of Moray, Nairn, Banff and the eastern part of Inverness-shire) are examined. For the period 1970 to 2030 a prediction of the available roundwood volumes indicates substantial increases: just over 4 Million Hoppus feet in 1970 to 12 Million Hoppus feet per annum by the year 2000, and 22 Million Hoppus feet per annum around 2030 A.D. The integration and comprehensive planning of the processes of growing and manufacture offer mutual benefits to forestry and to industry. Before integration can be achieved, however, economic models of technically feasible forest industries must be constructed. The wood-using industries here considered technically feasible are: sawmilling; Blockboard; Disc Refiner Mechanical Pulp; Particle Board; and Fibreboard processes.

Economic information relevant to Britain is scarce for forest processing industries and their products. Hence particular attention is paid in the thesis to the development of hypothetical models; two forest processing systems are used as examples. These are: Wet-Process Hardboard Mills and Linck Canter Chipper Sawmill installations.

The economic feasibility of these models is discussed. The minimum economic size of the hardboard models (125 metric tons per day, or 35,000 metric tons per annum of board product) requires approximately 2·9 Million Hoppus feet per annum of wood materials. A Linck Canter Chipper sawmill appears to be economic on an annual input of 1·5 Million Hoppus feet of roundwood assortments between $4\frac{1}{2}$ and 12 ins. diameter overbark.

Economic feasibility, however, should consider the Global Maximum Disposable Wood Price (MDWP), which is the average unit value of a defined wood supply (usually the total available wood supply) to one or more wood-using industries, the value being measured at the mill gate. (No attempt is made to undertake locational analyses of the wood-processing industries). The optimal combination of forest processing industries produces the highest Global MDWP. As an example, different allocations of the region's wood resources are considered for the period 1970-1990, and the timing of the investment in forest processing mills. The problems of the size of the mills are discussed, and the problems involved when other forest processing systems are included.

CHAPTER I

GENERAL APPROACH AND IDENTIFICATION OF THE PROBLEM

General Approach

A gap exists in Britain between the conceptual level of preliminary planning for forest industrial development and its implementation. The intention in this thesis is to use an actual situation in order to develop the following general ideas which are adapted from Davidson (1967):

(1) The interests of forest management, and of the industries which use wood as a raw material, are fundamentally the same. The planning of industrial development should therefore be on the same long time-scale as that used in forestry so that the processes of growing and manufacture may be integrated for mutual benefit.

(2) A high proportion of the forest in Britain is in young age classes and afforestation is continuing. As a result there will be rapid changes in output, both in quantity and quality, for more than the next half century, and it is necessary to plan for the time when a steady level of production will be attainable.

(3) Surveys of the forest potential which are based on too small an area or on too brief a time period are irrational and may result in wood-using factories in the wrong places or of the wrong type.

(4) The forecasts of forest production should show the qualities of the wood, especially the species and size

classes, both of which closely affect the choice of the industrial processes which may use the forest output. The forecast of the volumes is especially important around the minimum size for sawmilling, for there may be an overlap of the specifications for the sawmill and for other factories, which may be critical for the utilisation plan and for the financial results.

(5) The main aim of the forest industrial policy will be to establish industries which are commerically viable, and able to pay prices for their raw material which yield the best economic return to the forest in terms of stumpage. This calls for an appraisal of the demands for wood and wood-based products, and of the trend of demand in the light of technical, economic and political decisions. The demand and available supplies must then be matched.

(6) In making a preliminary survey the planner should consider the possible effects of changing demand and technological feasibility for a wide range of wood-using industries, as well as the possibility of two or more industries co-existing at one centre, and of vertical integration of the manufacturing processes.

(7) The selection of the wood-using industries most suitable for integration with the forests will depend on many factors:

(a) the volume and quality of the potential forest output within economic range;

(b) the minimum wood requirement of each industrial process;

(c) the demand for the manufactured products;

(d) the availability of power, water, efficient waste-disposal facilities and the other services;

(e) the possibility of integrating two or more processes vertically or horizontally to their mutual economic benefit, and to increase the stumpage value of the wood.

(8) In Great Britain the log supply is widely dispersed and very variable. As a result, the sawmill industry comprises many small dispersed units. Consideration is now being given to the pattern of distribution and type of sawmilling that may better match the future production of greatly increased quantities of logs of more uniform size and quality.

(9) The introduction of new wood-processing factories must be timed with the availability of wood. Flexibility in timing is assisted when forest management allows short-term departures from the estimated allowable cut, provided that these do not cause longer-term injury to its main objectives. The planning of new industrial use is especially difficult where the forest output is changing rapidly in quality or quantity. Size is critical to the economic viability of any processing plant, to an extent depending on the complexity of the process and the level of capital investment required in relation to the throughput.

(10) Where there is insufficient wood to meet the minimum requirements for a new industry from normal forest

production, the shortfall may be met by premature additional felling, by supplying higher value material to lower-value usage, or by meeting the cost of bringing supplies from further afield. Linear programming is a useful aid in this complex problem both for the selection of the option with the most favourable economic prospects, and in revealing the relative sensitivity of the factors to changes in the system.

Identification of the Problem

Before growers commit their wood resources to use by wood-processing industries, it is in their interests to discover what options exist. Such knowledge is needed for rational decisions as soon as it can be acquired, and, if planning is to be effective, the information will require continual reappraisal as major changes occur. Forest management and future planting policies should be influenced by carefully assessed expectations of demand and supply; hence a more advanced form of forestry planning is required than is now usual in Britain. Managements by guesswork, intuition and piecemeal development are no longer adequate or consistent with the national forestry investment. To achieve this improvement, however, necessitates the development of a complete model which can take account of the influences and requirements already mentioned (pp. 1-4). The problem to be considered arises directly from this: in a region with a heterogeneous wood resource (by age, species, quality and ownership), what information is needed to develop a complete model, and how may it be built in practice?

CHAPTER II

DESCRIPTION OF THE AREA

Boundaries of the Region Studied

The region studied is in north-east Scotland. The boundaries outlined in Figure 2.1 include the counties of Nairn, Moray, Banff and the eastern part of Inverness-shire.[1] The region is artificial to some extent as its boundaries are those of counties and parishes. The greater part of it, however, does form a natural forest region. It includes the forests of the Spey Valley and the Moray Firth plain. Its physical boundaries are the Moray Firth in the north, and the Monadhliath and Cairngorm mountain ranges in the west and south-east. Defined in this way several forest areas are conspicuously excluded, which, in the event of certain forest industrial developments, would probably be included.[2] The boundaries given in Figure 2.1, however, are retained in this study as forestry statistics are readily available for this region.[3]

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1. i.e. The parishes of: Abernethy, Kincardine, Duthil, Rothiemurchus, Kingussie, Insh, Moy, Dalrossie, Daviot, Dunlichty, Dores, Croy, Dalcross, Petty and Ardersier.

2. i.e. in the Invergordon, Strath Valley and Black Isle areas to the north-west and the Bin and Clashindarroch forest areas to the north-east.

3. This region is the area originally defined for the Consortium Feasibility Study (P.E. Consultants, 1969).

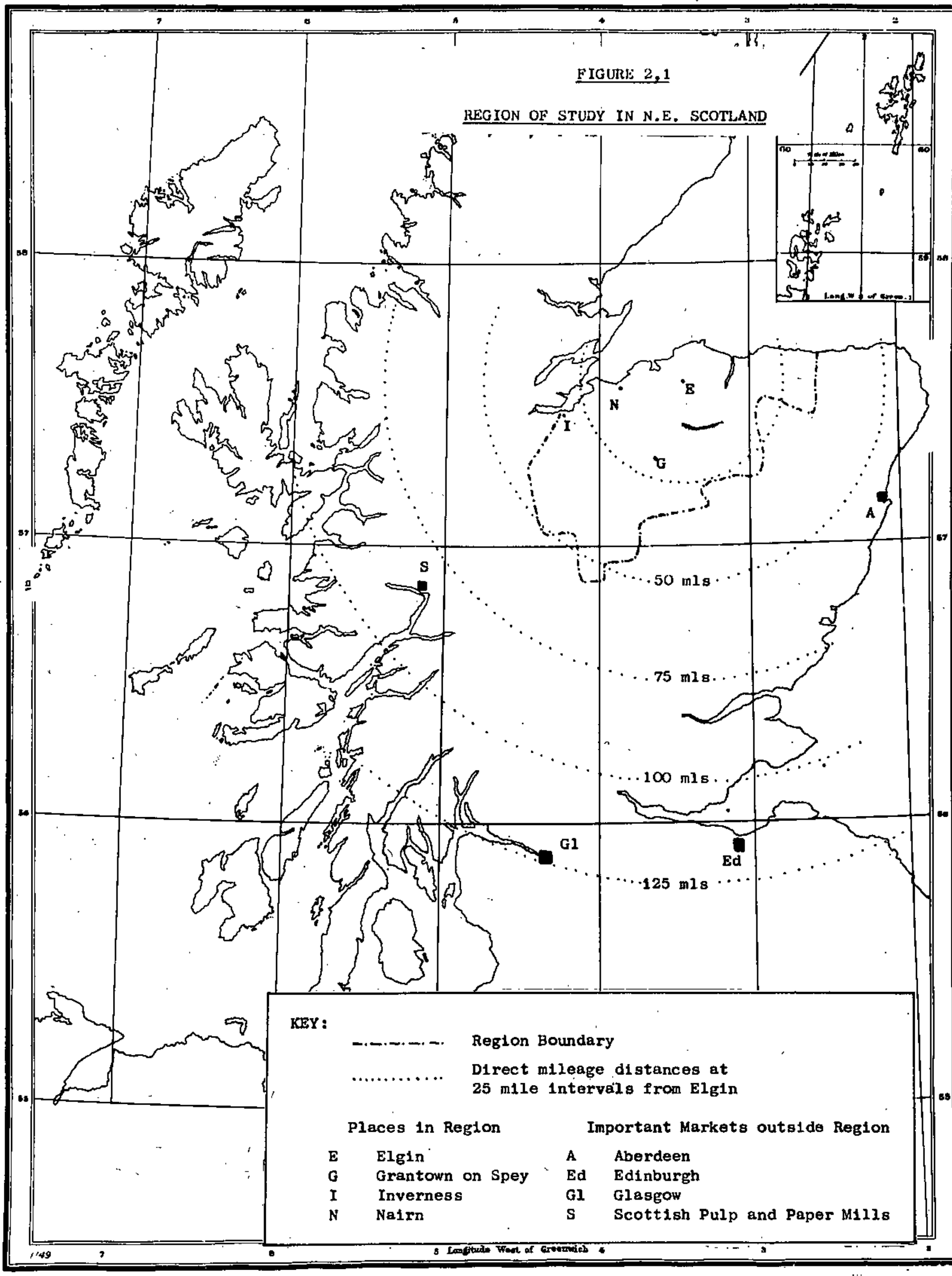
FIGURE 2.1
REGION OF STUDY IN N.E. SCOTLAND
E
N
I
G
A
S
50 mls
75 mls
100 mls
125 mls
Gl
Ed
KEY:
Region Boundary
Direct mileage distances at 25 mile intervals from Elgin
Places in Region
E Elgin
G Grantown on Spey
I Inverness
N Nairn
Important Markets outside Region
A Aberdeen
Ed Edinburgh
Gl Glasgow
S Scottish Pulp and Paper Mills
Longitude West of Greenwich

Forest Ownership within the Region

There are approximately 56 commercially managed private woodland estates of more than 100 acres in extent in the region. The area of 155,000 acres (Table 5.2) of productive coniferous high forest comprises: 71,000 acres of private woodlands[1] belonging to 42 private estates, and 84,000 acres of Forestry Commission woodlands in 15 separate forests (P.E. Consultants, 1969). This is the forest estate considered in the study; it represents 12 per cent of the total land area in the region.

Present Utilisation of Wood Resources

In 1968, 11 sawmillers operated 15 permanent and 22 small portable sawmills which processed altogether 4·3 million H.ft. of roundwood. From this raw material they produced 2·8 million cu. ft. of sawntimber and 0·5 million H. ft. of pit props, wood-wool and fencing material. A further 0·5 million H.ft. of poles, pulpwood and some firewood were dispatched direct from the forests. This represented the total saleable output from the region[2] (P.E. Consultants, 1969).

Sawmilling is the traditional wood processing industry; its equipment is of mixed ages, predominantly 10 to 20 years old; and except for the portable mills, all primary breakdown of logs is carried out by single-headed band saws.

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1. Believed to represent over 90 per cent of the private woodland estate managed on a commercial basis (P.E. Consultants, 1969).

2. The volume actually harvested within the region is estimated to have been 3·7 million H. ft. i.e. 1·0 million H. ft. was in the form of imports from other areas.

In its present form it is highly labour intensive owing to the kind of processing equipment employed; the production tends to be custom orientated; there is wide variation in the size and quality of logs.

CHAPTER III

EVALUATION OF THE PLANNING LEVEL REQUIRED, CRITERIA SELECTED AND THE LIMITS OF THE INVESTIGATION

Evaluation of the Planning Level Required

~~An initial~~ A review of the region's growing stock (Table 5.1, p. 24) ~~is sufficient to~~ suggests that appreciable changes are going to occur in the size and quality of roundwood assortments. By area 62 per cent of the growing stock is under 20 years old (i.e. planted since 1950); consequently a large volume of small roundwood thinnings should become available with the next 10 to 20 years, and later there should be a large increase in final crop felling volumes. The supply forecasts show the scale of these changes within the region; the basis of the actual period taken is the optimal rotation length for Scots pine, the predominant species. This rotation is 70 years ~~(Appendix A, p. A 6)~~ (Table 5.2, p. 28); hence the production forecasts (Table 5.3, p.31) are projected to the year 2030 (i.e. when the P.60 plantations will be 70 years old).

Clearly, comprehensive planning for forest industrial development should consider all possible processing systems and industries; some, however, will be unsuitable on technical grounds (log quality) and need not be considered further. Economic criteria, when applied to the industries that are technically feasible should determine their economic feasibility and the optimal combination attainable.

Since technologies, markets and the economic life of individual processing plants all change relatively rapidly compared to forect production it is difficult to state the actual period over which feasibility studies (economical and technical) of forest industries can be made realistically. To avoid this problem the opposite approach can be taken: determine when an industry first becomes an attractive proposition in terms of its roundwood requirements and evaluate the risks and uncertainties of waiting compared to the other options[1] available. Consideration of only the primary processing industries reduces the uncertainties of market changes.[2]

Nevertheless, technological changes will make revisions of an industrial plan essential. Such plans help an industry to avoid changing its raw material base, a problem which has affected the Scandinavian fibreboard industry.[3]

The Criteria Selected

With the exception of the Pre 1900 growing stock, the production forecasts (Table 5.3, p. 31) are based on the optimum rotation length of each species group according to

1. The possibilities of increasing supplies (crop treatment, larger planting programmes, different felling policies) so that the industry is started earlier or the setting up of other processing industries requiring small quantities of that particular wood assortment.

2. Market changes are more important for consumer goods. This does not imply that the consumer is necessarily more fickle, but a customer making producer goods has to consider his own investments and developed technology (Eklund, 1967).

3. Much of the fibreboard industry there was established in the 1940s to utilise sawmill residues. The expansion of the chemical pulp industry has curtailed the quantities of raw materials available to the fibreboard industry. Through increased competition and economies of scale, it has had to enlarge its own capacity (F.A.O. 1966). Hence its supply of raw wood materials presents an acute problem.

the criterion of maximum net discounted revenue (Appendix A, p. A6).

The criterion for comparing the economic feasibility of the forest industries which are technically feasible is the maximum disposable wood price[1] (MDWP) of the quality assortments produced. It is calculated by deducting all production costs (excluding wood cost) from the ex-mill product price.[2] The invested capital costs are included and can be based on any assumed rate of return. Hence this criterion permits the cost of each investment (p. B7) to be considered separately on merit; for instance a high risk venture requires a higher rate of return than a normal investment.[3]

The MDWP for a single forest processing industry is represented diagramatically in Figure 3.1. Where the ex-mill product price is constant (Figure 3.1(a)) demand is perfectly elastic. As the scale of processing (plant capacity) is increased, the succeeding economies of scale diminish until they become zero (i.e. where the curve becomes flat). In practice, the product price (ex-mill) will tend to be a decreasing function of the scale of processing (Figure 3.1(b)) as markets at increasing distances from the mill have to be sought. This possibility is noted

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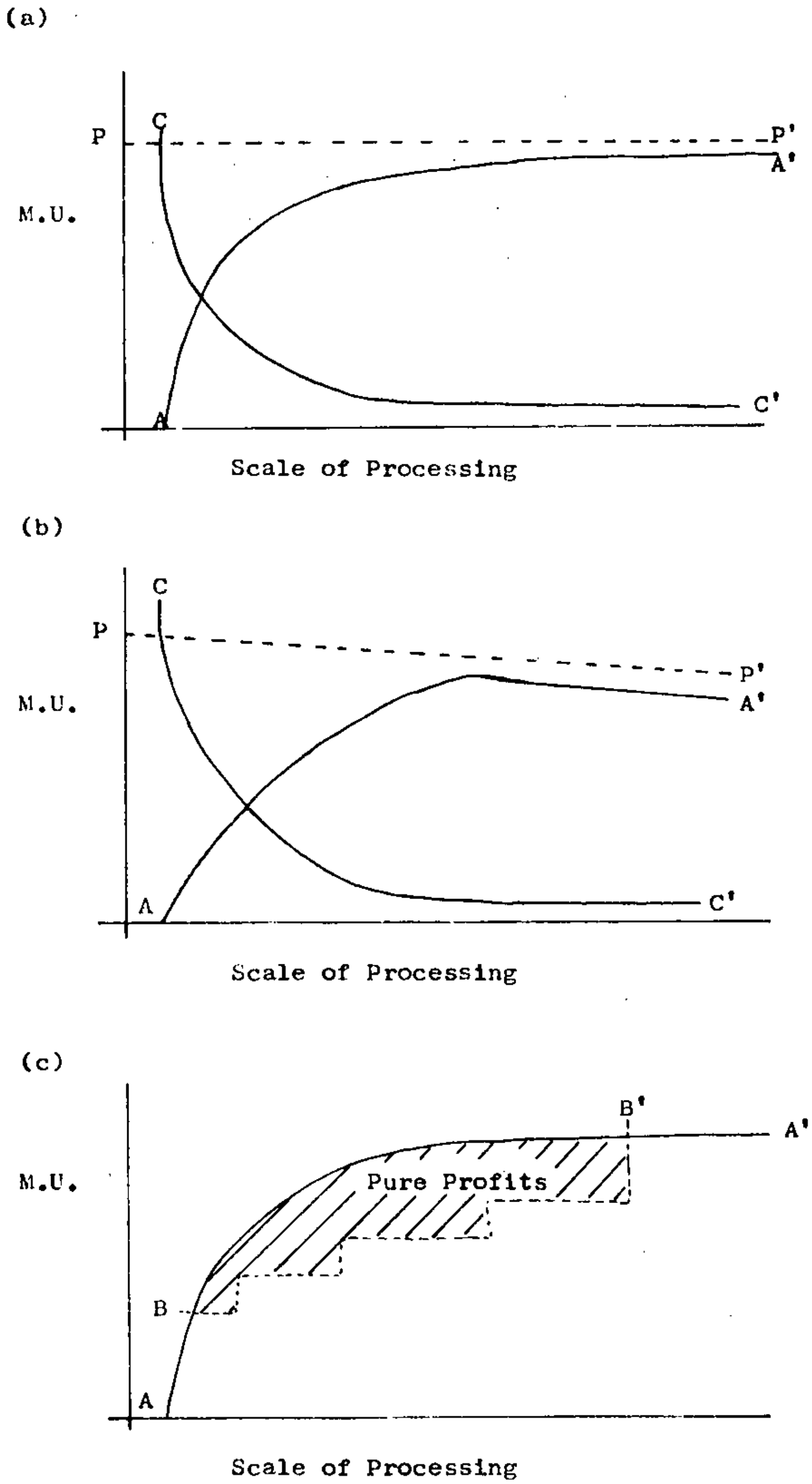
1. Other criteria, such as the maximum profitability of invested capital, or in the national interest, the maximum foreign exchange earnings, may also give useful guidance (Eklund, 1967).

2. Alternatively the product price less sales costs.

3. New industries with uncertain markets, or rapidly developing technologies would be high risk ventures. 10 years ago the particle board industry was such an industry (F.A.O. 1958).

FIGURE 3.1

RELATIONSHIP OF MDWP TO EX-MILL PRODUCT PRICE AND PRODUCTION COSTS



NOTE : AA' --- Maximum Disposable Wood Price
BB' --- Actual Delivered Wood Price
CC' --- Unit Production Costs
PP' --- Unit Ex-mill Product Prices
M.U. -- Monetary Units

but not developed further in this thesis. The MDWP curve (Figure 3.1(c)) represents the maximum delivered price a processing plant of a given size could pay and still break-even[1] by manufacturing the product. If the actual delivered price is less (the stepped curve BB'), then pure profits can be accrued(the shaded area of Figure 2.1(c)). The actual shape of curve BB' is immaterial to the analysis. The MDWP of a particular processing plant may be used at a later stage of planning in order to determine the limiting distance at which the mill may procure timber. The actual delivered wood price will depend also on the wood assortment and contractual agreements between grower and processor. These influences need not be evaluated during a preliminary study as MDWP's are independent of the actual delivered price of wood.

The stumpage value, the price charged by the grower for standing timber, may be regarded as the residual value of MDWP after subtraction of the transport and harvesting costs, including a normal rate of profit on these operations. Consequently, once a model of the optimal combination of industries is determined, an interaction between the MDWP's and stumpage value should be expected. The importance of this to the model would be that it could affect the roundwood supply pattern by changing the optimal rotation lengths of species (Chapter V, p.27).

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1. i.e. paying all production costs including a return to capital at the rate planned.

Limits of the Investigation

Owing to the scarcity of relevant economic material on forest processing industries and their products (Chapter IV, pp.15-16) and to personal time limitations, the study of this thesis is limited to the following:

(a) A 60 year prediction on the region's wood resources.

(b) The technical feasibility of various forest processing industries.

(c) The construction of hypothetical hardboard mill models and Linck Canter Chipper Sawmill models.

(d) The allocation of wood resources between hardboard mills and Linck Canter Chipper Sawmills, and to a discussion of possible combinations involving other processing systems and industries.

CHAPTER IV

METHODOLOGY

Previous Work in This Field

The approach to forest industrial planning suggested by Davidson (1967) and Richards (1967)[1] is being undertaken on a national scale in Finland. It has shown that appreciable differences exist[2] between the optimal and actual allocation of forest resources in the Finnish forest economy (Eklund, 1967). There is, however, no published evidence to show that this type of complete study is being carried out on any practical scale in Britain and the economic information required to undertake such work is extremely difficult to obtain.

The methods and mechanics of long term production forecasts are well covered by Johnston et al. (1967) for British conditions, although the available data on the existing crop in the study region of North-east Scotland is incomplete (Chapter V and Appendix A). The published[3] economic information on forest processing industries and their products is limited to a few partial analyses:

(1) Sawmilling. Grayson (1961); Endersby (1964); Curry (1965); Curry and Endersby (1965); and Rogers (1967).

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1. Richards like Davidson emphasises the importance of studying the technical and economic problem of the pattern of wood supply and the location of wood processing industry as a whole.

2. "an optimum program would yield about US $200 million higher annual profit (disposable wood price)...", at present product prices and costs for new mills.

3. The F.C. has a recent (1968?) report by Eklund on the feasibility of various forest processing industries in Britain, but its circulation is restricted (Richards, 1969).

(2) Fibreboard and Particle Board. Sandwell (1958); Tustin (1968).

(3) Pulp and Paper Mills. Sandwell (1957).

(4) Timber Prices. Forestry Commission (1956); MacGregor (1959).

Outside Britain more detailed studies have been published on the approach to an analysis of the cost structure of forest processing industries (Ryti, 1966;[1] Coolidge and Pfeiffer, 1956; F.A.O. 1958 and F.A.O. 1965). Beyond the analysis of individual cost structures and the building of hypothetical models, several authors have shown methods of comparing the relative economic feasibility of forest processing industries operating on a fixed wood resource. Amongst these authors are Rankin (1963); Pearse and Sydneysmith (1966); and Eklund,(1967).

Rankin investigates the average cost-price relationships of five Western Canadian forest industries,[2] and he determines the maximum average price which each conversion system could afford to pay for its logs at a financial break-even point. He concludes that the most satisfactory method of determining the relative profitability of these industries is based on net return to capital employed (after payment of taxes) when the logging profits are allocated to each processing system. Two objections to this procedure may be raised: (1) the introduction of logging profits is an

1. The longer English translation is apparently unavailable in Britain.

2. i.e. Logging, Lumber, Plywood, Pulp and Newsprint.

unnecessary additional complication, and (2) in the context used, the most profitable allocation of raw materials depends on the highest return obtainable on invested capital; it is unsatisfactory because it favours high risk ventures and does not seek to optimise the forest economy. Rankin (1963) comes near to adopting the criterion of maximum disposable wood price (MDWP) with his concept of "maximum average price"[1] for roundwood. Had he included a cost of capital[2] for each processing system, his analysis on development would yield a means of optimal wood allocation. Pearse and Sydneysmith (1966) are concerned with "providing a systematic framework within which the optimum (most efficient) allocation of logs can be identified." These two authors, together with Eklund (1967) are concerned with the same concept: maximising the net return to a fixed wood resource. This criterion for applying this concept is called by Eklund, the maximum disposable wood price.

<u>Methods Used in This Investigation</u>

(1) The Supply Predictions

The whole productive coniferous high forest[3] of the

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1. Calculated by deducting all manufacturing costs except wood materials <u>and the cost of capital</u> from the average product price.

2. The cost of capital is discussed in Appendix B, p.B8 where it is defined as "the net burden of paying for it"; it includes a premium which must be paid on high risk ventures.

3. i.e. The Forestry Commission plus the private woodland estate. Some doubt exists on the total area of Pre 1900 growing stock actually available in the region: during the Consortium Feasibility Study (1968/69) conflicting estimates arose between the calculations of the F.C. (based on the 1965 sample survey) and the voluntary returns by growers participating in the study (Locke, 1968; P.E. Consultants, 1969).

region is considered in the forecasts, which predict the available quantity and quality (species and size assortments) over the next 60 years (Chapter V). The forecast procedure is based on an application of the Forest Management Tables (F.C. 1966) to this growing stock using the optimal rotation lengths of the principal species as determined by the criterion of maximum net discounted revenue.

(2) Forest Industries

(a) Technical Feasibility. The recent literature is used to determine which industries are suitable on the available quality of wood resources.

(b) Economic models of two forest processing systems are developed from accessible information. The first, Wet-Process Hardboard mills (Appendix B) is based on two papers: "Board Mill Survey (United Kingdom)" by Sandwell (1958), and "The Influence of Mill Capacity upon Investment and Manufacturing Costs (Insulation Board and Hardboard)" by Asplund (1963).[1] An approximate method of combining the relevant information in these two papers is developed; subsequently, a series of mill models and their corresponding MDWPs are derived. Linck Canter Chipper Mill Installations (Appendix C) are the second set of economic mill models. These are based principally on information supplied by Gebrüder Linck (Kunz, 1969). This appendix develops a log conversion pattern, a cost structure for this type of

1. First published as a background paper for the International Consultation on Insulation Board, Hardboard, and Particle Board, Geneva, 1957. The figures are updated to June, 1963, in a subsequent re-issue by Difibrator A.B. in 1967(?). Throughout this thesis it is referred to as "Asplund (1963)".

sawmill processing, and a MDWP for the final model.

In the construction of these models the significant factors and methods are discussed in Appendices B and C. Finally the sensitivity of the models to changes of various kinds is examined.

(c) Economic Feasibility. A limited and simplified analysis based on the models developed is undertaken in Chapter VII and the main problems involved in a determination of the optimal allocation of wood resources in the region studied.

Assumptions

The principal assumptions made in this thesis are as follows:-

(1) The Forest Crop.

(a) A time horizon of 60 years for the roundwood production forecasts.

(b) The Forestry Commission and private woodlands are considered as one estate for the production forecasts.

(c) The afforestation rate after 1980 is 1,500 acres per annum for the region as a whole.

(d) The crop characteristics of the combined estate are based on the 1965 Census of Private Woodlands data from the region.

(e) Crop rotations follow the optimum lengths as determined by the criterion of maximum net discounted revenue when based on the general

Forestry Commission price-size relationship of roundwood and on discount rates for revenues and costs of $3\frac{1}{2}$ and 5 per cent respectively.

(f) Thinning and Felling volumes are based on the Forest Management Tables' production forecast yields.

(g) The Pre 1900 growing stock is felled over the next 20 years.

(2) Forest Industries

(a) Only primary processing industries are considered.

(b) Technologies and economic data are based on recent information published and general industrial cost indices.

(c) The technologies of the Sandwell and Asplund hard-board mills are similar at a capacity corresponding to 77·4 metric tons per day.

(d) The hypothetical mill models are eligible for investment grants and allowances, are able to claim all tax allowances, and their cost of capital is 10 per cent.

(e) The ex-mill product price of standard hardboard is £40 per metric ton; of undried sawntimber when produced from logs (i) under 6 inches (OB) diameter is 7·5 shillings and (ii) between 6-12 inches (OB) diameter is 10·0 shillings, per cu. ft. The demand for each of these products is perfectly elastic.

(f) The average sawntimber yield is 36 per cent of the log volume (OB), owing to the quality of the roundwood thinnings.

CHAPTER V

SUPPLY OF RAW WOOD MATERIALS

Introduction

The time horizon over which the future roundwood supplies are considered should be sufficiently long to allow any major changes expected within the rotations of the existing growing stock to become apparent in quantitative terms. This period will depend upon the age class distribution and the accepted rotation lengths for the species composing the existing growing stock.

The supply of raw wood materials should be regarded in the widest context possible, since the technology of the wood-using industries is not static, but may well continue to change and develop at a rate similar to that experienced over the past two decades. Full tree utilization may become commercially feasible in the next 20 to 30 years and some consideration should be given to future production levels in bark, branchwood, and stumps. Estimates of branchwood and stump volume yields are not available yet and cannot be included in the production forecasts. Sawdust and chips (or other wood industrial residues) depend on the processing systems built into the preliminary planning model. These are endogenous inputs and can be taken into account during the construction of the forest processing models.[1]

1. Later (Chapter VII, p. 50) an example is shown, where the residues from a Linck Canter Chipper Sawmill are made available to a hardboard mill.

The Coniferous High Forest Area: its species and age-class distribution

The productive forest of the region is taken to comprise all coniferous woodland belonging to the Forestry Commission and 90 per cent of the coniferous woodland belonging to private owners (P.E. Consultants, 1969); see Table 5.I.

Hardwoods have not been considered since their total area forms a small percentage (approximately 3 per cent) of the total high forest area and most of the broadleaved woodlands are grown primarily for amenity and shelter purposes rather than the production of roundwood. The coniferous high forest area that has been excluded is composed of amenity areas, other areas not primarily intended, or unsuitable for production purposes and to estates which did not participate in P.E. Consultants 1968 survey. The Forestry Commission Private Woodland Census 1965[1] indicated that approximately 30 per cent (5,000 acres) of the Pre 1900 growing stock has been excluded. This implies that some 30 million H.ft. (OB) of standing mature timber is intended to remain uncut. The total area under pines is almost exclusively Scots pine (Pinus sylvestris), the area under larches is approximately 85 per cent European Larch (Larix decidua) and under spruces 65 per cent Sitka spruce (Picea sitchensis) and 35 per cent Norway

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1. Private communication with G.M.L. Locke.

Table 5.1. THE PRODUCTIVE CONIFEROUS HIGH FOREST BY SPECIES AND P. YEAR CLASS, 1968.

	P. Year Class						Acres	
Species Group	Pre 1900	01 - 20	21 - 30	31 - 40	41 - 50	51 - 60	Post 1960	Total
Pines	8907	4076	13040	9544	11724	39164	29554	116,009
Larches	126	315	899	661	1481	4120	1742	9,345
Spruces	11	83	1618	1151	3734	9083	8920	24,600
Other Conifers	181	184	651	241	524	1400	1923	5,104
TOTAL	9225	4658	16206	11597	17463	53767	42139	155,055

Source: P.E. Consultants (1969).

spruce (Picea abies). The short term forecasts (1970 to 1985) by the private growers (P.E. Consultants 1969) indicated that over 25 per cent of the planting will be with spruces and 60 per cent with pines in future decades. The existing composition varies in the different age classes but has an overall average of 75 per cent pines, 6 per cent larches, 16 per cent spruces and 3 per cent other conifers.

The Pre 1900 growing stock consists of mature to over-mature woodlands which on account of past management are variable in form and quality. Some areas are uneven-aged, naturally regenerated stands on old cut-over sites. These areas have had little or no silvicultural tending and many are extremely poor in stocking, form and quality. Other stands in this age class are in very good condition, and altogether there is great variation in the size distribution. Owing to the size distribution and age structure, the growing stock has a very low annual increment (approximately 2 per cent). Post 1900 growing stock is composed of even-aged plantations with fairly uniform stand characteristics. On account of these differences, the region's growing stock is kept separate in the production forecasts.

Standing volume, stocking, stem straightness and yield class

Information for Table 5.1 on the standing volume, stocking, stem straightness and yield class distribution was obtained from the 1965 Census of Private Woodlands. This generalization is necessary due to the absence of other, more relevant management data, and hence the results must be held with reservations as to their accuracy. A summary of these data and their use in the calculated results is given in Appendix A.

The estimated Pre 1900 total growing stock volume is 36·7 million H. ft. (OB). Owing to the proportion of defective trees in this age class a 15 per cent reduction was made in this volume (p. A5) to give a utilizable volume of 31·2 M. H.ft. (OB). The Post 1900 felling volumes are obtained from the Forest Management Tables (Forestry Commission, 1966), and the 1965 Census data on stocking were used to ascertain that these tables may be applied. Quite a high proportion (50% and over, Table A.5, p.A 17) of the private woodland owners' crops are overstocked according to the stocking assessment, and will therefore tend to have higher standing volumes than normal. But the thinning cycles for the private growers tend to be longer than those practised by the Forestry Commission and the relative absence of grossly overstocked or understocked crops is the most important point brought out by these data. The assumed yield classes (Table A.8(a), row 6, p.A 20), together with the species used to represent each species group are given in Table 5.2 below. It is considered that these are underestimates of the true yield classes.[1]

1. cf. The weighted y.c's in Table A.8(a), row 6, with the weighted y.c. distribution (by age class) in rows 1 to 5.

Future Roundwood Supplies

1. The General Principles applied in the Production Forecasts

A basic model has been built on the growing stock of Table 5.1, the 1965 Census of Private Woodlands' data, the current and future planting programs of the Forestry Commission and the private owners and the application of the Forest Management Tables (F.C., 1966). The main points on which the forecasts are based are given in summary below and in detail in Appendix A.

(a) The determination of the rotation lengths. It is assumed all growers wish to maximise the net discounted revenue on their woodlands; that they are prepared to use a discount rate of 3·5 and 5 per cent on revenues and costs respectively and that the general price-size relationship for thinnings and fellings in use within the Forestry Commission is applicable to the region's roundwood produce. The felling ages so determined were applied to all the Post 1900 crops, whilst the Pre 1900 growing stock was given an arbitrary 20 year felling period from 1970.

(b) Future Planting rates and species proportions. The future planting rates are based on the current planting programmes, the private growers forecasts up to 1980, the assumption that all felled crops will be replaced and an upward adjustment arbitrarily assumed to round off the total figures. The planting rate obtained for the period between 1961 and 2010 is given in Table 5.2. It is necessary to make assumptions up to the year 2010 since the production forecasts extend to the year 2030 and first thinnings

Table 5.2. ASSUMPTIONS IN THE PRODUCTION FORECAST MODEL

Species Group	Weighted Yield Class	Assumed Yield Class	Representative species	Rotation of max NDR	Age of first thinning	Assumed Future Planting Rates				
						1961-70	71 - 80	81 -90	91-2000	2001-2010
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Pines	100	100	Scots pine	70	27	39130	12000	9000	9000	9000
Larches	92	80	E.L.	50	24	2236	1000	750	750	750
Spruces	134	120	S.S.	60	25	11739	5000	3750	3750	3750
Other Conifers	127	120	S.S.	60	25	2795	2000	1500	1500	1500
TOTAL						55,900	20,000	15,000	15,000	15,000

yields can be expected from crops around 25 years old.

The proportions by which species are assumed to be planted during the period are derived from the current planting proportions for the present decade, i.e. Pines 70 per cent, Spruces 21 per cent, Larches 4 per cent and Other conifers 5 per cent, and on the private growers' planting forecasts (P.E. Consultants, 1969) for future decades since they are expected to do the bulk of the planting up to the year 2000. The species proportions assumed from 1971 onwards are: Pines 60 per cent, Spruces 25 per cent, Larches 5 per cent and Other conifers 10 per cent.

(c) The period of the Production Forecasts. It is necessary to look ahead to the time when the extensive plantings of the 1950's are expected to be felled in order to be aware of the ultimate scale of future production. By using the yield classes applicable and the criterion of maximisation of N.D.R. to the growers' crops, the longest rotation expected is 70 years. Consequently, the 10-year forecast periods are taken to the year 2030.

(d) Other factors affecting the production forecasts. No allowance has been made besides that incorporated in the Production Forecast Tables (F.C., 1966) for the effect of agencies such as Fomes annosus, Peridermium pinii and windblow on the region's production forecasts.

2. The Production Forecasts for the period 1970-2030

The production by 10-year periods is summarised in

Table 5.3. The production of small roundwood increases rapidly at first as the crops planted in the last two decades enter the thinning stage. It reaches a peak in the year 2000 and thereafter gradually decreases due to the assumptions on the future planting level. The production of sawlogs, defined as having a minimum top diameter of 6 inches overbark, is boosted in the 1980 decade by the felling of pines in the 1901-20 age-class in addition to the Pre 1900 crop, whereas in 1990 there are no final fellings of this species expected. This is due to the forecasting procedure adopted, but in reality detailed adjustments can easily be made to level out such differences. The important features for long term planning purposes are that the present estate could yield approximately 3 million H.ft. (OB) of sawlogs per annum up to the mid nineties, then rapidly increase its production to over 8 million H.ft. (OB) from around the year 2000, followed by a gradual increase up to 12-13 million H.ft. (OB) in the year 2020, and finally rise to over 20 million H.ft. (OB) as the extensive plantings in the last two decades reach the final felling stage.

The actual production may improve upon the forecasts through more intensive ground preparation, drainage and fertilisation programmes, but such measures could not raise the sawlog production in the 1970-1990 period to 8 million H.ft. (OB) per annum or to 20 million H.ft. by the year 2010. After 2030 sawlog production may be expected to rise slightly

Table 5.3. SUMMARY OF THE PRODUCTION FORECASTS FOR THE PERIOD 1970 to 2030

(a) Small Roundwood Millions H.ft. (OB)

Species Group	1970	1980	1990	2000	2010	2020	2030
Pines	1·25	2·52	3·53	4·24	3·09	2·10	1·92
Larches	0·11	0·26	0·27	0·21	0·18	0·12	0·09
Spruces	0·38	0·90	1·57	1·57	1·43	1·29	1·15
Other Conifers	0·08	0·15	0·31	0·37	0·39	0·39	0·39
TOTAL	1·82	3·83	5·68	6·39	5·09	3·90	3·55
Pre 1900	0·18	0·18	-	-	-	-	-
TOTAL	2·00	4·01	5·68	6·39	5·09	3·90	3·55

(b) Sawlogs Millions H.ft. (OB)

Species Group	1970	1980	1990	2000	2010	2020	2030
Pines	0·56	2·20	1·58	6·37	6·47	8·00	15·70
Larches	0·11	0·23	0·25	0·47	0·92	0·49	0·24
Spruces	0·11	0·22	0·93	1·04	2·17	3·96	4·67
Other Conifers	0·08	0·06	0·29	0·20	0·36	0·71	1·14
TOTAL	0·86	2·71	3·05	8·08	9·92	13·16	21·75
Pre 1900	1·58	1·58	-	-	-	-	-
TOTAL	2·44	4·29	3·05	8·08	9·92	13·16	21·75

NOTE: Sawlog volumes are to a minimum 7 inch top diameter (OB) and 10 feet in length. Small roundwood volumes are the residual volumes to 3 inch top diameter (OB).

in the following decade and then to decline unless more extensive plantings are made, i.e. above the currently assumed rates, or unless various measures are used to bring the forest estate towards a sustained yield. Even this last approach need not be the ultimate course of action since the region is not an isolated area and adjoining districts to the northwest and southeast would be natural extensions of the present supply basin.

The pines and spruces together account for approximately 90 per cent of the total production throughout the forecast period, and it is between these two species that the significant changes in the volume proportions occur; this may readily be seen in Table 5.4; the remaining percentages are split between the larches and other conifers.

The Pre 1900 felling yields are presented as separate subtotals in Table 5.3 to show the effect of this age class on the total production, and because it is a distinct separate crop with respect to the rest of the production output. 96 Per cent of the volume is Scots pine. There is a wide variation in its diameter distribution and the quality[1] of the timber.

To complete this section on the production forecasts it is necessary to consider the changes in the distribution of production occurring within the region with time. The available short term forecasts (P.E. Consultants, 1969) are

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1. The methods of tending tolerated the persistence of dead side branches on the main boles, so that this growing stock presents acute difficulties of dead knots, loose knots, and powder knots.

Table 5.4. PRINCIPAL CHANGES IN THE PRODUCTION PROPORTIONS BY PERCENTAGES.

(a) Small Roundwood

Species Group	Percentage of Total Production						
	1970	1980	1990	2000	2010	2020	2030
Pines	71·1	72·7	62·1	66·3	60·8	54·0	54·2
Spruces	19·2	24·3	27·5	24·6	28·1	33·1	32·3
SUM	90·3	96·9	89·6	90·9	88·9	87·1	86·5

(b) Sawlogs

Species Group	Percentage of Total Production						
	1970	1980	1990	2000	2010	2020	2030
Pines	87·6	88·0	51·8	78·8	65·2	60·8	72·2
Spruces	4·6	5·2	30·5	12·9	21·9	30·1	21·5
SUM	92·2	93·2	82·3	91·7	87·1	90·9	93·7

NOTE: Sawlog volumes are to a minimum 7 inch top diameter (OB) and 10 feet in length. Small roundwood volumes are the residual volumes to 3 inch top diameter (OB).

sufficient for the present purposes; a detailed locational analysis has not been carried out at this preliminary planning level. Table 5.5 below gives a guide to the location of supplies for the period 1970-1985 by dividing the region into 4 districts. The relative changes in the proportions of the small roundwood in addition indicate the location of sawlog supplies during the forecast period: by 1985 all crops planted in the 1951-60 decade will be in the thinning stage, and it is unlikely that a major shift was made in the proportions planted in any of the districts during the following decade. Hence it may be concluded from Table 5.5 that the Inverness district will not substantially increase its proportion of the supplies over the forecast period, although a large increase in the future planting rate relative to other areas would affect the location of small roundwood supplies in the region.

The high percentage of sawlogs to be produced in the Grantown-Carrbridge district at the beginning of the 1970's is caused by the concentration of Pre 1900 growing stock in the area forecast to be felled. Although the felling of this growing stock continues at approximately the same rate in all districts, the weighting effect of the sawlog production from the Post 1900 growing stock probably accounts for the rapid decline in the percentage of sawlog supplies coming from the Grantown-Carrbridge district. The downward trend in the small roundwood supplies within the Forres-Nairn district indicates that after 2000 AD a decline can be expected in the relative proportion of sawlogs produced there. In contrast

Table 5.5. THE LOCATION OF SUPPLIES BETWEEN 1970 AND 1985 AS PERCENTAGES OF TOTAL PRODUCTION

Year	Inverness		Forres/Nairn		Fochabers/Keith		Grantown/Carrbridge	
	S.R.W.	S.L.	S.R.W.	S.L.	S.R.W.	S.L.	S.R.W.	S.L.
	Percentages							
1970	3·7	7·5	41·7	22·0	24·7	7·5	29·9	60·3
1975	9·9	8·7	35·3	29·0	26·7	9·5	28·1	52·8
1980	10·1	11·4	30·0	36·5	35·3	15·3	24·6	36·8
1985	11·9	5·2	26·1	45·7	34·2	18·5	27·8	30·6

Source: P.E. Consultants 1969.

NOTE: S.R.W. = Small roundwood. S.L. = Sawlogs (as defined in Table 5.3).

the Inverness and the Fochabers-Keith districts should increase their proportion of the sawlog supplies and the Grantown-Carrbridge district remain with a fairly constant proportion.

Other Raw Wood Materials

Bark, slab-wood and sawdust are currently regarded as waste products within the region. Elsewhere the commercial utilization of these products is already considered feasible. Tustin (1968) mentions that Scots pine bark has particular qualities which make it useful in the production of fibre-board. The conversion of slab-wood into chips is becoming more and more the standard practice, and many sawmills now consider chip production provides the profit margin in this industry. Sawdust is used by fibreboard, particle board and certain pulping processes on a commercial basis in places where it is available in quantity close to the mills.

Estimates of bark production can be derived without difficulty from the roundwood production forecasts. The outturn of slabwood and sawdust can be estimated for the existing sawmill industry (provision would have to be made in planning industrial development for this type of processing system and the wood residues it produces). It would be appropriate to consider also the deduction made in the Pre 1900 roundwood volume (p. 26) as a further source of low quality wood, which is a potential source of raw material to a residue-using industry such as fibreboard.

CHAPTER VI

THE TECHNICAL FEASIBILITY OF FOREST INDUSTRIES

The principal species in the region are Scots pine, Sitka spruce, Norway spruce and European larch. The composition of the wood supplies by species varies over the forecast period (Tables 5.3 and 5.4) but may be taken approximately as 60 per cent pines, 30 per cent spruces, 6 per cent larches and 4 per cent other conifers. The requirements of wood processing industries in terms of the quality, condition and form of the raw wood materials differ considerably according to the product.

1. Sawmills

Each of these species has good sawmilling and timber properties (F.P.R.L., 1965, 1967(a) and 1967(b)). The existing sawmilling industry uses single bandsaws principally. for the primary breakdown of the sawlogs. Bandsawing gives great flexibility in the range of diameters that may be sawn and is most suitable for the larger sawlogs of Pre 1900 crops which are a limited and dwindling resource. Future sawlog supplies, more especially over the next 20 to 30 years, are going to come increasingly from thinnings of the Post 1900 crop; these will be predominantly small in diameter (Table C.1) and probably poor in form. For this type of sawlog the frame saws, multiple band and circular saws and the profile chipper sawmills systems are all technically feasible and are employed in different parts of the world in similar circumstances. There are many combinations of the different types of sawmilling system, each with its own advantages and disadvantages (conversion accuracy and yields, investment costs and productivity). Since all these systems are technically feasible, the selection of a particular type can be made only after economic models have been developed (like those of Appendix C for Linck Canter Chipper mills). In addition, the choice could depend on the other forest processing industries that may exist in the region.

2. Plywood and Veneer Mills

The predominant species, Scots pine, can produce good facing veneers, but the presence of knot whorls and the variable gluing quality are distinct drawbacks to its use (F.P.R.L., 1965). Tests on Home-grown Scots pine, from logs of about 14 ins. diameter at breast height, show it can make a good sheathing quality plywood (Knight, 1965). In Finnish plywood manufacture the average diameter of birch logs is 8½ ins., which indicates that smaller diameters than 14 ins. may be possible.[1] It is, however, extremely unlikely that sufficient supplies of the size and quality could be found within the region.

3. Blockboard Mills

Blockboard manufacture should be considered as it could use small dimension sawntimber such as would be

1. It is not known if the physical properties of Scots pine would permit peeling to be feasible at smaller diameters.

available if a new sawmill were to operate on the Post 1900 sawlog thinnings. Blockboard requires two kinds of raw material: (1) facing veneers which generally constitute 25 to 35 per cent of the volume of the finished board (F.A.O., 1966). These would have to be imported for the reasons stated in the previous section on Plywood and Veneer Mills, (2) a wood core. The species in the core cannot be mixed (F.A.O., 1966), but Scots pine is suitable and already used for this purpose in Britain (F.P.R.L., 1965).

4. Pulp Mills

There are a number of different pulp processes which would be technically feasible if based on the species available in the region. Three chemical processes: (1) Sulphate (Kraft); (2) Bisulphite (Arbiso); and (3) Two-stage Sulphite (Stora), are all sufficiently flexible to handle the resinous wood of pine supplies (Packman, 1965). New chemical pulp mills are virtually ruled out completely for any location within the United Kingdom (Richards (a), 1967), owing to the scale of their raw wood requirements. Hence the only pulp process likely to be feasible for the region is the Disc (or Chip) Refiner Mechanical Pulp process. Under laboratory conditions, Scots pine on its own, and in mixture with other species, has been pulped successfully by this process (Packman, 1967). In addition, there are already two new mills using mixed softwoods by this process: (1) Thames Board Mills at Workington and (2) St. Anne's Board Mill at Bristol (Packman, 1968).

Disc Refiner mills can utilize sawdust (Tustin, 1968) but at their present stage of development they are too sensitive to bark traces to be able to make use of chips produced in sawmills, even when the sawlogs are barked before processing (McAinsh, 1969).

5. Particle (Chip) Board Mills

Pines and other conifers are readily acceptable for all types of particle board processing. Invariably it is the price which determines the roundwood species acceptable. Competition from pulp mills, fibreboard mills and sawmills has lead the particle board industry to utilize the less sought and cheaper hardwood species (Stegmann and von Bismark, 1968). Assortments of relatively large industrial residues (slabs, edgings, and veneer cores) and smaller sized waste (particularly offcuts and shavings) may be used exclusively in the manufacture of particle board (Akers, 1966). The industry can utilise unbarked residues and may include 15 per cent or more bark in the board product (Tustin, 1968). Sawdust, however, is the least desirable and is usually tolerated only in small quantities as a filler for the board surface. The particle board chip is formed by machines with cutters which make a thinner, lighter flake than the pulp chips cut by the Linck Canter Chipper heads used in the models of Appendix C. A Linck Canter Chipper fitted for the production of particle board flakes works at approximately one third of the rate used in

Appendix C, which consequently would make a large difference to the production costs.

6. Fibreboard Mills

The manufacture of various types of fibreboard makes use of a wide range of materials, particularly coniferous roundwood and residues. In non-compressed fibreboard (insulation board) virtually no bark content is tolerated but 15-30 per cent is acceptable in hardboard, especially from Scots pine as it actually improves the board properties (Tustin, 1968). In addition, sawdust can be utilized to a considerable extent, up to 30 per cent of the raw wood material without harming the board quality (Asplund, 1963; Tustin, 1968). The main limitation on its use is the bulk of the sawdust, which makes transport expensive and consequently restricts the distance it can be carried economically (F.A.O., 1966).

7. Wood-wool Mills

Raw material requirements are more exacting in wood-wool manufacture than in fibreboard or particle board. For the manufacture of concrete board, etc. species such as the spruces are preferred owing to their relatively low density and content of extractives such as resins. Wood-wool manufacture requires bolts of roundwood not less than 4 ins. in diameter to obtain acceptable processing yields, (F.A.O., 1966). It is understood that high quality Scots pine logs are sold for wood-wool manufacture as a packing material. The log specifications are high, the volume of trade small; consequently this outlet for Scots pine is one not likely to expand significantly.

CHAPTER VII

FOREST INDUSTRIES: ECONOMIC FEASIBILITY

Whatever goals are defined for the forestry sector of the economy, either on a national, regional or local scale, an economic criterion is required in order to measure the opportunity costs involved. The maximum disposable wood price (MDWP) allows forest processing industries to be compared and the optimal combination of industries to be determined for a defined wood resource. Using this criterion, management on a regional basis seeks to maximise the total value of wood resources by their allocation to various processing enterprises. Attainment of this goal would depend on the complete integration of forestry and forest processing industries; its realization, as Eklund (1967) states: "involves a great many organisational and other difficulties". The problems, however, are not insuperable and a solution may be sought by the construction of partial mathematical models of the system (Eklund, 1967).

The present analysis is restricted to the main problems involved in the development and uses of forest processing models for the determination of the optimal allocation of the wood resources in the region studied. Hypothetical mill models are used for two types of forest processing industries developed in Appendices B and C, taking the supply forecasts of the Post 1900 crop in Chapter V as the available wood resource. The Pre 1900 crop supply would have to be included in a complete study, but for the sake of simplicity it is left aside in the present discussion.

Economic feasibility should be considered in terms of the global MDWP of the defined wood resource as presented in Figure 7.1; the dotted ~~broken~~ line in that figure shows the approximate total annual roundwood supply. The analysis is confined to the roundwood supply between 1970 and 1990, although a brief reference is made to the supplies beyond that period.

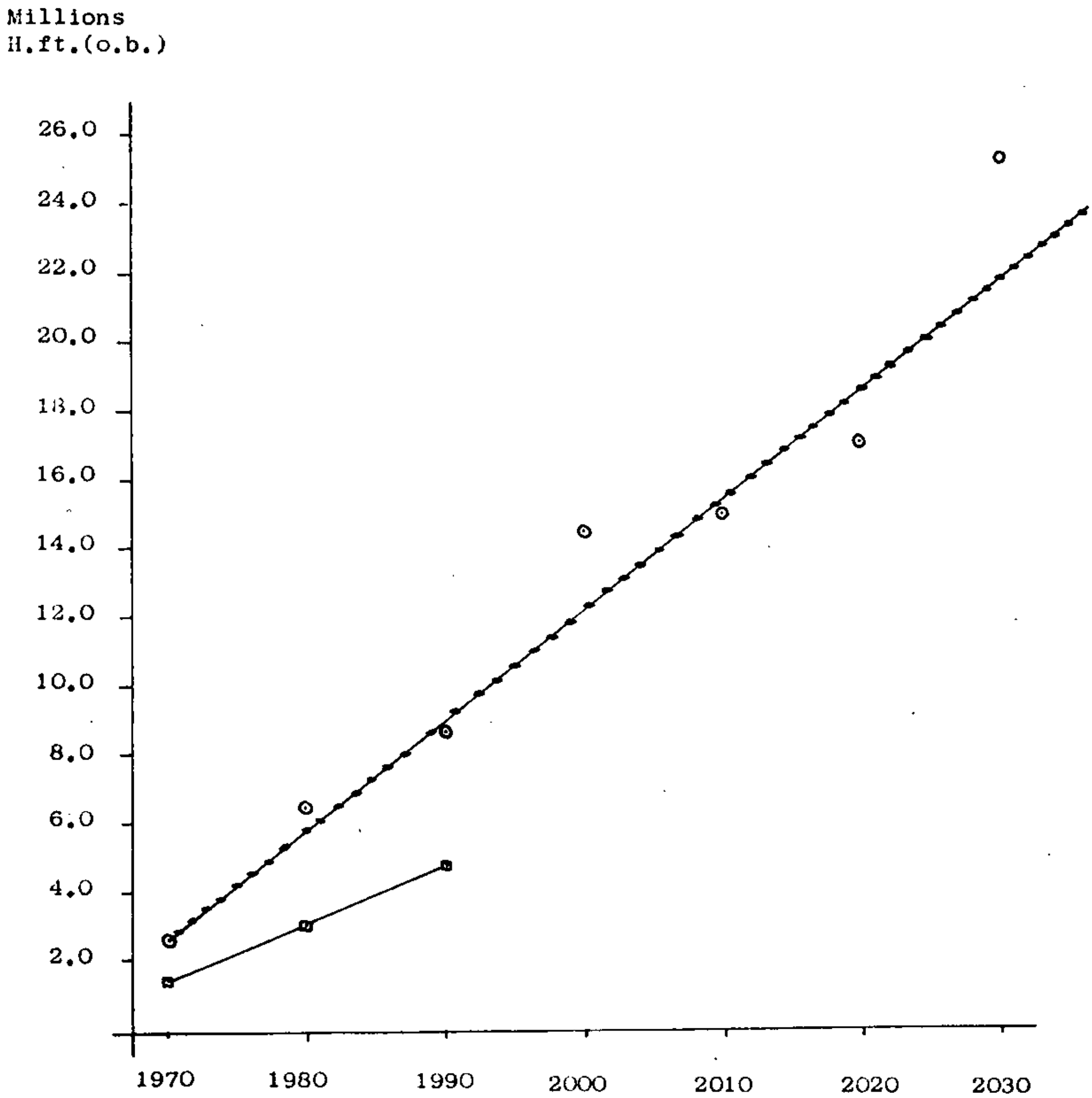
<u>Linck Canter Chipper Sawmill Installations and Hardboard (wet process) Mills</u>

The hypothetical models of these two forest processing industries are developed in the appendices. Both industries are suitable for processing the species and assortments which are likely to be available in the next 20 years. It is possible that other processing systems and industries would be economically more attractive as users of the region's wood resources than the two chosen for study, but the decision was taken to restrict the model development to two industries owing to a time limitation; the analysis is thus partial, and it is possible to examine the features of only the present models and the allocation of the wood resources between them. A full analysis would require the same treatment for each industry that is technically feasible for processing the available wood supplies.

There are virtually constant returns to scale in the Linck mill models when processing the qualities and size

FIGURE 7.1

POST 1900 CROP : TOTAL ROUNDWOOD VOLUME
(PRODUCTION FORECASTS)



NOTE : ⊙——⊙ Total roundwood volume
⊡——⊡ Total Potential Sawlog Volume

SOURCE : Chapter V, Table 5.3

assortments expected in the forecasts (pp. C.1 and C.14-15). Consequently, only the results from the smallest model, the Linck No.1 mill, are considered: at an input capacity of 1·48 million H.ft. per annum (i.e. working 2000 hours per annum) the average MDWP is 4·075 shillings per H.ft. (Table C.13, p. C25) for the sawlog assortments expected for production in 1970-90. As the roundwood supplies increase this mill could improve the MDWP slightly by increasing the annual working hours.[1] Whilst the sawlog quality is low, however, and logs are small in diameter, it would probably be more feasible to build an additional mill for each additional 1·5 million H.ft. of log supplies, since the potential savings are likely to be offset by cost factors such as haulage costs and difficulties in obtaining staff who are prepared to do shift-work. In later years the increased sawlog volume could be processed by the Linck No.1 mill either by an extension of the operating time of a single mill or by building more than one mill; neither extension of the hours nor replication of the mill would alter the MDWP importantly. For the purpose of the allocation analysis it is therefore possible to consider the MDWP as constant for this type of processing without distorting the results significantly. By 1990, however, when the potential sawlog volume reaches 4·7 million H.ft., the quality of sawlog may be improved sufficiently to justify the installation of a single large mill (p. C15).

1. Doubling the operating time would increase MDWP by 9 per cent. Trebling working time would increase MDWP only by a further 3 per cent.

The hardboard mill models show appreciable returns to scale (Table B.9, p. B34 and Figure B.5) and capacity is the predominant factor determining the economic feasibility of the models in this type of processing.[1] Whereas in sawmilling the dimensions and qualities of logs are important factors in determining the value of the end product and consequently the MDWP, hardboard processing can utilize practically all roundwood dimensions and wood residues available within the region without any pronounced affect on its MDWP.

In these circumstances there are three principal logical alternative procedures in the general allocation of the wood resources:

(1) Roundwood supplied to hardboard processing alone

(2) Roundwood supplied to a combination of hardboard and sawmill (Linck mill) processing

(3) Roundwood supplied to a combination involving other processing systems and industries.

The option producing the highest global MDWP offers the optimal solution under the conditions stated. For example, with technologies and relative prices fixed, the optimal solution lies between alternative 2 and 3 as the following considerations show:

(a) By processing the sawlog assortment assumed (Table C.7), a Linck No.1 mill's output expressed as a percentage of the log input volume (OB) is: 36 per cent lumber, 40 per

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1. Capacities below 13,000 MTPA actually yield negative MDWPs (Figure B.5).

cent chips, 16 per cent bark, 2 per cent sawdust; the residual 6 per cent is a production loss due to lumber shrinkage and chip waste. The chip, bark and sawdust residues are acceptable raw wood materials in hardboard processing (Chapter VI) and together they amount to 58 per cent of the log input volume (OB) to the Linck mill. For the period 1970-1990 the sawlog volume, very small roundwood volume (3-4½ ins. diameter (OB)), and wood residue volume may be stated as percentages of the total roundwood supply. These percentages given in Table 7.1 are approximate since they are based on the diameter distributions of the pines and spruces (Table C.1)[1] and assume the allocation of

Table 7.1. THE PROPORTION OF SMALL ROUNDWOOD, SAWLOGS AND WOOD RESIDUES EXPRESSED AS PERCENTAGES OF THE TOTAL ROUNDWOOD SUPPLY.

Roundwood Diameter Class ins. (OB)	Assortment Class	Percentage of the Total Roundwood Supply	
		Roundwood	Residues
3-4½	Very small roundwood	46·0	-
4½-6	Sawlogs	27·5	16·0
6-12	Sawlogs	26·5	15·4
TOTALS		100·0	31·4

Sources: Tables C.1 and C.7.

roundwood assortments depend on dimension of the logs alone (i.e. no account is taken of defects making a proportion of the logs over 4½ ins. small end diameter (OB) unsuitable for

1. The justification of this approximation is that these two species can be expected to produce around 90 per cent of all roundwood supplies (Table 5.4).

sawmilling). Hence for any year in the period 1970-1990 the potential input volumes to a Linck No.1 mill and a hardboard mill can be assumed to depend on the allocation of the sawlog assortments; these are presented in Table 7.2 as percentages of the total roundwood supply.

Table 7.2. THE ALLOCATION OF WOOD MATERIALS BETWEEN A LINCK No.1 MILL AND A HARDBOARD MILL

Roundwood Diameter Class (ins. OB)	Mill allocated to:	Mill Wood Material Inputs Expressed as Percentages of the Total Roundwood Supply			
		Linck No. 1 Mill	Hardboard mill		
		Roundwood	Roundwood	Residues	Total
3-12	Hardboard	-	100	-	100
4½-12	Linck	54	46	31	77
6-12	Linck	26·5	73·5	15	88·5

Sources: Based on Table 7.1.

(b) The Global MDWP (i.e. the MDWP of the whole roundwood supply) is the weighted average of the MDWPs derived for the processing systems using the region's roundwood supply.

i.e. $\alpha_1 P_1 + \alpha_2 P_2 \ldots\ldots \alpha_n P_n$

where, $\alpha_1, \alpha_2, \ldots\ldots \alpha_n$ are the proportions of the total roundwood supply used by each processing system,

and, $P_1, P_2, \ldots\ldots P_n$ are the derived MDWPs for the processing systems involved.

The expression 'αP' for any particular processing system is the value contributed per H.ft. of the total available roundwood to the global MDWP (i.e. it is the value added to the global MDWP by each processing system). This concept is applicable particularly in complex situations where many processing systems are involved, and techniques such as linear programming are required to determine a solution. As is shown in Table 7.1, the calculations must take account of the anomaly that there appears to be more than 100 per cent of the roundwood production available for processing; 46 per cent is technically suited only for hardboard processing and 54 per cent may go to a Linck sawmill, but 31·4 per cent reappears as Linck residues suitable for reprocessing for hardboard. To avoid double-counting of the value contributed by wood materials used more than once (e.g. the wood residues from the Linck mill which are also considered as wood inputs to the hardboard mill) the MDWPS are based only on the final products of each system. Formerly (Appendix C and p. 46) the MDWP calculated for the Linck No.1 mill (equal to 4·075 shillings per H.ft.) was based on assumed values for chips, bark and sawdust (Tables C.5(a) and C.13). The MDWP for these residues now depends on the capacity, production costs and ex-mill product prices of the hardboard mill, while the MDWP of the Linck No.1 mill is calculated on its production costs and the product prices of sawtimber (lumber) alone. A MDWP so derived for the Linck No.1 mill is considered constant on the basis of the discussion (p. 46) and the condition that a minimum quantity of sawlogs is available, sufficient to keep the mill operating at capacity for 2000 hours per annum. There are, however, two values of MDWP for the Linck mill corresponding to the two sawlog assortments which can be allocated to it: 3·046 and 4·120 shillings per H.ft. for the 4½-12 ins. and 6-12 ins. diameter class assortments respectively. Hence the contribution per H.ft. of the total available roundwood to the global MDWP is 1·64 or 1·09 shillings per H.ft. (i.e. $\alpha P = 0{\cdot}54 \times 3{\cdot}046 = 1{\cdot}64$ or $0{\cdot}265 \times 4{\cdot}120 = 1{\cdot}09$; see Table 7.2) depending on the sawlog assortment allocated to the Linck mill. The corresponding values for the hardboard mill are set out in Table 7.3, columns 3-5 (1973 is the first year possible for the commencement of process operations). The values, given at two-year intervals up to 1989, are based on the allocation of different proportions of the total roundwood supply and the MDWP a hardboard mill would have when built to that particular capacity.[1]

To discover the option which yields the highest global MDWP, a comparative calculation could be made for each alternative combination such as the example in Table 7.4. Alternatively the optimal solution can be found by comparing the value-added by each processing system when making use of the sawlog assortments. The values in Table 7.3 columns 6 and 7 correspond to the value-added by hardboard processing of the sawlog assortments. When the Linck No.1 mill processes the whole sawlog assortment the value-added

1. For the present all prices are considered in relative terms to be constant.

Table 7.3. THE VALUE CONTRIBUTED PER H.FT. OF THE TOTAL AVAILABLE ROUNDWOOD TO THE GLOBAL MDWP BY HARDBOARD PROCESSING.

Year	Total Available Roundwood Volume (millions H.ft.)	Value-added to the Global MDWP (αP_{hb})			Additional value-added by the sawlog assortments: Diameter Classes	
		$\alpha = 1 \cdot 0$	$\alpha = 0 \cdot 77$	$\alpha = 0 \cdot 885$	4½ to 12 ins. (cols. 3-4)	4½ to 6 ins. (cols. 5-4)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1973	3·6	2·35	1·56	1·98	0·79	0·42
1975	4·2	2·47	1·73	2·12	0·74	0·39
1977	4·8	2·55	1·85	2·21	0·70	0·36
1979	5·4	2·65	1·89	2·27	0·76	0·38
1981	6·0	2·70	1·96	2·35	0·74	0·39
1983	6·6	2·75	2·00	2·39	0·75	0·39
1985	7·2	2·80	2·04	2·42	0·76	0·38
1987	7·8	2·85	2·08	2·45	0·77	0·37
1989	8·4	2·90	2·12	2·48	0·78	0·36

Sources: Figure 7.1 and Figure 8.5.

Table 7.4. COMPARATIVE ANALYSIS OF ROUNDWOOD ALLOCATION OPTIONS IN 1973.

1. Allocation of all roundwood assortments (i.e. 3 to 12 ins. diam. classes) to a hardboard mill.
2. Allocation of the 6 to 12 ins. diam. class assortments to the Linck No.1 mill; its residues and the remaining small roundwood, 3 to 6 ins. diam. class assortments to a hardboard mill.
3. Allocation of the 4½ to 12 ins. diam. class assortments to the Linck No.1 mill; its residues and the remaining small roundwood, 3 to 4½ ins. diam. class assortments to a hardboard mill.

	Total Available Roundwood Supply (V) (millions of H.ft.)	Proportion of total roundwood supply (α)		MDWP of Processing System (P)		α P		Global MDWP α P Shs. per H.ft.	Total value of wood V α P Millions of Shs.
		Linck	Hard-board	Linck	Hard-board	Linck	Hard-board		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1.	3·6	0·0	1·0	-	2·35	-	2·35	2·35	8·46
2.	3·6	0·265	0·885	4·120	2·24	1·09	1·98	3·07	11·04
3.	3·6	0·54	0·77	3·046	2·03	1·64	1·56	3·20	11·52

Sources: MDWPs: Figure B.5 and Table C.13 (note value of chips and sawdust excluded).
Proportions of Total Roundwood Supply: Table 7.1.
Total Available Roundwood Supply: Figure 7.1.

is 1·64 shillings per H.ft., which is greater than any corresponding value given in Table7.3 column 6. There is still the possibility that the smallest diameter class of sawlog ($4\frac{1}{2}$ - 6 ins. (OB)) should be allocated to the hardboard mill instead of the Linck mill. The additional value-added, however, by processing this smallest sawlog assortment in the Linck mill is 0·55 shillings per H.ft. (i.e. 1·64 - 1·09 shillings) which is greater than any value given in Table 7.3 column 7. Consequently, the optimal solution for any year between 1973 and 1989 is to allocate all sawlogs (i.e. above $4\frac{1}{2}$ ins. diam., small end OB) to the Linck mill, and the remaining raw wood material and the Linck mill residues to a hardboard mill.

(c) When other forest processing industries are included the analysis becomes progressively more complex and techniques such as linear programming are required to obtain an optimal solution. An immediate alternative which can be briefly considered is the establishment of a Linck mill and the sale of small roundwood and chips to Scottish Pulp and Paper Mills Ltd., at Fort William. In 1973, the ex-region price of small roundwood ($P_{S.R.W.}$) and chips (P_C) must exceed the value contributed by the establishment of a hardboard mill if optimal use is to be made of the roundwood resources.

i.e. $0{\cdot}46\ P_{S.R.W.} + 40{\cdot}0 \times {\cdot}54\ P_C > 1{\cdot}56$ shillings

If $P_{S.R.W.} = P_C$

Then $(0{\cdot}46 + {\cdot}22)P > 1{\cdot}56$ shillings.

Therefore, P (the ex-region price of small roundwood and chips) must be greater than 2·32 shilling per H.ft. before the wood would be profitably diverted to Scottish Pulp and Paper Mills instead of to a local hardboard mill. In effect, the analysis has examined the optimal combination of two types of processing plant in any particular year between 1973 and 1990, and shows that they are mutually compatible on the available resources. Once built, a hardboard mill can only increase its output to a limited extent without the addition of a large integral capacity (i.e. increasing capacity twice, or more, by new capital investment). Consequently, to decide when and what size of mill should be built requires a further analysis. The cumulative opportunity costs in delaying construction, or in premature crop fellings must be compared to the higher value-added by a mill of larger capacity than is used in Table 7.3. Premature crop fellings could be advantageous in another way: unsatisfactory crops could be felled and replaced with more profitable investments.

Development of the Analysis.

Further steps and refinements to the analysis have to be made before it can function reliably. In the solutions involving a delay in the commencement of a timber processing plant, the risks and uncertainties caused by changes in technologies, markets and relative prices have to be assessed. The sensitivity of critical factors is essential. In the two processing industries examined (i.e. the models of Appendices B and C) the factors affecting the MDWP are:

(a) For Linck Canter Chipper Sawmill Installations

(1) The lumber recovery

(2) Lumber prices.

Unless the sawntimber (lumber) prices are considerably overestimated (Table C.5(a)), processing costs and chip price changes have relatively little effect by comparison with the lumber recovery (Table C.14).

(b) For Hardboard Mills

(1) The predominant factor is the mill capacity since it not only makes appreciable changes in the MDWP, but also affects the sensitivity of other factors (Table B.10). A characteristic of this industry, as in others with appreciable economies of scale, is that the economic instability increases as the size of mill decreases (Table 7.5).

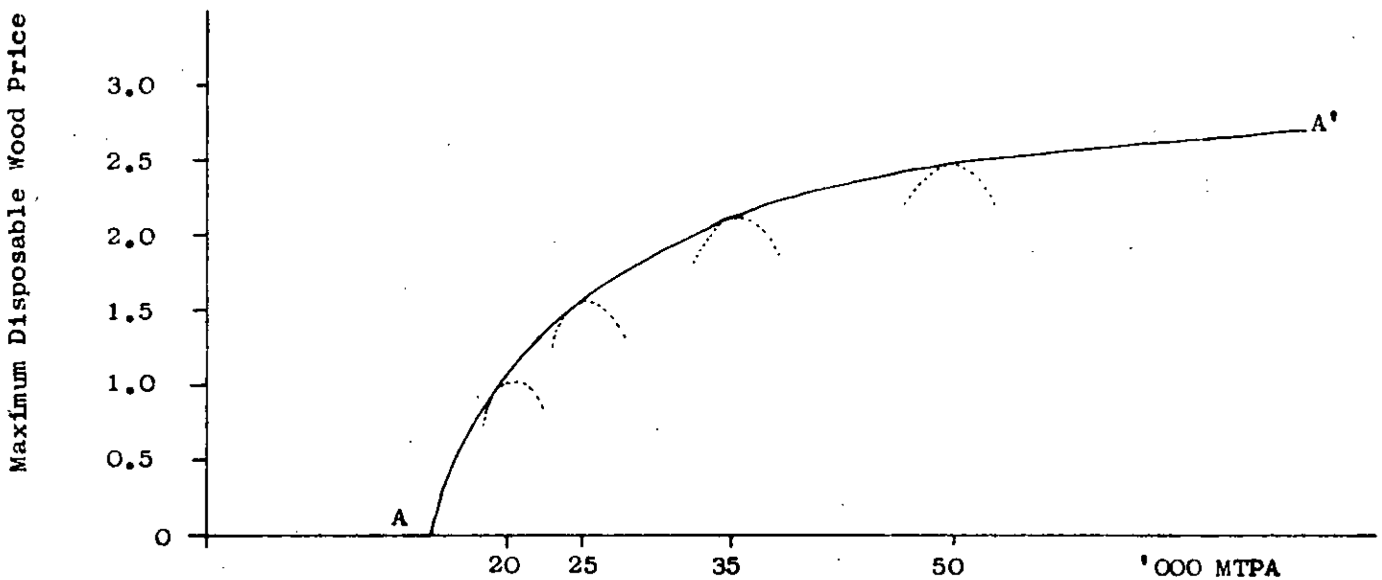
(2) Hardboard product price

(3) Investment grants and allowances and tax concessions. If these were abolished, the unit cost of amortization and interest would increase by 46 per cent and the MDWP would be reduced by 42 per cent.

Until models for other processing systems and industries are published, the opportunities for using alternative combinations cannot be estimated. Statements suggesting the minimum feasible size for a particular processing plant may be misleading unless some idea is given of its relative position with regard to the economies of scale in its industry. The hardboard models constructed for the region exemplify this: Figure 7.2 and Table 7.5. The MDWP given at any point along curve AA' in Figure 7.2 represents an optimal price for a mill designed to a specified capacity. Once a mill is constructed its production may be varied within limits and its MDWP again expressed as a function of the production rate. The shapes of the four short run curves in Figure 7.2 are hypothetical, although their maximum values are known: they may be equal to, but cannot exceed the optimal MDWP value (curve AA'). Hence a short run curve is more sensitive to changes in the level of annual production than the optimal curve derived for the hardboard models (Figure B.5 and curve AA', Figure 7.2). Consequently as a first approximation, it should be possible to determine the minimum size economically feasible for a particular processing system in terms of the change in MDWP with capacity (i.e. at points along curve AA'). It is suggested that this minimum size could be defined as the size at which a proportional change in the operating capacity is greater than the corresponding proportional change in MDWP. This would mean the minimum size for a hardboard mill as shown in Table 7.5. is approximately 35,000 MTPA (125 MTPD). Such constraints would have to be built into all models to avoid planning plants which, although in themselves appearing to break-even and raise the global MDWP, would be unstable, economically inefficient and too sensitive to changes in production costs and product

FIGURE 7.2

THE CAPACITY-STABILITY RELATIONSHIP OF HARDBOARD MILL MODELS



NOTE : ———— Optimal MDWP
·········· Short Run MDWP

Table 7.5. THE CAPACITY-STABILITY RELATIONSHIP OF HARDBOARD MILL MODELS

Mill Capacity '000 MTPA	MDWP	A 25 per cent change in the wood supply '000 H.ft.	Percentage change in MDWP	
			Wood supply reduced	Wood supply ~~reduced~~ increased
20	1·07	416·0	100·0	44·9
25	1·55	520·0	41·9	24·5
35	2·10	728·0	23·8	13·8
50	2·47	1040·0	10·9	5·3

Source: Figure B.5.

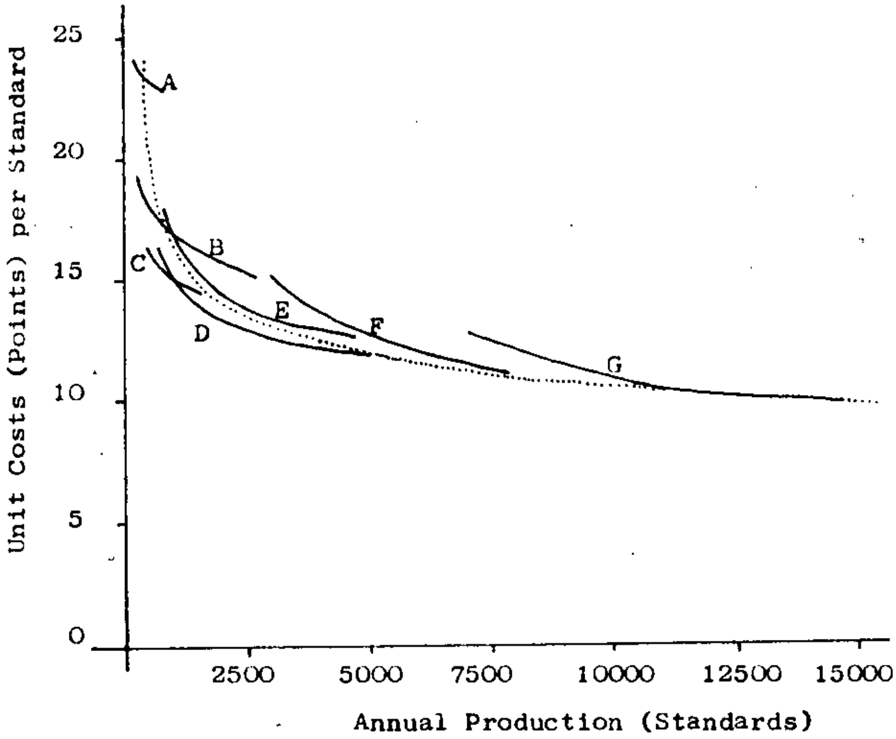
prices. A similar processing plant, by being built at a greater output capacity would be able to increase its raw material supplies since its MDWP would be raised; i.e. it could either extend its supply procurement area, or take in more valuable wood assortments than the smaller mill.

The Economic Feasibility of Other Forest Processing Industries

Some general observations may be made on other forest processing industries. Thunell (1965) discussing conventional sawmill systems (circular, band and frame mills without profile chipper headrig installations) says "costs for mills of varying types and sizes show that during normal optimal conditions, the differences in production costs are relatively small". He has, however, over 200 per cent difference in production costs for 10 types of mill given in his examples. The overall decline in cost with increased capacity for these mills is estimated by the broken line in Figure 7.3. By comparison the Linck No.1 mill produces

FIGURE 7.3

UNIT PRODUCTION COSTS AS FUNCTIONS OF SAWMILL CAPACITY



SOURCE : Thunell (1965)

NOTE : Production costs (excl. wood) include external and internal cost factors, and the value of processing residues.

A ---- Single Circular Saw
B ---- Circular with Edger
C ---- Complete Circular
D ---- 1 Log Frame
E ---- 1 Log Frame with barking
F ---- 1 Log Frame without barking
G ---- 2 Pairs of Log Frames (Modern)
...... Estimated Average Unit Costs

approximately two standards per hour (Table C.13), or 4,000 standards per annum from sawlog assortments probably much inferior to those used in Thunell's mills. No direct comparison can be made on costs, or conversely on MDWPs, but the profile chipper headrig (of all makes) should substantially reduce sawmill costs and increase the profits on small dimension sawlogs. In fact the chipper headrig could increase productivity sufficiently to overcome the problem posed by Zaremba (1963) for American sawmilling:

> "labour productivity has not changed appreciably since the beginning of the twentieth century. Many technological discoveries in the economy have been introduced to the lumber industry, tending to improve its efficiency. However such improvements have been largely cancelled out by factors which tend to lower productivity - notably a decline in quality and stocking of sawlogs and increased distance between forest and mill".

Certainly the chipper headrig machinery could substantially improve the labour productivity, as Table 7.6 indicates, even though the comparisons are not strictly correct.

A new chipboard mill would require a minimum capacity between 160 cubic metres (Tustin, 1968) and 200 cubic metres (Stegmann and von Bismarck, 1968) of board per day to be viable in the United Kingdom. Wood input requirements to produce this output would be in the order of 2 to 2·5 million H.ft. per annum. The capital requirements of a chipboard mill are between a half and two-thirds of those for a hardboard mill of a similar capacity (Tustin, 1968). Hence, the economies of scale and the minimum size of plant economically feasible (p. 57) are smaller than

Table 7.6. LABOUR PRODUCTIVITY OF SAWMILLING IN THE REGION

Personnel Type	Number	Assortment Dimensions Processed	Total Volume Processed Per annum	Volume Processed per man per annum
1. Total Existing Sawmill Industry in Region				
(a) Foremen and Maintenance	30			
(b) Production Labour	100			
(c) Mill Labour (Handling)	200			
(d) TOTAL	330	6"-24"	4·3 Mill H.ft.	13,000 H.ft.
2. Linck No.1 Mill				
(a) Foremen and Maintenance	3			
(b) Production Labour	2			
(c) Mill Labour (Handling)	12			
(d) TOTAL	17	4½"-12"	1·48 Mill H.ft.	87,000 H.ft.

Sources: P.E. Consultants (1969) (Existing industry only) and Appendix C (Linck Mill)

those of hardboard mills. If, however, wood supplies develop as suggested by the forecasts (Figure 7.1) a chipboard mill would not have any advantage over hardboard on the timing of 'start-up'. There would not be sufficient wood supplies to operate both these industries on the region's wood resources; hence the MDWP and its contribution to the global MDWP must be evaluated for the particle board industry before the relative merits of each processing system can be ascertained.

The available evidence (F.A.O., 1966; Sandwell, 1957, and 1958) suggests that a pulp mill could pay higher prices for its wood requirements than either the fibreboard or particle board industries. A mechanical pulpmill is the only pulp process with small enough economies of scale to be considered as a possible option on the region's wood resources alone. The St. Anne's Board Mill at Bristol and the Thames Board Mills at Workington recently commenced operating on about 120 and 200 tons (respectively) of green, mixed softwoods[1] per day (Packman, 1968). This quantity of roundwood is approximately 1.5 to 2.7 million H.ft. per annum. Depending on the residues available (and acceptable; see p. 40), the forecasts suggest that the region's wood supplies are insufficient to support a mechanical pulpmill before 1980.

If pulpmill models, however, produce very attractive MDWPs, then the possibilities of procuring extra wood supplies[2] should be evaluated. Alternatively, as a short term strategy for industries with large economies of scale, final products with high prices and not suited to large-scale manufacture could be sought.

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1. Both mills are using the Disc Refiner Mechanical pulp process.

2. e.g. Different thinning and felling policies, and wood supplies from areas outside the region may be feasible alternatives.

Integration

The optimal allocation of the region's wood assortments to a combination of forest processing industries is, in the analysis, an implied form of integration. Other types of integration may produce further savings although in industries with pronounced economies of scale these may be relatively unimportant.[1] At the same time integration may bring certain disadvantages, such as decreasing flexibility in meeting changes in technologies and markets; increasing investment requirements; having different economies of scale in consecutive processing stages; and conflicting environmental requirements[2] (Eklund, 1967). In consequence, at a preliminary stage of forest industrial planning, processing models should be considered as independent units. Once it is ascertained that various processing systems have a reasonable chance of success, allowances for integration savings can be made in the latter stages of the analysis (F.A.O., 1958).

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1. Important reasons for integration could be: security of wood supplies, product markets, or the acquisition of sufficient resources of finance, management, and, technological expertise.

2. Timber, water and effluent disposal are difficult to obtain in industrial areas which are the main markets.

CHAPTER VIII

GENERAL CONCLUSIONS

The object of the study was to examine, from the growers' point of view, the allocation of their wood resources to forest processing industries. It is concerned with the most efficient use of wood resources in economic terms. The private and state (Forestry Commission) forest estates were combined since the main constraint on the development of forest processing industries is the scarcity of wood supplies. This is a general problem in many regions of the world, although in areas with surplus wood supplies, (i.e. under-developed wood resources) a different approach can be taken.

As a practical study example a region in North-East Scotland was selected. The allocation of wood resources was based on the maximum disposable wood prices (MDWPs) of hypothetical mill models of forest processing industries. MDWP is a useful criterion; it indicates the allocation which yields the highest net economic value to a defined wood supply. Owing to time limitations the study was restricted to an analysis of two industrial forest processes only: Linck Canter Chipper sawmills and Wet-process hardboard mills. Consequently it is a partial analysis of the problem, and models of other technically feasible forest industries would have to be completed before the optimal allocation of the wood supplies can be determined.

A Linck No.1 mill, a canter chipper sawmill, and a hardboard mill would be economically viable processing systems in the study area by 1973 provided that the Post 1900 roundwood supplies were available in the quantity suggested by the forecasts (Tables 5.3 and 7.3). Of the 3·6 Million H. ft. (OB) available in 1973 as roundwood, 54 per cent (1·9 Million H.ft. OB) comprises potential sawlogs; this volume would provide an input to the Linck No.1 mill, which would keep it operating above 2,000 hours per annum (Table C.7). The remaining roundwood and residues, amounting to 2·8 Million H.ft., exceed the input required for the minimum size of hardboard mill which is economically feasible: this mill, 35,000 MTPA (P. 57) needs approximately 2·2 Million H.ft. per annum to operate at capacity. The MDWP as calculated in Appendices B and C depends on the assumptions used in the construction of the models and the integrated allocation of the wood resources (Chapter VII). Apart from these limitations, it must be stressed that the MDWPs derived for these two forest industries are not necessarily the delivered wood prices the forest growers would obtain. The prices of wood supplies outside the region may influence the delivered prices of the local grown roundwood; or mill managers may require a higher income from their plants than the MDWP would allow, in order to provide for economic fluctuations, particularly in the demand for processed products. If the costs, product prices and conversion percentages are calculated accurately, however, then the growers would be in a strong position to ask for delivered wood prices which approached the calculated MDWPs. This is not the primary intention of MDWP as used in this thesis, although it may

usefully be employed for this purpose by the growers.
In conclusion it should be noted that the analysis of the optimal allocation of a defined wood resource by the development of forest processing industries is made very much more complex in regions such as the study area where appreciable changes in wood supplies are occurring (P. 55 and Figure 7.1) than in situations where a sustained yield is probable.

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APPENDIX A

THE FOREST ESTATE AND PRODUCTION FORECASTS

APPENDIX A

THE FOREST ESTATE AND PRODUCTION FORECASTS

The coniferous high forest by ownership, species, and age classes is tabulated in Tables A.1(a) and A.1(b). Table A.1(c) gives the species percentages by age classes of the combined forest estate (Table 5.1 p. 24).

Planting forecasts and the species proportions.

(a) The Forestry Commission's position. New planting amounted to 90 per cent of the 2,600 acres planted by the Forestry Commission in 1967 leaving only ~~and it then retained~~ a further 9,000 acres only for future afforestation (P.E. Consultants 1969). In recent years the Forestry Commission has been unable to obtain new land acquisitions within the region and the Conservancies concerned do not anticipate any change in this situation. It was ~~hence~~ assumed ~~in the calculation of the rate of future afforestation~~ that no further land would be acquired ~~acquisition will be made~~ by the Forestry Commission. ~~This implies a planting rate of negligible proportions during the next 20 - 30 years.~~

(b) The Private Growers' position and future forecasts. Land-use assessments are currently being undertaken within the region and the Forestry Commission does not consider there is any shortage of land available and suitable for afforestation. Thus it may be assumed that the future planting rate for the private growers is not dependent on land availability in the foreseeable future. The replacement of the devastated woodlands from the two World Wars and the 1953 gale probably accounts to a large extent for the accelerated planting programme from 1951 onwards. In consequence the future planting rates adopted by the private growers need not be expected to continue at the same rate in future years. The private growers' forecasts (P.E. Consultants 1969) however tend to underestimate the future planting rates since many growers were unable to make returns beyond 5-10 years ahead.

The trends in the species proportions are shown in the graphs in Figure A.1 from the data in Tables A.1 and A.2 below.

(c) Estimation of the future planting rate and species proportions. The planting rate can be estimated by using the private growers 1971-80 estimates (Table A.2), and assuming felled crops are replaced. An arbitrary adjustment has been made also. The resulting statistics have no claim to complete accuracy, although they appear reasonable and are satisfactory for the present purposes.

In the 1961-1970 decade the species proportions are based on the 1961-68 establishment record (Table A.1(c)), i.e. pines 70 per cent, spruces 21 per cent, larches 4 per cent and other conifers 5 per cent. The species proportions used for 1971 onwards are derived from the average percentages of the last column in Table A.2. These percentages were subjectively rounded off as: pines 60 per cent, spruces 25 per cent, larches 5 per cent and other conifers 10 per cent.

The 1965 Census Data: Coniferous High Forest Area, Standing Volume, Stocking, Stem Straightness and Yield Class.

The Forestry Commission 1965 Census of Private Woodlands was begun in the region in August 1965 and was completed in April 1967. The Census statistics refer to September 1965 for all woodlands outside the Forestry Commission's control, and were based on a 15 per cent sample of the land area (cf. the 100 per cent coverage in the previous national census of 1947/49). It is estimated (Locke, 1969) that the totals for the coniferous high forest (C.H.F) area and the pines are probably correct within ± 7½ per cent and the other species groups and P. year classes within ± 10 per cent.

The statistics in Tables A.4 to A.8, inclusive, are used to characterize the forest estate of Tables A.1(a) and A.1(b). It should be noted, however, that the 1965 Census did not cover the Forestry Commission estate (Table A.1(b)), but included private woodlands which Table A.1(a) excludes (Chapter V p. 25). It is the absence of any other collated statistics which makes it necessary to base the production forecasts and the Pre.1900 crop standing volume on the combined C.H.F. acreage (Table 5.1 p. 24) and the 1965 Census. In addition, the following points on these tables should be noted:

(1) The high proportion of the crops in the thinning stage classed as overstocked in Table A.5. Thinning cycles on private estates, however, tend to be longer than is

Forestry Commission practice; what is more important is the relative absence of grossly overstocked or understocked areas. This assessment was carried out subjectively by the Census field teams.

(2) The four classes in Table A.6 are defined as:

(a) Over 75 per cent of the trees are utilizeable to timber point without loss of volume due to defects.

(b) 51-75 per cent of the trees are utilizeable to timber point without loss of volume due to defects.

(c) 26-50 per cent of the trees are utilizeable to timber point without loss of volume due to defects.

(d) Under 25 per cent of the trees are utilizeable to timber point without loss of volume due to defects.

The Pre 1900 age classes have a higher proportion of defective trees than would normally be expected in a coniferous crop.

(3) The progressive increase in yield class in Table A.8 is probably due to better establishment practices than in the former years. The general dearth of information on the Post 1951 plantations (see the sample areas in Table A.8) which were 62 per cent of the total coniferous area planted in September 1968 has given weighted yield classes which probably underestimate the actual average weighted yield class of the region. Hence future production yields will tend to be underestimated by the production forecasts.

It should be noted also that the weighted yield classes of each species group other than pines are based on a very low sample area, i.e. compare the total areas in Table A.8(b) with Table 5.1 p. 24.

Estimation of the Pre 1900 crop standing volume.

The standing volume of the Pre 1900 crop in Table A.7 (i.e. the 1965 Census estimate) has been reduced by direct proportions between the areas in Table A.4 above and the corresponding areas of the combined estate in Table 5.1 p 24 There are several objections to this method: (1) the volume results of Table A.7 were computed for each species irrespective of its location, i.e. in pure stands and mixtures, whereas the statistics in Table A.4 were for areas by principal species. (2) The combined forest estate area (Table 5.1 p. 24) is not truly represented by the area in Table A.4. It is necessary to calculate the standing volumes of the present crop in this way since other data as noted (p. A.3) are totally lacking. Hence the total standing volume of the Pre 1900 crop in Table A.7 is reduced from 79·8 to 36·7 million hoppus feet (OB).

The statistics in Table A.6 suggest that 30 per cent of the Pre 1900 crop trees are defective. Assuming there is a 50 per cent loss in the utilizeable volume in these trees, the loss in the total standing volume is 15 per cent. Hence the total utilizeable volume of the combined forest estate Pre 1900 crop has been taken as 36·6 x 0·85 or 31·2 million hoppus feet (OB) in September 1965.

Production Forecasts.

(a) Introduction

A forecast of the future supply of roundwood is required to enable the feasibility study of forest processing industries which could be developed on the region's wood resources to be undertaken. A general forecast model capable of reflecting current management techniques, objectives and expectations is needed. The Forestry Commission and private owners own respectively 53 and 45 per cent of the combined forest estate whilst timber merchants, local councils and others own the remainder. Inevitably there must be many different objectives towards roundwood production and marketing between the present diverse group of growers. In the model adopted for making the preliminary forecasts, however, the conflict of objectives seems less great than ~~may be expected.~~ it might have been.

(b) The Forecast Model Adopted.

The combined forest estate (Table 5.1 p. 24) is used in conjunction with the 1965 Census data and the following assumptions:

(1) The annual thinning predictions are given in the Forestry Commission production forecast tables (F.C. 1966) for each species according to its respective weighted yield class. The thinnings begin at the stated age in these tables and continue up to the time of final felling.

(2) The felling age is determined by the rotation which maximises the net discounted revenue (N.D.R.) for the species according to its yield class.

(3) The Pre 1900 growing stock is treated separately since it now exceeds the optimum felling age and should be

felled immediately according to the N.D.R. criterion used elsewhere. Instead, this growing stock is felled over the next 20 years at a constant level in volume production per annum.

(4) The planting rates and species proportions are as stated (p.A 2)

(5) Felling yields follow the Forestry Commission (1966) production forecast table volumes.

(c) The basis and an assessment of the assumptions in the forecast model.

Thinning yields. The Forest Management Tables (FC 1966) assume an intermediate type of thinning to which the marginal thinning intensity[1] is applied. Over a wide range of thinning intensities the total increment is little affected by treatment in the long run and is considered to be virtually independent of the thinning cycle. In addition Johnston and Bradley (1963) indicate that these Forest Management Tables are applicable to any type of thinning which is silviculturally acceptable.

The thinning yields are based on the Production Tables in the Forest Management Tables. Implied in the forecasted yields is therefore a 15 per cent volume reduction which the Forestry Commission use to allow for understocking, unproductive areas (e.g. roads) and production reducing agencies

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1. Marginal thinning intensity is the highest intensity which can be sustained without diminishing the total production, i.e. it ensures maximum volume production.

(e.g. pathogens, windblow, etc.). It is a generalised estimate and its application to a specific region and particularly to the private growers is arbitrary.[1]

The Felling Age of the Post 1900 crop. A decision has to be made on the criterion to adopt and what assumptions should be made. The use of non-economic criteria for long term planning is unacceptable since no account is taken of the cost or financial returns involved. For existing crops the maximisation of the internal rate of return can yield ambiguous results; in addition the rotation length is determined by historical costs (Johnston et al. 1967). This criterion is unsuitable for present purposes and instead the rotation ages are determined by the Forestry Commission's net discounted revenue (N.D.R.) drillbook solutions. These depend upon several assumptions of which the chosen 3½ per cent discount rate is the most contentious. It implies that the growers have a low time preference on forest investments. Johnston et al. (1967) consider other factors[2] are generally more important to the private growers than the expected return on capital. Indeed the optimum rotation lengths indicated by the maximum N.D.R. criterion at this discount rate are shorter than those commonly practised by the private growers in the region. This implies that an even lower discount rate should be applied. It is felt,

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1. This is a reasonable assumption since it is based on some general experience whereas any other estimate cannot be more reliable until specific data relevant to the region's growing stock area are obtained.

2. e.g. diversification of investments, opportunities for reducing tax burdens, a high implied valuation of intangibles etc.

however, though without specific data,[1] that in future higher discount rates will be expected as the growers become more aware of the economic implications and as capital becomes more costly to them. The adoption of the Forestry Commission's $3\frac{1}{2}$ per cent discount rate does not make a radical change in the present rotation lengths generally accepted for species in the area, although it is probably too conservative by future standards i.e. even shorter rotations will be required.

The other assumptions contained in the N.D.R. drillbook solutions of Table A.9 are: expenditure; the price-size relationship for stumpage; that the existing species continue in perpetuity; and future growth rates. The culmination of N.D.R. depends upon the displacements and the rate of change in the discounted revenue and expenditure curves. The selected examples in Tables A.10-12 below show the influence of these variables and represent the likely range of conditions experienced in the region. In these tables the following should be noted:

(1) An establishment cost of £50, brashing in year 20 of £15 and an annual maintenance charge of £0·7, together with the standard price-size relationship (Johnston _et al_. 1967) are assumed in Tables A.10 to A.12.

(2) The variation in the optimum felling age between a single rotation and a crop repeated in perpetuity is given in Table A.11 with the discount rate on revenue and costs held constant at $3\frac{1}{2}$ per cent.

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1. The rapid increase in faster growing species during the last 15 years is an indication of a greater desire for higher and quicker returns than can be provided by Scots Pine.

(3) An increase in one yield class from YC 100 to YC 120 increases the discounted revenue for Scots pine or Sitka spruce by £30, and to bring about a similar increase by a change in the standard price-size relationship would require a general price rise of 1/- per hoppus foot on stumpage (Table A.13). Table A.9 shows that the optimum rotation age for both Scots pine and Sitka spruce does not change by more than 5 years for an increase in one yield class. Thus it is unlikely that a significant change in the optimum rotations would be required with a variation in the local stumpage price-size relationship for the region.

(4) Finally in Table A.12 the periodical costs are changed and the discount rate on the costs is taken as 5 per cent and on the revenue as 3½ per cent. The table assumes the crops are continued in perpetuity. Thus with a fixed annual maintenance charge, this cost has no effect on the optimum rotation length.

These examples show the optimum rotation length is relatively insensitive within the order of variations given in Tables A.9, A.11 and A.12 and to discount rates of 3½ per cent and over. In addition these partial analyses indicate that the optimum rotations of Table A.9 are unlikely to be significantly changed by the actual variations or differences experienced in the region from those assumed in the drillbook. Hence the figures in column 5 of Table 5.2 p. 28 were derived from Table A.9 and used in the forecast model for all Post 1900 crops.

The Felling Period: Pre 1900 growing stock. In terms of sizes and quality, this is a heterogeneous crop with a low current annual volume increment. The felling period selected should take account of: (a) its future marketability, (b) the capacity and life of the existing sawmilling industry and (c) the effects on the growers' income.

It is a small resource in terms of the size of future sawlog supplies within the region. The future sawlog supplies are predicted (Table A.3(b)) to exceed 8 million hoppus feet (OB) per annum by the end of this century, i.e. the total standing volume of the Pre 1900 growing stock today is equivalent to 3 to 4 years' sawlog supplies by the year 2000. Post 1900 sawlogs are in smaller size assortments and more uniform than the pre-1900 supplies. The growing quantity and quality of this new source of sawlog supplies should be sufficient to stimulate new sawmill investment with equipment unlikely to be suitable for processing the old Pre 1900 sawlogs. Much of the equipment in the existing sawmilling industry is 10 to 20 years old. It is doubtful if it can continue as a viable industry for very long. Thus on the question of marketability, beyond 1990 the position of the Pre 1900 crop is very uncertain.

The capacity of the present sawmilling industry is between 4·3 and 5·7 million hoppus feet (OB) of roundwood per annum on a single shift basis (P.E. Consultants 1969).

The price for quality ~~income~~ on the Pre 1900 crop will not necessarily increase. The net annual income will vary between growers since this crop is unevenly distributed between owners. For those growers who own Pre 1900 growing stock, the return on the capital tied up in it is low. As Lorraine-Smith (1969) writes: 'A policy designed to maintain a timber reserve for estate duties is difficult to operate over a long period due to the uncertainty in the timing of death and as a general rule a better course is obtained by increasing productivity and making use of more orthodox financial benefits.'

For long term planning purposes it makes little difference whether this crop is cut over a 10 or 20 year period. Because of the uncertainty in the long term market and the duration of the present sawmilling industry it would be unwise to anticipate holding any part of this crop beyond 20 years. In addition the financial value to the growers in keeping this crop beyond the minimum period required to market it satisfactorily is doubtful. The selection of a 20-year period has been chosen arbitrarily and the decision is based on the hypothesis that this is the longest time reasonably available in which to harvest this crop.

Felling Yields. The Felling Forecast Tables (FC 1966) like the Thinning Forecast Tables, make the 15 per cent allowance previously discussed p. A7. The incidence of the principal pathogens in the region, Fomes annosus and Peridermium pinii, and their affect on production could be incorporated into a more sophisticated forecast than the present one. The loss in production through these pathogens and the probability of windblow losses has yet to be measured.

There would be little point in going further however until the yield classes and the actual stocking of the combined estate has been more accurately assessed. The Felling Forecast Tables have been used in the production forecasts of the Post 1900 crops (Table 5.3 p. 31). The accuracy of the predictions from the Felling Forecast Tables (in addition to what is said above on the 15 per cent allowance) depends largely on the degree of correspondence between the actual treatment and the assumed treatment in these tables.

The Pre 1900 felling yields were calculated as follows:

1. Assumed current annual increment = 1 per cent per annum.

2. Total standing volume (as in September 1965) = 31·2 Million Hoppus Feet (OB).

3. Over felling period.

(a) annual increase in volume due to increment

$$= \frac{31{\cdot}2 \times {\cdot}01}{2} = 0{\cdot}156 \text{ MHft.}$$

(b) total annual felling yield $= \dfrac{31{\cdot}2 + (22^{1} \times 0{\cdot}156)}{20}$

$\simeq 1{\cdot}73$ MHft. per annum.

4. 90 per cent of felled volume assumed to be in the sawlog assortment (Table A.7).

Hence annual production of sawlogs from Pre 1900 crop = 1·56 MHft.(OB).

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1 i.e 22 = 1990 - 1968

Table A.1 CONIFEROUS HIGH FOREST BY OWNERSHIP, SPECIES AND P. YEAR CLASS, 1968.

(a) PRIVATE WOODLANDS

	P. Year Class					Acres			
Species Group	Pre 1871	1871-1900	01 - 20	21 - 30	31 - 40	41 - 50	51 - 60	Post 1960	Total
Pines	3619	3949	3160	6233	5201	5022	15092	14354	56,630
Larches	8	84	139	318	359	357	1141	637	3,043
Spruces		1	32	72	38	347	4028	4448	8,966
Other Conifers	71	108	124	118	112	262	270	1251	2,316
TOTAL	3698	4142	3455	6741	5710	5988	20531	20690	70,955

(b) FORESTRY COMMISSION, WOODLANDS

	P. Year Class				Acres			
Species Group	Pre 1900	01 - 20	21 - 30	31 - 40	41 - 50	51 - 60	Post 1960	Total
Pines	1339	916	6807	4343	6702	24072	15200	59,379
Larches	34	176	579	302	1124	2979	1105	6,299
Spruces	10	51	1546	1113	3387	5055	4472	15,634
Other Conifers	2	60	533	129	262	1130	672	2,788
TOTAL	1385	1203	9465	5887	11475	33236	21449	84,100

Source: P.E. Consultants (1968)

Table A.1 (Contd.)

(c) ALL WOODLANDS

	P. Year Class				Percentage			
Species Group	Pre 1900	01 - 20	21 - 30	31 - 40	41 - 50	51 - 60	Post 1960	Total
Pines	96·6	87·5	80·5	82·3	67·1	72·8	70·1	74·8
Larches	1·4	6·8	5·5	5·7	8·5	7·7	4·1	6·0
Spruces,	-	1·7	10·0	9·9	21·4	17·0	21·2	15·9
Other Conifers	2·0	4·0	4·0	2·1	3·0	2·5	4·6	3·3
TOTAL	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0

Table A.2. PRIVATE WOODLANDS PLANTING RECORD AND FORECAST 1960-1985

	P. Year Class			Percentages		
Species Group	1961 - 65	66 - 70	71 - 75	76 - 80	81 - 85	TOTAL
Pines	70·1	64·4	52·6	54·2	50·4	61·6
Larches	3·4	3·4	7·4	9·0	9·3	5·3
Spruces	19·7	25·2	30·3	32·2	36·0	26·3
Other Conifers	5·8	7·0	9·7	4·6	4·3	6·8
TOTAL (a) Per Cent	100·0	100·0	100·0	100·0	100·0	100·0
(b) Acres	12,366	13564	9158	4135	3497	42,720

Source: P.E. Consultants (1968)

Table A.3. PLANTING RATES FROM 1961 - 2010

Source	P. Year Class 1961-70	1971-80	1981-90	1991-2000	Acres 2001-2010
1. P.W. Estimates[1]	25,900	13,000	-	-	-
2. F.C. Estimates[2]	30,000	2,100	-	-	-
3. Crop Replacements					
(a) Pre 1900		4,500	4,500		
(b) 1901-20	-	-	4,600		
(c) 1921-30	-	-	-	14,000	2,000
(d) 1931-40	-	-	-	-	11,000
4. TOTAL	55,900	19,600	9,100	14,000	13,000
5. ADJUSTMENT	-	+ 400	+5,900	+1,000	+2,000
6. ADOPTED PLANT RATE	55,900	20,000	15,000	15,000	15,000

1. Private Woodland Planting Record and Forecast (P.E. Consultants 1969)
2. Forestry Commission (P.E. Consultants 1969)

Table A.4. 1965 CENSUS: CONIFEROUS HIGH FOREST BY SPECIES AND P. YEAR CLASS, PRIVATE WOODLANDS

	P. Year Class								Acres
Species Group	Pre 1861	1861-1900	01-10	11-20	21-30	31 - 40	41 - 50	51 - 60	61 - 65	Total
1. Pines	7002	12021	872	3195	5445	4469	4480	25198	10319	73001
2. Larches	201	360	8	127	224	154	157	880	374	2485
3. Spruces	49	56	-	62	174	151	736	3044	3876	8148
4. Other Conifers	-	-	-	41	28	57	41	187	2185	2539
5. Total	7252	12437	880	3425	5871	4831	5414	29309	16754	86173

Table A.5. 1965 CENSUS: CONIFEROUS HIGH FOREST BY DEGREE OF STOCKING AS PERCENTAGES. PRIVATE WOODLANDS

	P. Year Class					Percentages
Degree of Stocking	Pre 1861	1861-1900	1901-1920	1921-1940	1941-1965	Total
1. Grossly Overstocked	-	-	2·3	2·5	0·6	0·7
2. Overstocked	46·5	65·4	49·8	75·4	1·6	26·2
3. Average	37·7	34·5	47·4	21·5	97·3	71·4
4. Understocked	15·8	-	0·5	0·6	0·5	1·7
5. Grossly Understocked	-	0·1	-	-	-	-
6. Total (a) By Per Cent	100·0	100·0	100·0	100·0	100·0	100·0
7. (b) By Acres	7252	12437	4305	10702	51477	86173

Source: G.M.L. Locke (1968)

Table A.6. 1965 CENSUS: CONIFEROUS HIGH FOREST BY STEM STRAIGHTNESS AS PERCENTAGES PRIVATE WOODLANDS

	P. Year Class				Percentages	
Stem Straightness Class	Pre 1861	1861-1900	1901-1920	1921-1940	1941-1965	Total
1. 76% and over	20·3	42·7	92·7	75·2	99·1	81·1
2. 51-75%	68·9	51·3	6·5	24·4	0·4	16·8
3. 26-25%	10·8	6·0	0·4	0·4	0·5	2·1
4. 0-25%	-	-	0·4	-	-	-
5. Total (a) By Per Cent	100·0	100·0	100·0	100·0	100·0	100·0
6. (b) By Acres	7252	12437	4305	10702	51477	86173

Source: G.M.L. Locke (1968)

Table A.7. 1965 CENSUS: TOTAL STANDING VOLUME BY SPECIES, P. YEAR GROUPS AND ASSORTMENTS

			P. Year Class						Millions H. ft. (OB)
Species Group	Assortment Category	Pre 1861	1861-1900	01-10	11-20	21-30	31-40	41-50	TOTAL
1. Pines	S.R.W.	1·1	6·5	1·3	4·3	11·0	7·8	1·2	33·2
2.	S.L.	22·9	45·2	1·8	5·4	4·0	0·6	-	79·9
3. Larches	S.R.W.	-	0·3	-	0·2	0·3	0·4	0·1	1·3
4.	S.L.	0·3	2·7	-	0·2	0·5	0·1	-	3·8
5. Spruces	S.R.W.	-	-	-	0·1	0·2	0·2	0·1	0·6
6.	S.L.	0·5	0·2	0·1	0·2	0·2	0·2	0·1	1·5
7. Other Conifers	S.R.W.	-	-	-	0·1	0·1	0·1	-	0·3
8.	S.L.	0·1	-	-	-	-	-	-	0·1
9. Total	S.R.W.	1·1	6·8	1·3	4·7	11·6	8·5	1·4	35·4
10.	S.L.	23·8	48·1	1·9	5·8	4·7	0·9	0·1	85·3

Source: G.M.L. Locke (1968).

N.B. Assortment Categories: S.R.W. is small roundwood below 7 ins. top diameter (OB)
S.L. is sawlogs with minimum top diameter 7 ins. (OB).

Table A.8. 1965 CENSUS: YIELD CLASS DISTRIBUTION BY SAMPLE AREA.

(a) Scots Pine Yield Class Distribution by Age, Class and Area.

P. Year Class	Yield Class by area in acres										Total Area	Weighted Y.C.
	240	220	200	180	160	140	120	100	80	60		
1. 51-60							13				13	120
2. 41-50					8	189	587	315	131		1230	114
3. 31-40					41	87	2695	752	315	292	4183	110
4. 21-30							1990	1702	1269	181	5142	102
5. 01-20						13	881	597	2266	886	4643	87
6. TOTAL					49	289	6166	3366	3982	1359	15211	100

(b) Species Groups: Yield Class Distribution

Species Group	Yield Class by area in acres										Total Area	Wt. Y.C.
	240	220	200	180	160	140	120	100	80	60		
1. Pines					49	289	6166	3366	3982	1359	15211	100
2. Larches							165	160	193	114	648	92
3. Spruces	113	-	16	24	65	104	70	199	147	12	750	134
4. Other Conifers	-	-	-	-	57	47	12	-	-	20	136	135

Source: G.M.L. Locke, 1969.

Table A.9. ECONOMIC ROTATIONS OF THE PRINCIPAL SPECIES IN THE REGION.

General Yield Class	Years			
	S.P.	N.S.	S.S.	E.L.
1. 140	65	65	55	-
2. 120	65	65	60	45
3. 100	70	70	60	50
4. 80	70	70	65	50

Sources: Johnston et al. (1967) and G.M.L. Locke (1969).

N.B. S.P. = Scots Pine. N.S. = Norway Spruce
S.S. = Sitka Spruce. E.L. = European Larch.

Table A.10: SITKA SPRUCE Y.C. 120: VARIATION IN THE OPTIMUM FELLING AGE WITH A CHANGE IN THE DISCOUNT RATE.

Discount Rate per cent	Optimum Rotation (years)
2	90
$3\frac{1}{2}$	60
5	55

Source: Johnston et al.(1967).

Table A.11: SITKA SPRUCE Y.C. 120: VARIATION IN THE OPTIMUM FELLING AGE BETWEEN A SINGLE ROTATION AND PERPETUITY.

Rotation Assumption.	Optimum Rotation (years)
Single Rotation	60
Perpetuity	55 - 60

Source: Johnston et al. (1967).

Table A.12. SITKA SPRUCE Y.C. 120: VARIATION IN OPTIMUM ROTATION LENGTH WITH EXPENDITURE

Expenditure Assumptions			Optimum Rotation Years
Type	Time	Amount	
1.(a) Establishment	Y.0	£50	60
(b) Brashing	Y.20	£20	
2.(a) Establishment	Y.0	£10	50 - 55
(b) No Brashing	-	-	

(1) Y.O. Means year zero

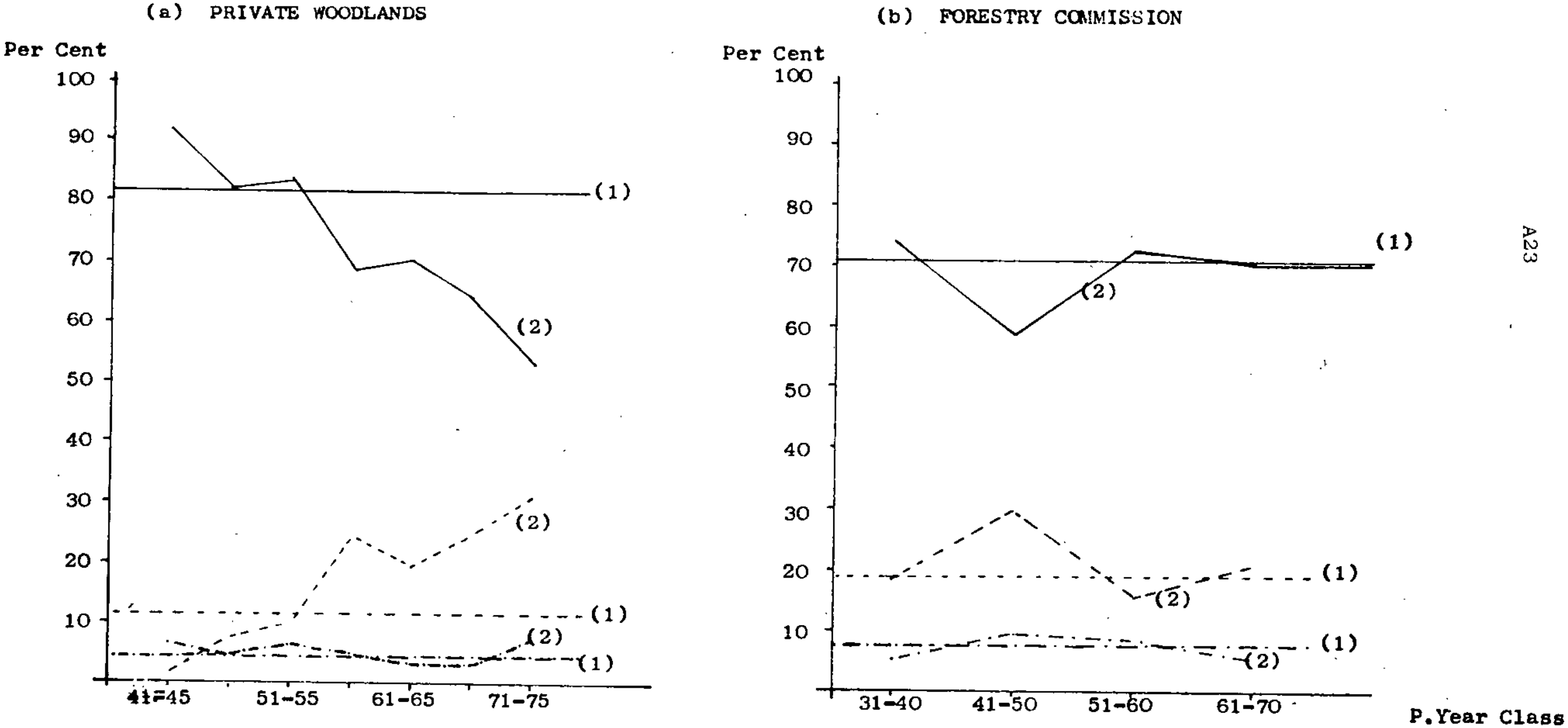
Table A.13. VARIATION OF DISCOUNTED REVENUE WITH YIELD CLASS.

Yield Class	Discounted Revenue in Perpetuity, 3½% Discount Rate.	Adjustments for Change in Price Level. 2d. per Hoppus Foot.
1. 80	55	5
2. 100	80	5
3. 120	110	10
4. 140	140	10

Source: Johnston et al. (1967).

FIGURE A.1

PLANTING PROPORTIONS BY PRINCIPAL SPECIES



NOTE : ——— PINES
- - - - - SPRUCES
-·-·-·- LARCHES

(1) --- Overall Average Proportion for All Age Classes
(2) --- P.Year Class Average

APPENDIX B

THE CONSTRUCTION OF HYPOTHETICAL MILL MODELS: HARDBOARD MILLS AS A STUDY EXAMPLE

APPENDIX B

THE CONSTRUCTION OF HYPOTHETICAL MILL MODELS: HARDBOARD MILLS AS A STUDY EXAMPLE.

The object in constructing hypothetical mill models is: (1) to evaluate the competitive ability of a given forest processing plant (a) within its own industry, and (b) with other forest industries; (2) to determine the optimum allocation of a given quantity of raw wood supplies to a group of forest industries. The analysis requires a knowledge of possible improvements in technology or productivity, and of the influence of scale.

With relatively few modern processing mills in Britain, there is very little relevant economic material available for analysis. Where local feasibility studies and evaluations are lacking it is necessary to examine the experiences and practices elsewhere, although such a course raises its own problems. The derivation of a series of hypothetical hardboard mill models brings out the practical difficulties in these circumstances.

Building Hypothetical Mill Models

Conceptual and practical problems arise in the construction of mill models; not only are there numerous possible combinations, but the results depend on the sources of information; the detail of the cost estimates; the type of technology considered and so forth. Subjective, sometimes even arbitrary decisions are inevitable and make the chosen models depend more often upon the experience and reputation of the estimator or consultant than on calculated probabilities of accuracy. Methods of cost estimation are not usually subjected to the rigorous approach of the scientist or mathematician and are frequently hindered by the lack of standardization in definitions and cost allocation procedures (Bauman, 1964). Time and location further complicate cost estimation so that considerable differences occur in the total plant erection costs from one site to another in Britain, or even between one job and another on the same site owing to different circumstances (Eady and Boyd, 1964, p. 154).

Hardboard Production Processes.

In 1963 there were conflicting opinions on hardboard technology, particularly on the relative economics of the dry and semi-dry processes compared to the wet process (F.A.O., 1966, p. 111). More recent evidence (Difibrator, 1967) indicates that the wet process is more suitable where coniferous raw materials predominate.[1]

The Economics of Wet-Process Hardboard Mills: Sources of Information.

Two papers contain relevant economic data: (1) "The Forestry Commission Board Mill Survey (1959)" by Sandwell

1. In 1966 Difibrator (1966) estimated there were 233 hardboard mills in production throughout the world. Difibrator (1967) has built or had on order 153 hardboard mills, of which there were 4 dry process mills based on hardwoods, one wet-dry process mill for bagasse and the remainder wet process mills.

and Company Limited and (2) "The Influence of Mill Capacity Upon Investment and Manufacturing Cost" by A. Asplund (1963?) of Difibrator A.B. The figures contained in these papers relate to locations in the United Kingdom in 1958 and Sweden in 1963; for the sake of brevity they are referred to as Sandwell (1958) and Asplund (1963). In addition only the hardboard mill figures relating to a location in the north of Scotland (Sandwell, 1958) are taken. In themselves they are insufficient for the models which require an up-to-date presentation of the cost structures and the economies of scale to be gained in hardboard production. There are two stages in the model building; firstly to bring the Sandwell (1958) figures into 1968 terms and secondly to estimate the costs for other mill capacities. A basic point to consider beforehand is whether Sandwell and Asplund refer to similar technologies. Tables B.1(a) and B.1(b) present a comparison between the factor input costs and quantities of the 77·4 MTPD[1] Sandwell (1958) mill with the 90 MTPD Asplund (1963) mill. The value of the raw wood materials is excluded since it is subject to a wide variation in price depending on the quality and the composition[2] of the raw material. In Table B.1(b) there is a wide variation in the quantity of raw wood materials required to produce one metric ton (MT) of hardboard. The

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1. 77·4 metric tons per day (MTPD) is equivalent to 70 long tons per day (LTPD).

2. i.e. in what proportions roundwood:slabs:sawdust, are.

reason for the disparity between these figures is not known, nor can the difference between the capital investment per ton of annual output (per yearly ton) be explained entirely.[1] A comparison between chemical requirements is not valid since they are presented as different compounds by Sandwell and Asplund.

Although there are these differences, it is assumed that the figures in Tables B.1(a) and B.1(b) are sufficiently close to indicate similar technologies. This suggests that hardboard mills of different capacities will tend to use the same ratios of factor inputs in Great Britain as are used in Sweden. Upon this hypothesis the hardboard mill models are constructed.

Hardboard Mill Model Production Costs.

For the purposes of this study, production costs are considered to include the following costs elements:

(a) Chemical materials

(b) Other materials (excluding wood)

(c) Fuel (cost of coal used in steam generation)

(d) Electric Power

(e) Labour

(f) Administrative Operating costs (administrative and supervisory salaries, insurance, property tax, communications and contingencies)

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1. Parity in the currencies' purchasing powers, a slight difference in the number of operating days per year, and a decrease in capital requirements with increase in capacity may contribute; but the time factor and the relative labour inputs required in production would tend to have the opposite effects.

(g) Interest on Working Capital

(h) Amortization and capital interest charges.

The notable exclusion from this list is the cost of raw wood materials. Since the intention is to derive its maximum value at mill using the models, it is unnecessary to consider it here as a separate element. Apart from this exception, these cost elements broadly correspond to those given by Asplund (1963, Table III), and the most important of these are labour; administrative and overheads; and amortization and capital interest charges (see Table B.1(a)), which together form up to two-thirds of the total production costs. The labour and the administrative and overhead elements are roughly estimated in the following model building procedures since the calculations involved are time consuming, but fairly straightforward. In contrast, the amortization and capital interest element is the most difficult to estimate; it is the largest single cost element and is subject to the most important cost changes with increase in mill capacity. Hence more care must be taken in its estimation.

Owing to the categories of costs recognised by Sandwell (1958) and Asplund (1963) it has been necessary to vary the usual distinctions made between various types of cost element (i.e. direct, indirect and fixed costs). Throughout this present investigation the relevant cost elements from Sandwell (1958) have first been brought to 1968 values. Subsequently the relative costs of factor combinations for other mill capacities are used in conjunction with these revised Sandwell figures to estimate the cost structures of the final models. It is basically an empirical approach in which relative rather than absolute accuracy is sought. The direct costs[1] (chemicals, fuel, electricity and plant supplies) and working capital, an indirect cost, are taken as constant unit costs for all capacities above 77·4 MTPD[2] Labour, the other indirect cost element, changes significantly as a unit cost at all capacities.[3] In such circumstances, the ratio of costs at different capacities to a specified mill capacity is calculated and by interpolation the corresponding ratio for a 77·4 MTPD mill is obtained. Subsequently the unit costs for all mill capacities may be estimated by using the derived 1968 unit cost and this ratio of the 77·4 MTPD mill. In practice, supervision and administration salaries are combined with the labour costs before the ratios are calculated from Asplund's (1963, Table III, row 17) figures and then applied to one element called: "Labour, Administration and

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1. These are the same per ton of product in a given mill, regardless of the operating rate. They tend, however, to vary slightly with mill capacity and board size as a result of operating efficiency and yield (Sundelin and Maskinaffär, 1958); as can be seen in Asplund's (1963, Table III) figures.

2. For capacities below 77·4 MTPD, the estimates are made by the technique used to estimate changes in labour and salary costs (p. B24).

3. The unit cost of labour per metric ton is 38 per cent lower in a 360 MTPD mill than a 90 MTPD mill (Asplund, 1963, Table IV).

Overhead". This element includes certain fixed costs (insurance, property taxes and sundry overheads) which cannot be taken into account in the ratios owing to Sandwell's (1958) presentation of costs. A reasonable result can be expected, however, since labour wages, supervision and administrative salaries togethr form over 90 per cent of this element. The remaining fixed cost element, amortization and capital interest charges, is converted to a unit cost by dividing throughout by the corresponding annual production of each mill.

Before calculating the unit production costs, the cost of capital and the total capital investment requirements must necessarily be evaluated. This will be done in the sections following.

The Cost of Capital

There has been much controversy[1] over the definition

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1. Jääskeläinen (1966) considered there was no explicit and generally acceptable account of what is the correct conceptual approach to its measurement. His summary of economists' views shows the conflict that exists:
   (a) equivalent to: "the preferred maturity of outside riskless investment (government bonds)"
   (b) equivalent to: "the external yield available on outside investments having (subjectively) similar risks"
   (c) : "the current earnings yield on common stock is the proper discount rate when no debt is outstanding", or where outside financing used: "a current-market-value weighted average cost of debt and equity capital".
   (d) : "the rate at which current and future dividends are capitalized".
   (e) : "the long run average return on past investments".

and measurement of the cost of capital to a firm, and it certainly has no unique or constant value even for a single firm. A simple and neat definition of the cost of capital funds is: "the net burden of paying for them" (Merret and Sykes, 1963, p. 51). It is a function of the sources of finance available and the financing policy pursued (e.g. the debt-equity ratio desired and the percentage of earned income distributed).

As the hypothetical models represent a "generalized" situation, the cost of capital is based on the average finance structure of public quoted companies in Great Britain (Merret and Sykes, 1966, Table 4.1, p. 31). It is assumed that the capital investment requirements of the models are obtained from financial sources in the same proportion and that the rate of return required to meet the cost of each type of capital has been correctly estimated by Merret and Sykes (1966, Table 4.1, p. 31); on this basis the net burden or weighted cost of capital is 10·46 per cent[1] in money terms (the models are considered to be normal risk investments). To simplify calculations, the cost of capital is taken as 10 per cent throughout the following study. It must be appreciated, however, that this historical approach is only suitable in a general appraisal of the cost of capital. In contrast, the cost

1. i.e. (·260 x 14 + ·524 x 11·5 + ·216 x 3·7) = 10·46. N.B. It makes a negligible difference but a 42·5 per cent corporation tax rate is assumed in the above calculation, instead of the 40 per cent rate used by Merret and Sykes.

of available funds existing (or anticipated) at that point in time would have to be appraised for any project which is definitely proposed.

Total Mill Capital Investment Requirements.

The total capital needed to establish a new industrial plant consists of three elements:

(i) Installed plant costs. These include all equipment and structures, mill site, engineering and administration costs.

(ii) Interest on capital during construction.

(iii) Working capital.

The amortization charge depends directly upon the values of the first two elements; these are evaluated in the following discussion.

(a) Investment Cost - Capacity Relationships. From the figures for hardboard mills (Asplund, 1963, Table II, rows 8-11) between 90 and 360 MTPD the capital investment in machinery and equipment, building structures, labour and interest are given as separate elements; all tend to be straight line functions of mill capacity. This finding conforms with previous investigations[1] which show similar relations to exist in other forest industries and processing plant. For the present purposes it is more convenient to work with cost ratios in order to avoid an

1. Coolidge and Pfeiffer (1956); Sundelin and Maskinaffär (1958).

evaluation of the cost function below 90 MTPD. Hence the cost ratios in terms of a 90 MTPD mill are presented in Table B.2 and Figure B.1, based upon these figures by Asplund. If the F.A.O. (1966, Table IV-12, p. 109) figures quoted in U.S. dollars for the estimated capital investment requirements of Scandinavian hardboard mills are ratioed in terms of the 25,000 metric tons per annum[1] (MTPA) mill, the results indicate that these estimates were derived from the same source as the Asplund (1963) figures[2]: both the 35,000 MTPA mills quoted by F.A.O. (1966) and Asplund (1963) are 8·6 per cent less than the capital investment - capacity function; this suggests they have a common source although it is not acknowledged. A variation in mill investment costs of 8·6 per cent from the general investment-capacity function is well within the bounds of accepted accuracy for preliminary or pre-design cost estimates (White, 1965, p. 510).

The total capital mill costs for different mill sizes in the U.K. could be calculated rapidly using the above ratios once one estimate had been established. But such

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1. i.e. this is equivalent to a 90 MTPD mill.

2. The F.A.O. capital investment ratios are 1:1·17:2·03 for the 25,000, 35,000 and 60,000 MTPA mills respectively. When these ratios are plotted as functions of their capacities, they correspond exactly with the total installed plant ratios in Figure B.1.

a procedure would increase estimating errors, if there is any relative difference in the weighting of machinery, building, labour, interest and overhead costs between Sweden and the U.K. The capital cost structures of the Sandwell (1958) mills are compared with those of mills of corresponding sizes given by Asplund (1963) in Table B.3. Owing to differences in the layout of costs by Sandwell and Asplund, the figures are not directly comparable. Row 4 of Table B.3 includes "Other Costs" (Overheads and contingencies) for the Sandwell mills only, while Asplund's mill capital costs are attributed directly to machinery, buildings and sundry.[1] The distribution of Sandwell's "Other Costs" would probably bring the machinery, buildings and labour plus interest elements in his mills much nearer to the cost structures shown in the Asplund mills in Table B.3. The directions in which the relative cost structures change are opposite (Table B.3). In theory the reverse trends would be expected in the Sandwell mill cost structures.

The ratio of the total capital costs of the 38·7 MTPD mill to the 77·4 MTPD mill, according to Sandwell (1958), are much lower than that between the two nearest Asplund mills.[2]

These comparisons are over the range of capacities in which the cost-capacity relationships show most change

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1. Sundry includes: construction and installation labour, planning costs (see Asplund, 1963, Table I) and interest during construction.

2. i.e. Capital Cost ratio of:
   (1) 38·7 to 77·4 (Sandwell) mill = 0·52.
   (2) 45 to 90 (Asplund) mill = 0·72.

relative to each other (Figure B.1), according to Asplund (1957 and 1963). Nothing conclusive can be drawn about these differences[1] except that estimates based upon ratios derived from Asplund (1963) figures may not be particularly representative of the hardboard mill capital costs in the U.K., especially at capacities below 90 MTPD. Even so, the use of ratios is the most accurate method available in the present study.

A series of mill capital costs (in 1968 terms for the U.K.) obtained by ratios developed in the next paragraph are compared with a set of results derived by an alternative method (see Table B.4 and Figure B.2). Coolidge and Pfeiffer (1956) refer to the "Six-Tenths Factor",[2] which is frequently mentioned in literature on chemical plant cost estimation: the ratios of total installed plant costs tend to approximate to the two-thirds power of the ratios of their capacity. White (1965), amongst others, says that data show this 'power' factor varies between 0·5 and 1 in practice. Consequently if the power factor is evaluated from the 1968 (Sandwell) mill figures, it can be used to estimate the approximate capital costs at other mill capacities by the same formula.[3] The differences

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1. Time and location could make the relative cost structures different, but cannot be expected to cause the opposite effects in the direction in which the relative cost structures change.
2. Also known as the two-thirds rule.
3. i.e. $C_2 = C_1 \left(\frac{P_2}{P_1}\right)^x$

   where, C_1 = Cost of known plant
   C_2 = Cost of new plant
   P_1 = Capacity of known plant
   P_2 = Capacity of new plant which will be known.

   Hence x can be found, substituting the 38·7 and 77·4 (Sandwell) mill costs: $x = \cdot 92$
   And the costs of plants (C_2), at other capacities (P_2), can then be calculated.

between the results are relatively small, except for the 38·7 MTPD mill, which indicates that a reappraisal of the costs of small mills would have to be undertaken before it can be known which function best represents their capital investment costs in the U.K.

The cost elements for the 77·4 MTPD (Sandwell) mill and the 90 MTPD (Asplund) mill are rearranged in Table B.5 to present the structures on which the capital investment requirements can be calculated. Installed machinery and building structure costs are obtained from their respective 'Total' columns. The overhead and contingencies have been left undistributed as "Other Costs" for the 77·4 MTPD (Sandwell) mill. Although the U.K. installation costs are approximately double Swedish ones, they will have little effect on the total plant investment costs; the most important difference is that machinery, relative to the total plant costs, is much cheaper in the U.K. than Sweden. Strictly speaking, the "Other Costs" make the two sets of figures not directly comparable.

Since the labour content in the installed machinery and building costs is relatively insignificant (Table B.5 ratios), a good approximation to the total (Asplund) mill costs can be obtained by multiplying the total installed costs of these two elements by their respective ratios[1] (without labour) and adding to the figures so derived the

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1. See Table B.2, rows 1 and 2.

construction interest.[1] Both the machinery and building cost ratios become straight-line functions of capacity on mills of 90 MTPD and over. Therefore these functions can readily be evaluated[2] and used to calculate the machinery and building costs for any mill capacity between 90 and 360 MTPD, instead of the graphs in Figure B.1.

Asplund does not show a set of costs equivalent to the "Other Costs" of Table B.5, hence to estimate this element at other capacities, it is assumed these costs remain as a constant proportion of the machinery and building costs combined[3] (i.e. 0·314).[4] By interpolation of the machinery and building cost ratio curves (Figure B.1), the respective ratio values of these cost elements for a 77·4 MTPD can be obtained. Thus, the installed machinery,

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1. This approximation gives a 4·1 per cent overestimate and a 0·6 underestimate of the total capital investment costs for the 270 MTPD and the 20 MTPD (Asplund) mills respectively. Such differences are insignificant by comparison with the accuracy presented in both Asplund and Sandwell's estimates which would be within ± 25% order.

2. $R_{mX} = 8{\cdot}685 \times 10^{-3}X + 0{\cdot}218$
   $R_{bX} = 9{\cdot}311 \times 10^{-3}X + 0{\cdot}162$
   where: X is a given capacity and, $90 \leq X \leq 360$ MTPD.
   R_{mX} = Machinery cost ratio at mill capacity X MTPD
   R_{bX} = Building cost ratio at mill capacity X MTPD.

3. It may be expected that as a general assumption this would tend to be true. In addition, it may be seen from the original Sandwell estimates and Table III that the proportion of overheads plus contingencies (= Other Costs) change from 23·8 to 23·1 per cent of the total investment costs on doubling the mill size. This is an insignificant change and hence supports the above assumption.

4. From Table B.5:
   Machinery and Building Costs = £760 + 290 = £1,050
   Other Costs = £330
   Therefore Ratio (R_o) = $\frac{330}{1050} = 0{\cdot}314$

buildings, and consequently other costs, may be quickly evaluated for any given size of mill.[1]

(b) Estimation of Capital Plant Cost Changes. Between 1958 and 1968, the costs of machinery, its installation, building structures etc. may be expected to have changed. The cost indices found in the general government statistical publications are either not directly relevant or incomplete for the period. Chemical and Process Engineering (C.P.E.) publishes a monthly index, which is for complete installed plants and it is used, since hardboard, along with particle board and pulp and paper mills are analogous to chemical processing plants. (Both Coolidge and Pfeiffer (1955) and Ryti (1966) make use of general chemical processing plant cost relationships for these types of forest processing industry). Eady and Boyd (1964) outline the basis of the

---

1. i.e.

(a) $R_{m77\cdot4} = 0\cdot90$, $C_{m77\cdot4} = 760{,}000$

$\therefore C_{m90} = \frac{760}{0\cdot90} = £844{,}000$

(b) $R_{b77\cdot4} = 0\cdot96$ $C_{b77\cdot4} = 290{,}000$

$\therefore C_{b90} = \frac{290}{0\cdot96} = £302{,}000$

(c) $C_{o90} = \cdot314\ (844{,}000 + 302{,}000)$
$= £360{,}000$

(d) Total mill costs (1958) for 90 MTPD mill = £1,506,000

where R_{mX} = Machinery cost ratio
R_{bX} = Building cost ratio
C_{mX} = Installed machinery costs
C_{bX} = Constructed building costs
C_o = Other costs
$= R_o(C_{mX} + C_{bX})$
R_o = constant = $\cdot314$

(e) Hence, using ratios in Table 2 (rows 1 and 2) or ratio curves in Figure B.1, total installed mill cost at any capacity between 20 and 360 MTPD may be quickly calculated; mill costs at a capacity (X) MTPD given by:-

$(R_{mX}\cdot C_{m90}) + (R_{bX}\cdot C_{b90})(1 + R_o)$

C.P.E. index of the erected process plant costs:[1] it does not include land or contractor's overheads and profits, and it assumes a weighting of the cost elements. The proportions of the weighting are approximately: mechanical plus electrical engineering (0·6), construction labour (0·2) and structures (0·2); these can be seen to have a similar order of weighting in the hardboard mill cost structures in Table B.5. No attempt has been made to take out the cost of land or the contractors' overheads and profits. This introduces a small error to the hypothetical models. The contractors' overhead and profits (if any) cannot be extracted from Sandwell (1958) estimates and site costs are left owing to their overall insignificance.[2]

Mill erection costs vary considerably (Eady and Boyd, 1964) and for the present purposes, the Sandwell (1958, p.11) figure of a 4 per cent increase in total capital costs has been adopted for the study area of N.E. Scotland. Thus, making corrections for time and location, the estimated mill capital cost (C_{TOT}) becomes:

$$C_{TOT(1969)} = C_{TOT(1958)} \times 1{\cdot}41.$$ [3]

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1. Originally there were 4 separate indices for 4 types of plant. However, there was very little variation (C.P.E. indices for 1964 = 116·4 $\pm$ 0·4, 1958 = 100) and in recent years a single index has been published to cover all chemical process plant.

2. The site cost element was less than 1 per cent of the total mill costs in the Sandwell (1958) estimates.

3. $C_{TOT(1968)} = C_{TOT(1958)} \cdot I_t \cdot I_l$
   $= C_{TOT(1958)} \cdot 1{\cdot}36 . 1{\cdot}04$

   where I_t = rise in installed plant costs 1958-1968/69 (C.P.E.)
   I_l = rise due to location in N.E. Scotland (Sandwell, 1958).

(c) Investment Grants and Allowances. Hardboard mills, in common with other forest processing industries, are eligible for investment grants and allowances (BOT (a) and (b) 1968), since the region is within a Development Area; hence the capital investment and production costs should be reduced. This gives a particularly large advantage to those new industrial plants such as hardboard mills, in which as the total mill capital investment is a major element of the production costs.[1]

For the hardboard mill models, the conditions under which the investment grant and allowances may be assumed to be payable, are taken for calculation purposes as:

(a) Machinery and Installation Costs (C_m) would attract the full rate (40 per cent) investment grant, an annual reducing balance allowance (15 per cent), but no initial allowance.

(b) Building structures, including construction labour (C_b) would obtain an initial allowance (15 per cent) and an annual straight line depreciation allowance (4 per cent), but no investment grant.[2]

(c) Other Costs (C_o). Being predominantly overhead costs there is greater doubt on the proportion of these that would be eligible and consequently no allowances are used.

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1. Asplund (1963, Table III, row 21) inclusive of wood costs, amortization and interest charges together form 24-60 per cent of the total production costs.

2. Investment grants are given for buildings (BOT (b) 1968) ranging from 25-35 per cent of total building costs. These depend however on a BOT assessment of the employment benefit yielded by the project to the area in which it is located.

(d) An 18 month delay (typical) can be expected in the payment of these grants and allowances. In addition a $42\frac{1}{2}$ per cent Corporation Tax is assumed and that there is sufficient taxable income to absorb the capital allowances fully at the time they become available (the normal situation Merret and Sykes, 1966, p. 16).

Applying the derived cost of capital (10 per cent), discount factors for each type of capital investment can quickly be evaluated[1] using present value discount tables (Merret and Sykes, 1966, Appendix Table C). The effective capital cost net of tax (ENT) (i.e. net of investment grants and tax allowances) should be used because it is that part of capital sum which would actually have to be financed with long-term capital.

Adopting the procedure outlined in pp. B9-18, rows 1 to 6 of Table B.6 present the results obtained. In addition, the capital costs of the 38·7 MTPD and 77·4 MTPD are given, updated to 1968, and for comparative purposes the capital structures without investment grants or allowance are

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1. i.e. (1) Machinery investment (C_m)
   (a) 40 per grant: θ·40 x 0·8668 = 0·34672
   (b) Capital allowances on remaining 60 per cent of installed machinery costs = 0·60 x 0·5721 x 0·425 = 0·14589
   (c) Combined present values of the grant and allowance is therefore (a) + (b) = 0·49261.
   (d) The Effective Net of Tax (ENT) capital cost is thus: $C_m(1 - 0{\cdot}49261)$ i.e. $C_m \times 0{\cdot}50739$
   (e) The discount factor (A_m) = 0·50739
   (2) Likewise, Building Investment (C_b)
   (a) Capital allowances: 0·4610 x 0·425 = 0·195925
   (b) Building ENT capital cost: $C_b\ (1 - 0{\cdot}195925)$ i.e. C_b 0·804075
   (c) The discount factor (A_b) = 0·804075.

included. The estimates of mill capital cost (1968) with allowances in row 5 include a further approximation since their calculation implies the cost indices for machinery and buildings are the same and equal to the weighted mean cost index for complete mills.[1] In practice this approximation makes no significant difference to the estimates.[2]

(d) Construction Interest. To evaluate the interest burden on capital investment during the construction period, two situations are taken to represent all mill capacities from 20 to 360 MTPD. The cost of capital remains as determined at 10 per cent.

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1. It makes the implicit assumption that:

$$C_m.I_m.A_m + C_b.I_b.A_b + (C_m.I_m + C_b.I_b)R_o \qquad (a)$$
$$= [C_m.A_m + C_b.A_b + (C_m + C_b)R_o] \times 1{\cdot}41 \qquad (b)$$
= MILL CAPITAL COST (1968)

where C_m = Cost of installed machinery
I_m = Index of installed machinery in N.E. Scotland (1968) and 1958 = 100
A_m = Installed machinery discount factor
C_b = Cost of erected buildings
I_b = Index of erected buildings in N.E. Scotland (1968) and 1958 = 100
A_b = Erected buildings discount factor
R_o = Other costs ratio = constant
$1{\cdot}41$ = Rise in installed plant costs due to time and location

This approximation will only be true if: $I_m = I_b = 141$.

2. e.g. If $I_m = 1{\cdot}57$ and $I_b = 1{\cdot}00$
Then a rise in installed plant costs due to time and location is still = 1·41 for a 77·4 MTPD mill
And, when all values are put into (a) of the previous footnote for the 77·4 MTPD mill, mill capital cost (1968) becomes: £1,298
cf. $C_{TOT(1968)}$ of Table B.6 = £1,342
i.e. $C_{TOT(1968)}$ of Table B.6 overestimates capital cost by 0·34%, for this example.

For mills up to and including 90 MTPD, the construction period and the flow of capital are based on Asplund's (1963, Table I) to obtain a cumulative interest factor of 0·1.[1] Since large mills will take longer than two years to build, a $3\frac{1}{2}$ year construction period and a series of hypothetical capital flows are assumed for mills over 90 MTPD. The evaluated cumulative interest factor is 0·17.[2]

The interest burden or construction interest (Table B.6 row 6) is therefore 10 per cent of the mill capital costs for mills up to and including 90 MTPD in capacity, and 17 per cent for those over this capacity. The effect of adding this element to the mill capital costs is to ~~discount~~ move the capital investment flows forward to year 0 (the start-up point in mill production), and it is this capital sum which is consumed during production; its replacement and

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1. Capital flows suggested by Asplund (1967, Table I) can be treated as occurring in three integral periods:
   37% capital cost between 0-12 months
   92% capital cost between 12-18 months
   100% capital cost between 18-24 months.
   Therefore total capital cost including interest
   $$= C_T[\cdot 37(1+i)^{1\frac{1}{2}} + \cdot 55\,(1+i)^{3/4} + \cdot 08(1+i)^{1/4}]$$
   $$= C_T \times 1\cdot 099 \simeq 1\cdot 10$$
   when $i = \cdot 100$ (i.e. 10%)
   Hence cumulative interest factor = 0·1.
2. Supposing (a) a $3\frac{1}{2}$ year gestation period
   (b) Capital flows of:
   20% capital cost between 0-12 months
   50% capital cost between 12-24 months
   90% capital cost between 24-36 months
   100% capital cost between 36-42 months.
   Therefore, total capital cost including interest
   $$= C_T[\cdot 2(1+i)^3 + \cdot 3(1+i)^2 + \cdot 4(1+i)^1 + \cdot 1(1+i)^{\frac{1}{2}}]$$
   And, where $i = 0\cdot 10$ (i.e. 10%)
   $$= C_T \times 1\cdot 17$$
   Hence a cumulative interest factor = 0·17.

cost, amortization and interest, is entered in Table B.6, row 7 and discussed in the next section.

(e) Working Capital is the net sum[1] financed from long-term capital that is tied up in operating a mill (Merret and Sykes, 1966, p. 140). As such it is an initial capital investment outlay which, unlike the other elements, is not subject to capital consumption.

In estimating the total sum required for the present models a conceptual problem arises: although wood material costs are not estimated, they form approximately 30 per cent of the working capital requirements (Sandwell, 1958, Appendix 4, p. 43). But the unit cost of working capital per MT of hardboard is small,[2] so that large variations in wood costs would have an insignificant effect upon total unit production costs in relative or absolute terms.

Sandwell (1958, Appendix 4, p. 43) estimates the total current assets required for a 77·4 MTPD mill to be £210,000 and for the present purposes, the working capital for this size of mill is arbitrarily assumed to be £250,000 in present day terms. Asplund (1963, Table III) indicates that working capital requirements are almost directly proportional to mill size above 77·4 MTPD. Therefore, the estimates of working capital requirements are based upon a

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1. i.e. the current assets less the current liabilities (creditors and trade bills, bank overdrafts and other short term borrowings).

2. Asplund (1963, Table III, rows 19 and 22) indicates the unit cost of working capital will be in the order of 2% of the total unit costs.

constant figure of £12·95 per annual ton of production,[1] except for mills of lower capacity than 77·4 MTPD. These smaller mills have their working capital requirements calculated by ratioing Asplund's (1963) figures in terms of the 90 MTPD mill.

To conclude this section, the estimates of the total capital mill investment in 1968 is given in Table B.6, row 9, for the range of production capacities between 20 and 360 MTPD. It is obtained by adding the figures in rows 5, 6 and 8 for each capacity respectively. Figure B.3 shows the relationship between the total capital investment requirements and mill capacity, and the effect of investment grants and allowances.

Amortization and Interest Charges.

Asplund (1963, pp. 11 and 12) considers a 10-year economic life for a hardboard mill to be a conservative estimate owing to the mature stage of development in processing reached by this industry. There is, however, an additional consideration: the uncertainty of product obsolescence due to new developments in the technologies of substituting products. On balance it should be reasonable to assume a 10 year life for the hardboard mill models in this study. This is the period over which the mill capital

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1. i.e. £ $\frac{250,000}{19,300}$ = £12·95 per MT, where 19,300 is the MTPA of board produced by the 77·4 MTPD mill (derived from Sandwell (1958) figures).

investment at start-up[1] will be consumed. Assuming 10 per cent cost of capital, a 10 year period and no terminal value, the capital investments have annuity value of 16·3 per cent (Merret and Sykes, 1966, p. 111 and Table B). This annuity, representing the combined interest and amortization charge, is used in Table B.6, row 7.

The Calculation of Unit Production Costs.

The Sandwell (1958, Appendix 2, p. 22) estimates are brought to 1968 terms in Table B.7 by the use of cost statistics from a number of sources. As estimates of 1968 costs, all elements are subject to two types of error: (a) owing to technological changes, different proportions of factor inputs may be required compared to those applicable in 1958 and (b) the use of general cost statistics may not be truly representative of these particular cost elements. Since the table is built on many assumptions, further research on determining more appropriate ~~cost~~ statistics to measure cost changes would not yield more accurate results than are presented.

The unit costs for the 38·7 MTPD (1968) mill are calculated by the same methods as given in Table B.7. Other capacities' unit costs are based on those calculated for the 77·4 MTPD (1968) mill and the changes indicated by Asplund (1963, Table III). The labour, and administrative and overhead cost elements are combined and are equivalent

1. i.e. the mill capital cost (1968) in row 5 plus construction interest in row 6 of Table B.6.

to the Asplund figures on wages and salaries.[1] To estimate the unit costs of this element at different capacities, Asplund's (1963, Table III, row 17) figures are ~~ratioed~~ expressed as ratios in Table B.8 and in Figure B.4. in terms of the unit costs of wages and salaries in a 90 MTPD mill. By interpolation of these ratios from the graph (Figure B.4), the equivalent ratio of a 77·4 MTPD mill is obtained as 1·08, and used to calculate the 90 MTPD mill unit costs of this element.[2] The unit costs for all other mill capacities is then simply estimated by multiplying the Table B.8 ratio by £8·492. The same technique is used to calculate the unit costs of the other elements, except amortization and interest,[3] for the 20 and 45 MTPD mills, whilst for capacities of 90 MTPD and over, they are held constant. With the unit production costs in Table B.9 are estimates of the maximum disposable wood prices (row 8) for each mill size. This wood price is derived from the total unit production costs (row 7) and an assumed ex-mill product price of £40 per MT[4] for

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1. The average earnings of administrative, technical and clerical employees in "Paper, Printing and Publishing Industries" between 1959 and 1967 grew at 6 per cent per annum (A.A.S. 1962, Table 146 and 1968, Table 148). The average earnings of manual workers in the Manufacturing Industries grew at 6·2 per cent per annum between 1958 and 1968 (A.A.S., 1962, Table 148 and 1968, Table 150).

2. i.e. For 77·4 MTPD mill:
   (a) Unit cost of labour and administrative and overhead element is £9·171.
   (b) Unit cost ratio is 1·08.
   Therefore, for the 90 MTPD mill the unit cost of this element is: $\frac{9\cdot171}{1\cdot08} = £8\cdot492$.

3. The amortization and interest element is calculated as a unit cost by dividing the estimates in Table B.6, row 7 (with allowances) by the total annual production.

4. cf. The average imported value (cip at wharf) of hardboard for 1968 and the first half of 1969 is £41·5 (BOT (c), 1968, 1969).

standard hardboard. Also, as a function of mill size, the maximum disposable wood price is represented graphically in Figure B.5.

The sensitivity of the maximum disposable wood price to changes in costs and prices for two sizesof mill: (a) 90 MTPD and (b) 180 MTPD are given in Table B.10. For a 5 per cent change in any one factor the corresponding change in wood prices are shown in columns (2) and (3). Since the most significant change is due to the product price, particular attention would have to be paid to its evaluation and to estimating the relative change in its value over time compared with other factors. Finally, in contrast to the figures in Table B.10, a doubling of mill size, i.e. from 90 to 180 MTPD, increases the maximum disposable wood price by 52·5 per cent.

Table B.1(a). A COMPARISON OF FACTOR COSTS BETWEEN A SANDWELL AND AN ASPLUND MILL

	77·4 MTPD Mill (Sandwell, 1958)		90 MTPD Mill (i) Asplund, 1957,		(ii) Asplund (1963)	
Factor Inputs	Annual Cost £(sterling)	Percentage of Total Annual Cost	Unit Costs per MT, 1957. Skr (Swedish Kronor)	Percentage of Total Unit Costs 1957	Unit Costs per MT, 1963 Skr (Swedish Kronor)	Percentage of Total Unit Costs 1963
1. Chemicals	99,600	18·3	7·70	3·2	9·55	3·8
2. Other Materials	34,000	6·3	10·00	4·2	12·00	4·8
3. Heat (Coal)	30,000	5·5	52·50	21·9	27·30	10·8
4. Electric Power	66,200	12·2	27·50	11·5	27·50	10·9
5. Labour	49,800	)	) 58·00	)	) 71·40	)
6. Administration and Overhead	42,000	) 19·4	) + 5·20	) 26·4	) + 5·80	) 30·6
7. Contingencies	13,400	)	-	)	-	)
8. Interest on Working Capital	21,000	3·9	7·76	3·2	7·95	3·2
9. Amortization and Interest	187,500	34·5	71·08	29·6	90·88	36·0
10. TOTAL	£543,500	100·0	239·74	100·0	252·38	100·0

Sources: Sandwell (1958), Asplund (1957) and (1963).

Table B.1(b). A COMPARISON OF FACTOR QUANTITIES BETWEEN A SANDWELL AND AN ASPLUND MILL

Factor Inputs	77·4 MTPD Mill	90 MTPD Mill	
	Quantities	Quantities	
	(Sandwell, 1958)	(Asplund, 1957)	(Asplund, 1963)
1. Chemicals	62·7 Kg per MT.	15·7 Kg per MT.	19·5 Kg per MT
2. Heat	2·0 G cals per MT	?	2·1 G cals per MT
3. Electric Power	541 KWh per MT	550 KWh. per MT	550 KWh. per MT
4. Wood	3·29 m^3 per MT	2·8 m^3 per MT	4·65 m^3 per MT
5. Labour	74 men	80 men	74 men
6. Capital Investment per annual ton.	£71·5	£36[1]	£46[1]

1. NOTE: Based on the official (pre 1967 devaluation) rates i.e. Skr 14·5 = £1.

Sources: Sandwell (1958). Asplund (1957) and (1963).

Table B.2. INVESTMENT COST-CAPACITY RATIOS OF ASPLUND'S HARDBOARD MILLS

Investment Element	MTPD 20	45	90	125	180	270	360
	COST RATIOS						
1. Machinery & Equipment	·57	·67	1·00	1·20	1·78	2·57	3·35
2. Buildings	·78	·84	1·00	1·05	1·86	2·65	3·51
3. Labour and interest in construct.	·69	·78	1·00	1·10	1·46	1·94	2·43
4. Total Installed Plant Cost	·64	·72	1·00	1·16	1·75	2·49	3·25

Source: Asplund (1963).

Table B.3. A COMPARISON OF MILL CAPITAL COST STRUCTURES BETWEEN SANDWELL AND ASPLUND MILLS

Cost Element	Cost Element ÷ TOtal Investment Cost				
	Sandwell		Asplund		
	38·7 MTPD	77·4 MTPD	20 MTPD	45 MTPD	90 MTPD
1. Equipment & Machinery	0·503	0·469	0·564	0·581	0·629
2. Building Structure Materials	0·122	0·147	0·273	0·257	0·222
3. Labour plus Construction Interest	0·136 ~~0·116~~	0·154 ~~0·119~~	0·163	0·162	0·150
4. Other Costs	0·238	0·231	-	-	-

Source: Sandwell (1958), Asplund (1963).

Table B.4. ESTIMATES OF HARDBOARD MILL CAPITAL INVESTMENT COSTS BY TWO ALTERNATIVE METHODS

	Mill Capacity		£'000			Difference as Percentage of Method (1)
			Estimate Method		Difference [(1) - (2)]	
	MTPD	LTPD	(1) Cost Ratios	(2) 'Power' Factor '		
1.	38·7	30	1120	760	+ 360	+ 32
2.	77·4	70	1476	1476	- 0	0
3.	116·1	100	1980	2177	- 197	- 10
4.	154·8	130	2560	2867	- 307	- 12
5.	193·5	160	3180	3550	- 370	- 12
6.	232·2	190	3790	4229	-439	- 12
7.	276·9	220	4380	4900	- 520	- 12
8.	348·3	250	5000	5569	- 569	- 11

' See explanation on p. B12 & White (1965)

Table B.5. THE 77·4 MTPD (SANDWELL, 1958) MILL AND THE 90 MTPD (ASPLUND, 1963) MILL COST STRUCTURES

Cost Element	Total costs in '000 Skr and £ and Ratios											
	77·4 (Sandwell) Mill						90 MTPD (Asplund) Mill					
	Labour		Materials		Total		Labour		Materials		Total	
1. Machinery	90	·063	670	·469	760	·531	550	·033	10505	·629	11055	·662
2. Buildings	80	·056	210	·147	290	·203	1000	·060	3700	·221	4700	·281
3. Other Costs	60	·042	280	·196	330	·231	-	-	-	-	-	-
4. Construction Interest	-	-	-	-	50	·035	-	-	-	-	950	·057

Source: Sandwell (1958, Appendix 3 pp. 33-34) and Asplund (1963, Table I).

Table B.6. TOTAL MILL CAPITAL INVESTMENT REQUIREMENT FOR HARDBOARD MILLS OF DIFFERENT CAPACITIES

£'000

Cost Element	Capacities (MTPD) 20		45		90		180		360		38·7[1]		77·4[1]	
Allowances	With	W/O	With	W/O	With	W/O	With	W/O	With	W/O	With	W/O	With	W/O
1. Machinery (C_m)[2]	244	481	287	565	428	844	763	1503	1432	2823	213	420	386	760
2. Buildings (C_b)[3]	190	236	204	254	243	302	446	555	635	1061	101	125	233	290
3. Other Costs (C_o)[4]	230	230	263	263	360	360	646	646	1220	1220	175	175	330	330
4. Mill Capital Cost (1958)	664	947	754	1082	1031	1506	1855	2704	3487	5104	489	720	949	1380
5. Mill Capital Cost (1968)	939	1339	1066	1530	1458	2129	2623	3823	4930	7217	691	1018	1342	1951
6. Construction Interest	94	134	107	153	146	213	446	650	838	1227	69	102	134	195
7. Amortization and Interest	168·4	240·1	191·2	274·3	261·5	381·7	500	729	940	1376	123·9	182·6	240·6	349·8
8. Working Capital	115	115	188	188	324	324	648	648	1295	1295	150	150	250	250
9. Total Investment (1968)	1148	1588	1361	1871	1928	2666	3533	4853	6718	9234	910	1270	1726	2396

1. Note: These estimates are based directly on the Sandwell (1958) figures (Cf. estimates for all other mill capacities are calculated using cost ratios).

2. $(C_m) = C_{m90} \cdot R_{mX}$

3. $(C_b) = C_{b90} \cdot R_{bX}$

4. $(C_o) = (C_m + C_b)R_o$

Table B.7. 1968 PRODUCTION COSTS FOR A 77·4 MTPD MILL: ORIGIN OF COST CHANGE AND CALCULATION

Cost Element	Origin of Cost Change (Year, Index, Base, and Definition)	Comments and Calculations with 1958 Costs for a 77·4 MTPD Mill	1968 Costs for 77·4 MTPD Mill: Annual Total (£)	1968 Costs for 77·4 MTPD Mill: £ per unit (MT) of production
1. Chemicals	BOT (a)(1969, Tab. 3a, 271 (General Chemicals) 1958 107·7 1954 = 100, 1958 SIC. 1963 99·5 " " " " 1968 102·9 1963 = 100, 1968 SIC.	Indices linked: $99,600 \times \frac{102 \cdot 9}{108 \cdot 2}$	94,000	7·161 (1 and 2)
2. Other Chemicals	30 per cent cost rise arbitrarily assumed	Element not specifically defined by Sandwell. 34,000 x 1·30	44,200	
3. Fuel (Coal)	BOT (a)(1969, Tab. 3a. 101 Coal) 1958 137·6 1954 = 100, 1958 SIC. 1963 153·7 " " " " 1968 112·8 1963 = 100, 1968 SIC.	Indices linked $30,000 \times \frac{112 \cdot 8}{89 \cdot 5}$	37,800	5·891 (3 and 4)
4. Electric Power	Min. Power Stat. Dig. (1968, Tab. 9b, Aver. Net Selling Price of Electricity to Factories). Pence per KWh. 1958 1·335d. 1967 1·514d.	Average increase in 10 years. (1958-1967): $\frac{1 \cdot 514}{1 \cdot 335} \div 10 = 1 \cdot 34$	75,900	

[Contd.

Table B.7 (Contd.)

Cost Element	Origin of Cost Change (Year Index Base and Definition)	Comments and Calculations with 1958 Costs for a 77·4 MTPD Mill	1968 Costs for 77·4 MTPD Mill	
			Annual Total (£)	£ per unit (MT) of production
5. Labour	AAS (1962, Table 148) & (1968, Table 150). Av. Earnings of Manual Workers in Manufacturing Industries) 1958 265/5d. 1948 BIC 1968 456·5/- 1958 SIC	$\frac{456}{265}$ x 49,800)	) 181,000	) 9·378
6. Administrative and Operating	Estimated by same cost rise as for (5) Labour	$\frac{456}{265}$ x (13,400 + 42,000))	)	)
7. Working Capital	Table VI, annual rate of interest at cost of capital.	10 per cent interest charge on £250,000	25,000	1·295
8. Amortization and Interest	Table VI, 10 year amortization with 10 per cent cost of capital	16·3 per cent annuity, assuming capital allowances, i.e. 16·3 per cent of £1,476,000	240,600	12·466

Table B.8. UNIT COST RATIOS OF WAGES AND SALARIES AT DIFFERENT HARDBOARD MILL CAPACITIES IN TERMS OF A 90 MTPD MILL'S COSTS.

Mill Capacity in MTPD	20	45	90	180	270	360
Unit Cost Ratios	2·282	1·415	1·000	0·710	0·647	0·566

Table B.9. THE INFLUENCE OF SIZE ON UNIT PRODUCTION COSTS IN HARDBOARD MILL MODELS AND THE DERIVED MAXIMUM DISPOSABLE WOOD PRICES

Mill Capacities							
(i) MTPD	20	45	38·7	77·4	90	180	360
(ii) MTPA	6000	12,500	9650	19,300	25,000	50,000	100,000
Production Costs per MT			£				
1. Chemicals and Other Materials	11·479	8·493	7·202	7·161	7·161	7·161	7·161
2. Steam (Coal) and Electric Power	7·269	6·580	5·896	5·891	5·891	5·891	5·891
3. Labour, Administrative and Overhead	19·379	12·016	11·710	9·171	8·492	6·029	4·806
4. Cost of Working Capital	1·914	1·502	1·554	1·295	1·295	1·295	1·295
5. Subtotal	40·041	28·591	26·362	23·518	22·839	20·376	19·153
6. Amortization & Interest	28·067	15·296	12·839	12·415	10·460	9·406	8·839
7. Total Cost per MT	68·108	43·887	39·201	35·933	33·299	29·782	27·992
8. Maximum Disposable Wood			Shillings per H.ft.				
Prices	-6·757	-0·934	+0·192	+0·978	1·611	2·456	2·887

Note: Assumptions in row (8): (i) Ex-mill product price is £40 per MT.
(ii) 83·2 H.ft.(solid measure) of wood yields one metric ton of hardboard.

Table B.10. MAXIMUM DISPOSABLE WOOD PRICE SENSITIVITY TO A 5 PER CENT CHANGE IN COSTS, CONVERSION AND PRODUCT PRICE, FOR A 90 AND 180 MTPD Mill.

Main Elements in which a 5 Per Cent Change is Considered	Percentage Change in Max. Disposable Wood Price	
	Mill Size (MTPD)	
	90	180
(1)	(2)	(3)
1. Chemicals and Other Materials (Excl. Wood)	5·3	3·5
2. Heat and Power	4·4	2·9
3. Labour, Administration and Overhead	6·3	3·0
4. Working Capital	1·0	0·6
5. Amortization and Interest	7·8	4·6
6. Hardboard Ex-Mill Product Price	29·8	19·6
7. Yield (Wood Quantity per MT of Board)	5·3	5·3

FIGURE B.1

INVESTMENT COST-CAPACITY RATIOS OF ASPLUND'S HARDBOARD MILLS

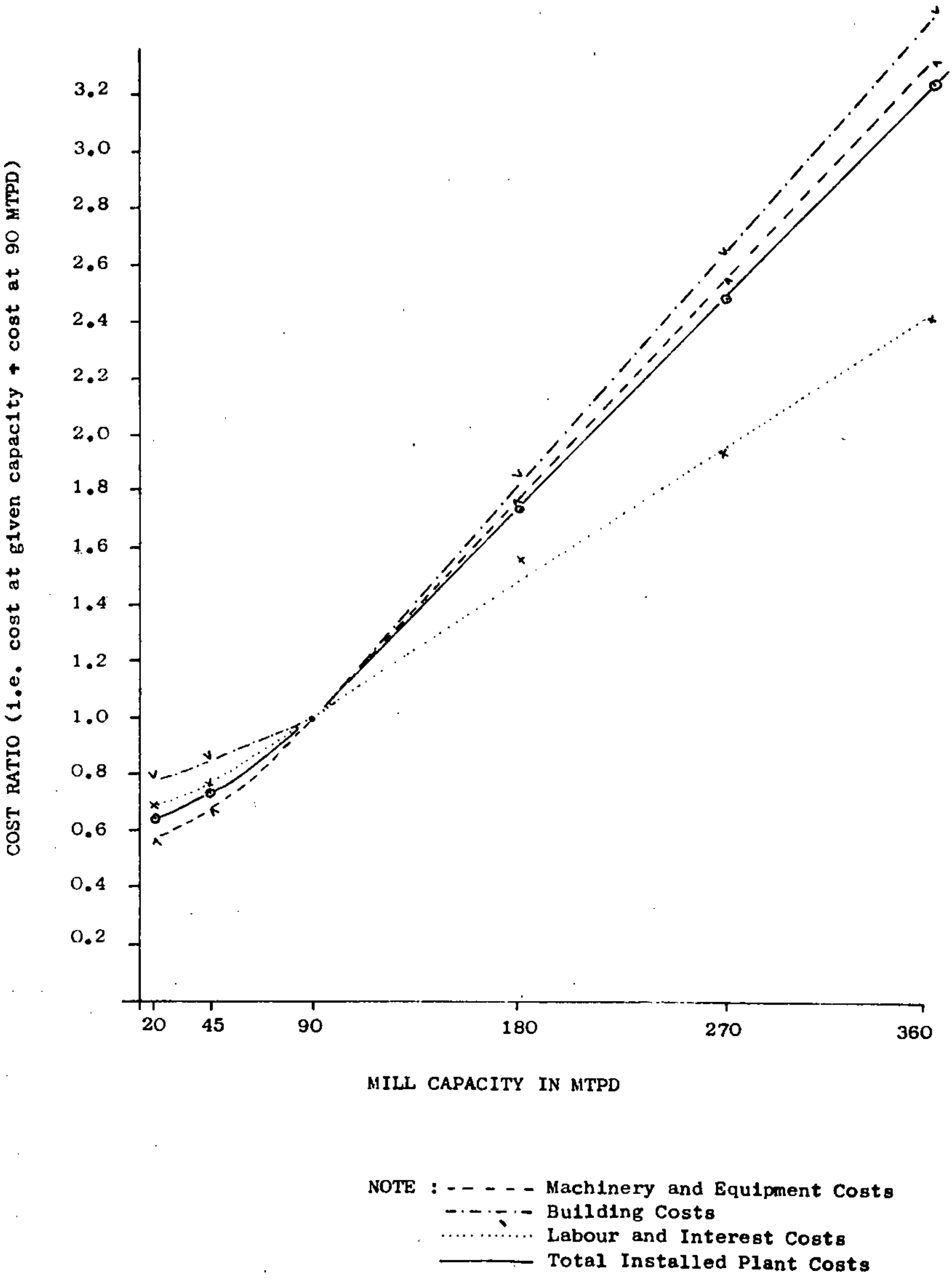


FIGURE B.2

ESTIMATES OF HARDBOARD MILL CAPITAL INVESTMENT

COSTS BY TWO ALTERNATIVE METHODS

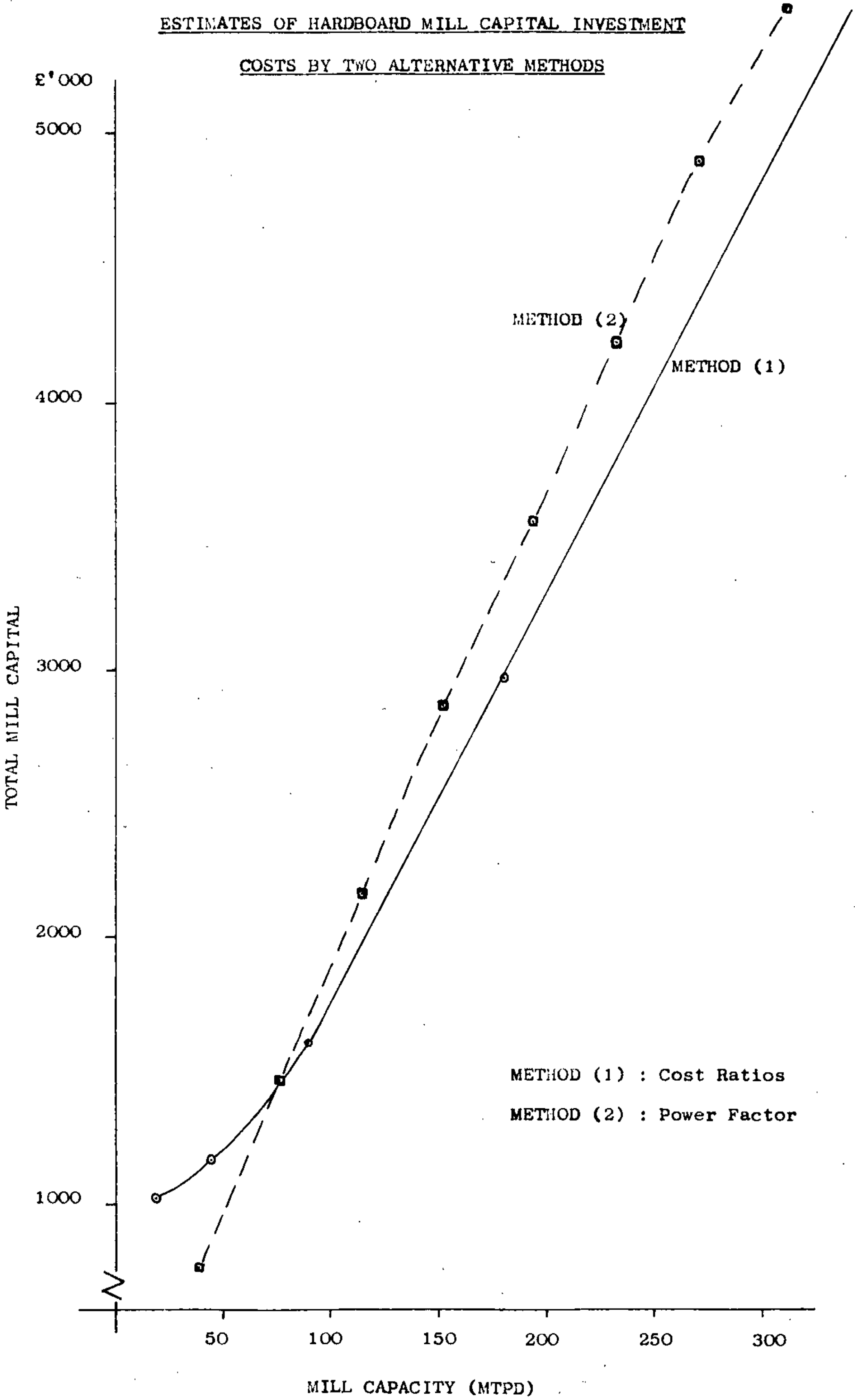


FIGURE B.3

RELATIONSHIP BETWEEN INVESTMENT REQUIREMENTS AND CAPACITY FOR HARDBOARD MILLS

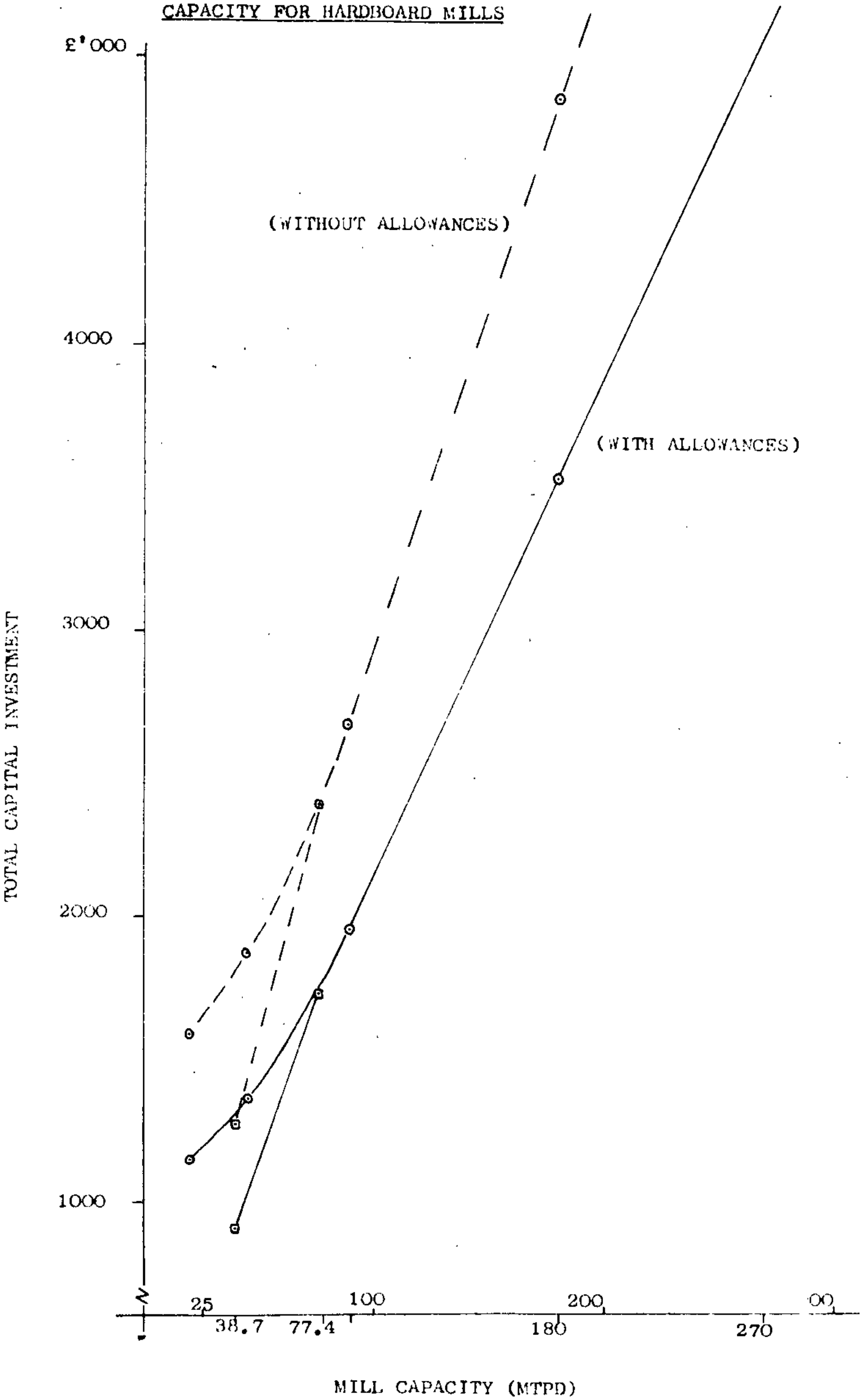


FIGURE B.4

UNIT COST RATIOS OF WAGES AND SALARIES
WITH MILL CAPACITY

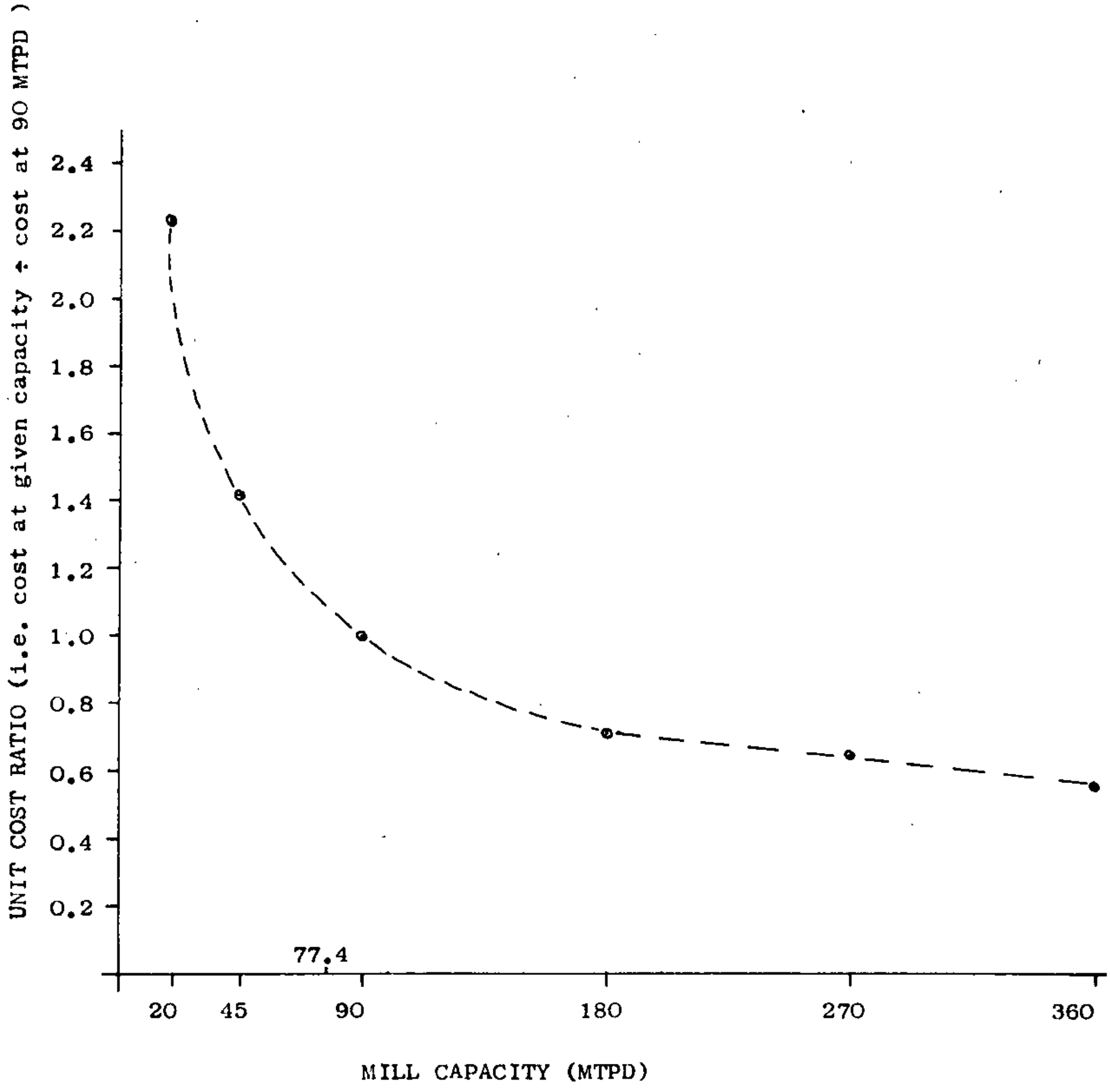
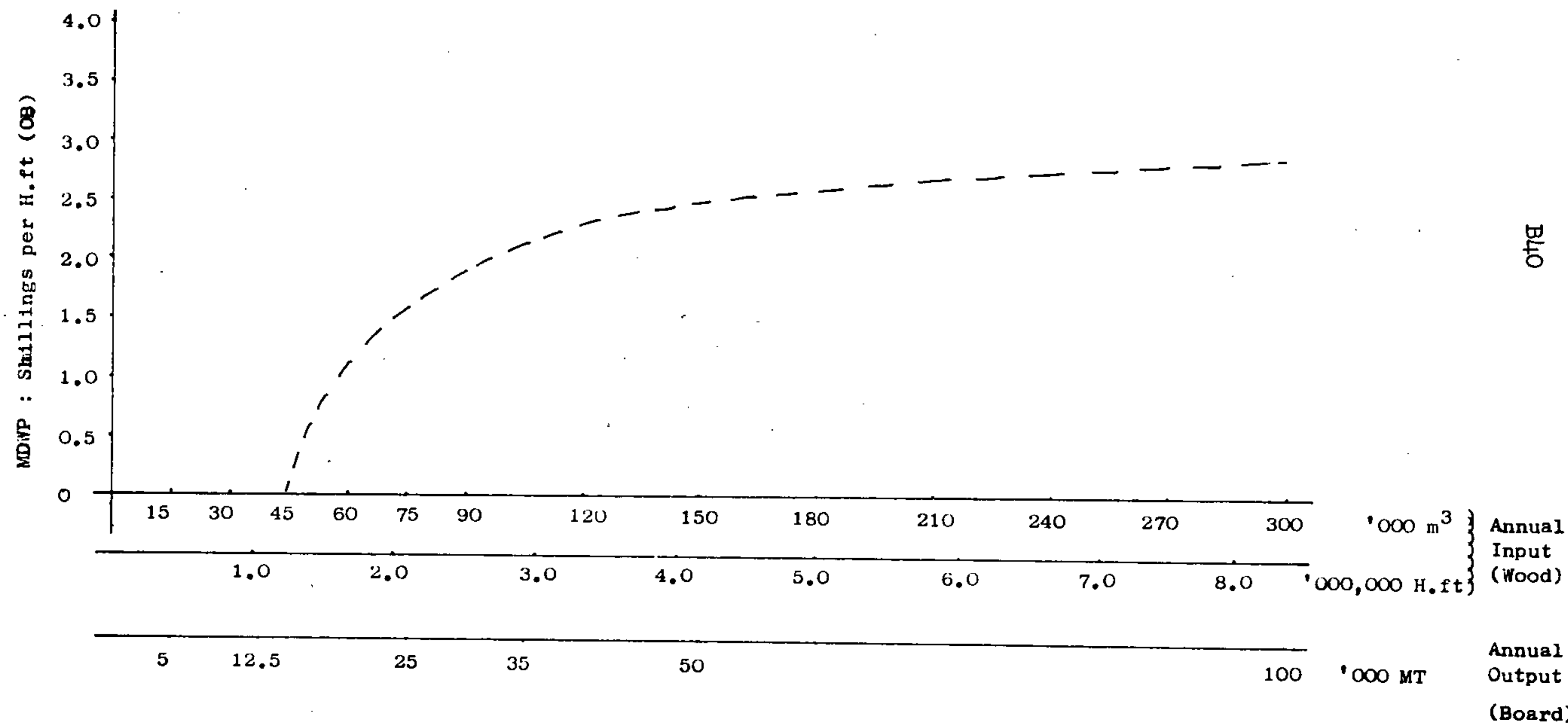


FIGURE B.5

MAXIMUM DISPOSABLE WOOD PRICE AS A FUNCTION OF MILL SIZE



APPENDIX C

THE CONSTRUCTION OF HYPOTHETICAL SAWMILL MODELS: PROFILE CHIPPER INSTALLATIONS

APPENDIX C

THE CONSTRUCTION OF HYPOTHETICAL SAWMILL MODELS: PROFILE CHIPPER INSTALLATIONS

Factors Affecting Sawmill Economics

The physical characteristics of the sawlog supply, the method of processing and the relative recovery, dimensions and prices of sawmill products (especially sawn timber) are the main factors affecting sawmill economics. The log supply, the sawlog dimensions available, and a conversion pattern, product prices and the cost structures of [illegible] profile chipper installations are analysed.

Until the large post war plantings reach rotation age which for Scots pine will be 30 to 40 years hence, sawlog supplies from the Post 1900 crop must come from thinnings predominantly. Thus a preponderance of small diameters and poor form are to be expected in sawlog supplies for many years ahead.

In order to simplify the analysis only the principal species groups, pines and spruces, are considered (Chapter V, Table 5.4, p. 33). As a further simplification, the three products, sawn timber (lumber), chips and sawdust, are treated as if each is uniform in quality and commands the stated market prices.

Explanation of the Tables and Figures.

Table C.1: PINE AND SPRUCE SAWLOG VOLUMES FROM THINNINGS OF THE POST 1900 CROP: DIAMETER DISTRIBUTIONS, 1970-1990.

The overbark (O.B.) volumes include over 98 per cent of the estimated potential sawlog volumes of these two species in the region. The corresponding small end diameters (S.E.D's) underbark (U.B.) are based on bark thickness measurements[1] for Scots Pine in the area (McKenzie, 1969). The (O.B.) volumes are to small end diameter in each class[2] (Forestry Commission, 1966). From column (8) it can be seen that over 50 per cent of the total roundwood supply to 3 inch S.E.D. is potential sawlogs.

Table C.2: Figure C.1: LOG, CANT AND CHIP VOLUME EQUIVALENTS

Logs are considered to be regular truncated paraboloids, circular in section and one inch diameter taper (OB) in every five feet,[3] (McAinsh, 1969). The sectional area of green cant is the largest square contained in the S.E.D. (U.B.) and does not correspond to any specific marketable dimension. This conversion pattern (set) would produce a lower lumber recovery than could be obtained in theory (and possibly would be obtained in practice) as is shown in Table C.4. Since, however, log form is likely to be poor owing to significant degrees of sweep and crook, and because of the likelihood of other wastage occurring during conversion to specified market sizes, this particular conservative set is

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1. The combined results of Forestry Commission measurements at Culbin, Balmoral, and Seafield, from 11 plots.
2. The volumes to S.E.D. in each class are derived from the F.C. stand assortment table.
3. Diameter taper (O.B.) measured on 5,000 logs from thinnings entering Peter McAinsh Ltd., Crieff, Perthshire.

used. The residual volume in each log diameter class is converted to wet chip volumes in cubic feet ($ft.^3$), solid measure. Diagramatically the primary conversion for each diameter class is given in Figure C.1.

The log length in the first diameter class (4·5 to 5·9 inches O.B.) is $7\frac{1}{2}$ feet; in the other diameter classes it is 10 feet.

Table C.3: LUMBER (SAWN TIMBER), CHIP AND SAWDUST OUTTURN PER LOG FOR EACH DIAMETER CLASS.

The outturn volumes depend on the cant set and the type of resaws used: The study assumes the following generalized assumptions:

1. (I) Cant conversion by circular and/or frame saws
   (a) Lumber volume = cant volume x 0·90 x 0·95.(1
   (b) Sawdust volume = cant volume x 0·10.(2
2. (II) Cant conversion by band resaw.
   (a) Lumber volume = cant volume x 0·95 x 0·95.(3
   (b) Sawdust volume = cant volume x 0·05.4
3. Chip volume assumes a 10 per cent loss on the wet chip volume in Table C.2, column (10) as suggested in recent studies (Mutch, 1969).

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1. i.e. 10 per cent loss in volume due to kerf and 5 per cent loss to lumber shrinkage.
2. i.e. Kerf volume through cant is 10 per cent and corresponds to lumber loss in note (1).
3. i.e. 5 per cent loss in volume due to kerf and 5 per cent loss to lumber shrinkage.
4. i.e. kerf volume through cant is 5 per cent and corresponds to lumber loss in note (3).

All volumes are expressed in cu. feet (solid measure).

Table C.4. Figure C2: EXAMPLES OF CONVERSION PATTERNS ON CANT AND CHIP RECOVERY FOR A 4·5 TO 5·9 (inch) DIAMETER CLASS SAWLOG, 7½ feet LONG.

For a sawlog of regular form, the taper, log length, and the degree of wane permitted make significant differences to the outturn of cants and chips. Set (1) is the conversion pattern adopted in this study; in contrast sets (2) to (4) show the order of magnitude in lumber recovery which could be attained without excessive degrade due to wane. As the logs are short, the taper has relatively little effect compared to wane (cf. sets (1) and (3) with (1) and (2)). On long logs, particularly over 10 feet, the loss in lumber through sawlog taper would be large. Conversely, end trimmings of short lumber lengths produce proportionately greater conversion losses than long lengths.[1]

Volumes in columns (8) and (9) are approximate: where wane occurs on the green cant, the actual cant volume is slightly less and the chip volume slightly more than stated.[2]

Table C.5(a): EX-MILL PRODUCT PRICES

In recognition of price differences which generally occur with increased dimension, two rates are assumed to represent the average value of undried lumber outturn.

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1. 1 inch off 7½ ft. reduces the recovery percentage by 0·5 per cent.
   1 inch off 3·¾ ft. reduces the recovery percentage by 1·2 per cent.
2. For each set, chip volume is assumed to be: log volume (U.B.) - green cant volume, where cant sections are taken as square even when wane occurs.

These rates are approximately equivalent to current lumber prices ex-mill in the fencing, mining and pallet board markets (McAinsh, 1969). The chip price is taken to represent the value ex-mill to the Scottish Pulp and Paper Mills at Fort William, whilst the sawdust price assumes a local market within the region; (it does not affect the final outcome of the analysis as Table C.5(b), row 3 suggests).

Table C.5(b): PRODUCT VALUE COEFFICIENTS FOR A 4·5 to 5·9 (ins.) DIAMETER CLASS SAWLOG.

Each cu. ft. of sawlog volume (O.B.) in the 4·5 to 5·9 (ins.) diameter class yields a total value (i.e. average unit revenue) of 3·286 to 3·412 shillings in products at the Table C.5(a) ex-mill prices. Comparing the differences between columns (2) and (3), and (5) and (6) it can be seen that a 1·8 per cent increase in the lumber recovery raises the total product value by 3·8 per cent. Furthermore, an increase of the order given in Table C.4, set (2) i.e. 11·2 per cent in terms of the sawlog volume (O.B.), would raise the total product value by 20 per cent.

Table C.6: ESTIMATED FEED RATES FOR A LINCK CANTER CHIPPER.

A Linck canter chipper headrig machines two flat parallel faces. Consequently the production of a square cant requires a round sawlog to be machined twice.[1] The feed speed is independent of log diameter. The number of

1. Mills with one headrig have a roundabout system which turns the two-sided cant through 90 degrees.

logs processed depends solely on log length and the effective working rate of the mill. The stated 20 per cent delay time allowance is high (Dobie, 1967), especially as mill equipment and layout permits pre-sorting of log classes.

Table C.7: INPUT-OUTPUT PROCESSING RATES WITH A LINCK CANTER CHIPPER.

The figures in column (2) are subjective estimates of the log supply diameter distribution based on the 20 year forecasts, Table C.1. Other figures are derived directly from Tables C.2, C.3 and C.6. The 'mix' in rows (5) and (6) is the weighted average from the percentages in column (2), and, as an input-output rate per hour, it is strictly conceptual. 2,000 hours, which is equivalent to 250 shifts of 8 hours each,[1] is the assumed annual mill operating period.

Table C.8: ALTERNATIVE MILL UNITS AND APPROXIMATE CAPACITIES OF LINCK CANTER CHIPPER INSTALLATIONS.

The mills depicted in Table C.8 are plants designed by Linck, either projected or in operation (Kunz, 1969); as such they are complete mill units and geared to the prescribed canter chipper headrigs. Annual input capacities depend on log size (Table C.7, column 4) and quality, lumber specifications and other parameters (Bruce, 1961).

1. Existing sawmills are working over 40 hours per week (P.E. Consultants, 1969). An annual operating period of 2,000 hours is an arbitrary, conservative estimate which could be increased (sawlog supplies permitting). Juvonen (1965) also uses 2,000 hours per annum as a standard operating period for evaluating the production capacity of different size of frame saw mills.

Mill No.1 is equipped to produce cants and studs, while the other mills can produce battens, deals and boards i.e. they have the ability to turn out higher value-added lumber products than the first mill.

Table C.9: PERSONNEL REQUIREMENTS IN LINCK CANTER CHIPPER INSTALLATIONS; WAGE AND SALARY COSTS.

Personnel requirement for master mechanics, sawdoctors, production, woodyard and mill workmen are based on Linck figures (Kunz, 1969), and those for storing, sorting and dispatch on Finnish frame mill installations of equivalent capacities (Juvonen, 1965). There is, of course, flexibility in the numbers employed,[1] chiefly depending on the degree of mechanisation and automation. Kiln drying operations are not considered.

The administrative, technical and clerical salaries are derived from the average weekly earnings in 'Timber Industries' (Dept. of Employment and Productivity, 1969, Table B.20, p. 53) and rounded up to estimate 1969/70 values i.e. £30 per person per week. The wage differential between production and other mill workmen is based on the basic weekly wage rates in 'Sawmilling' (Dept. of Employment and Productivity, 1969, Table B.7(a), p. 17). Since average weekly earnings are approximately 30 per cent higher than

1. The personnel requirements in the models (Table C.9) are probably overestimated as a recent example indicates: a Linck Canter Chipper mill in Norway with corresponding equipment and input-output wood volumes has a total labour force of 9-10 men. (Anon, 1968, p. 5).

the basic rate, the following rates are assumed:

(1) Production labour £20 per week

(2) Other labour £16.10s.0d. per week.

Table C.10: NET WORKING CAPITAL REQUIREMENTS

These estimates are approximate and have been detailed for the sake of completeness only. About 80 per cent of the estimated requirements are as capital held in the form of processed products: lumber and chips.

Table C.11: TOTAL MILL CAPITAL INVESTMENT REQUIREMENTS IN LINCK CANTER CHIPPER INSTALLATIONS.

The capital investment costs in columns (2), (4), (6) and (8) represent the gross costs for complete sawmill plants, installed. The machinery and equipment costs are based on Linck estimates (Kunz, 1969) for canter chipper installations in Scotland using the labour personnel detailed in Table C.9, rows 2(a), (b) and (c).

Building and construction costs, rows (3) to (6) inclusive are eligible (BOT (b), 1968) for investment grants and allowances. The net building capital costs are therefore calculated assuming the following:

(a) 15 per cent Initial Allowance.

(b) 4 per cent Annual Straight-Line Depreciation Allowance.

(c) No Investment Grant.

(d) 18 month delay in payments of Corporation Tax, and Investment Grants and Allowances (Merret and Sykes, 1966).

(e) $42\frac{1}{2}$ per cent Corporation Tax.

(f) 10 per cent cost of capital.

(g) Sufficient income to take full advantage of the tax concessions.

Likewise the installed machinery and equipment costs, row (7) are eligible (BOT (a), 1968), but with differences in the first three assumptions which affect their net capital costs:

(a) 40 per cent Investment Grant.

(b) 20 per cent Annual Reducing Balance Depreciation Allowance.

(c) No Initial Allowance.

Total mill capital requirements row (10) include the interest on capital, row (9), during the construction period which is taken as 12 months for all mills.

Table C.12: PRODUCTION COSTS (EXCL. WODD) FOR LINCK CANTER CHIPPER INSTALLATIONS.

The following assumptions are made:

(a) Electric Power Costs are calculated at 110 per cent of the rated mill equipment horse power; 1·5 pence per kilowatt hour, and 2,000 running hours per annum.

(b) Maintenance costs include two elements:

(i) machinery and equipment; $\frac{1}{4}$ per cent per annum of the total (gross) installed capital cost.

(ii) buildings maintenance and running; 5 per cent per annum of the total (gross) construction capital cost.

(c) Insurance and Property Taxes; 5 per cent per annum of the total (gross) mill investment costs.

(d) Wages and Salaries; 116 per cent of the Table C.9, row (3c) values, i.e. including employee benefits valued at 16 per cent of the total weekly earnings.

(e) Amortization and Interest, a 10 per cent cost of capital[1] and a 5 year amortization period is equivalent to a 26·4 per cent annuity on all depreciable assets, i.e. Table C.11, items in rows (3) to (7) inclusive; and a 10 per cent annual charge on non-depreciable assets, i.e. site costs.

(f) Net Working Capital; a 10 per cent charge on Table C.10, row (8) totals.

Average unit production costs (excluding wood costs), row (9), are relatively small by comparison with the product value even in the marginal diameter class of sawlog, i.e. these costs as indicated in this table range from 0·755 to 1·136 shillings per cu. ft. of sawlog (O.B.), whilst product revenue of the marginal log diameter is 3·286 to 3·412 shillings per cu. ft. of sawlog (O.B.) (Table 5(b), columns (5) and (6)). Indeed the implications for processing thinning supplies in the region with Linck canter chipper sawmill installations are twofold:

(1) The economic returns to scale are negligible.

(2) There is little advantage to be gained from increasing the mills' annual operating time even though 65 per cent of the production costs (excluding wood) are fixed. e.g. Taking the highest unit

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1. Based on the assumptions and argument of pp. B7 to B9.

The 'mix', referred to in row (5), is the annual sawlog size assortment of Table C.7, columns 1 and 2. The maximum disposable wood price is calculated from the total output value (column (10)); the hourly production costs, Table C.12 row (8) for Mill No.1: £35·5 per hour; and the sawlog volume (O.B.), i.e. columns (2) and (3) respectively.

Table C.14: MAXIMUM DISPOSABLE WOOD PRICE SENSITIVITY TO A 5 PER CENT CHANGE IN COSTS, CONVERSION AND PRODUCT PRICES.

The largest processing cost elements (Table C.12): wages and salaries, amortization and interest would have to change by 13 or 14 per cent to cause a 1·1 per cent change in the maximum disposable wood price.

production costs (in Table C.12, row 9); 1·1358 shillings per cu. ft. of sawlog (O.B.), the effect of double shift working produces an approximate saving of 0·37 shillings (4·4 pence). Although this is a saving of 33 per cent in unit production costs, it is only equivalent to a maximum increase of 13 per cent on the average product revenue of the marginal sawlog.[1] derived in Table C.13.

Mills Nos. 2, 3 and 4 can produce higher value-added lumber than Mill No.1 (p. C7) and on this basis would be economically more favourable so long as the quantity and quality of the sawlog supply allows them to operate. In reality, however, the forecasts indicate a predominance of small diameters and the quality is likely to be poor. This situation allows less opportunity to increase the lumber value than the extra processing equipment in Mills Nos. 2, 3 and 4 permits. In addition Table C.1 column (7) indicates that log supplies in the quantity or size required cannot be expected before the mid 1980's at the earliest.

Table C.13: MAXIMUM DISPOSABLE WOOD PRICE AT MILL WITH DIFFERENT SAWLOG SIZE CLASSES, AND THE AVERAGE ANNUAL SAWLOG SUPPLY FROM POST 1900 THINNINGS.

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1. Fixed costs as 65% of unit production costs = 0·738/- per H. ft.

   Therefore saving working double shifts = 0·738 ÷ 2 = 0·369.

   And, $\frac{0 \cdot 369}{1 \cdot 136} \times 100 = 32 \cdot 5\%$ saving on the unit production costs.

   But percentage increase in the MDWP is:

   (a) The marginal sawlog $\frac{0 \cdot 369}{2 \cdot 816} \times 100 = 13 \cdot 1$ per cent.

   (b) The whole log assortment $\frac{0 \cdot 369}{4 \cdot 075} \times 100 = 9 \cdot 1$ per cent.

Table C.1. PINE AND SPRUCE SAWLOG VOLUMES FROM THINNINGS OF THE POST 1900 CROP: DIAMETER DISTRIBUTION, 1970-1990

Year	Diameter Classes (ins.) OB and S.E.D. (ins.) UB.				Total Sawlog Volume		Percentage of all Pine and Spruce Thinnings
	4·5 - 5·9	6 - 7·9	8 - 9·9	10 - 11·9	Percentage	'000's of H.ft.(OB)	
	4·1	5·5	7·3	9·1			
	Percentage of Volume to S.E.D.						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1970	51·9	33·3	11·7	3·1	100·0	1329·1	58·3
1980	50·8	35·1	13·7	0·4	100·0	2079·1	53·5
1990	50·3	29·4	14·0	6·3	100·0	3758·1	53·7

Source: Study Roundwood Supply Forecasts.

Table C.2. LOG, CANT AND CHIP VOLUME EQUIVALENTS

Diameter Class (ins.) OB	S.E.D. (ins.) UB	Volume per Lineal Foot ft^3 (solid)				Volume Per log $ft.^3$ (solid)				Conversion Percentage (9) ÷ (8)
		Log (OB)	Log (UB)	Green Cant	Chips (4)-(5)	Log (OB)	Log (UB)	Green Cant	Chips (8)-(9)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
4·5-5·9	4·1	0·1530	0·1283	0·0584	0·0727	1·148[1]	0·962[1]	0·438[1]	0·524[1]	45·5
6·0-7·9	5·5	0·2683	0·2278	0·1050	0·1228	2·683	2·278	1·050	1·228	46·1
8·0-9·9	7·3	0·4418	0·3712	0·1850	0·1862	4·418	3·712	1·850	1·862	49·8
10·0-11·9	9·1	0·6589	0·5499	0·2875	0·2624	6·589	5·499	2·875	2·624	52·3

Note: 1. Based on a 7·5 ft. log length; log length in all other diameter classes is 10 ft.

Table C.3. LUMBER (SAWN TIMBER), CHIP AND SAWDUST OUTTURN PER LOG FOR EACH DIAMETER CLASS

Diameter Class (ins.) OB	S.E.D. (ins.) UB	Volumes ft.^{3} (true, solid measure) per log.				
		Lumber		Sawdust		Chips
		I	II	I	II	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
4·5-5·9	4·1	0·3745	0·3953	0·0438	0·0219	0·4716
6·0-7·9	5·5	0·8978	0·9476	0·1050	0·0525	1·1052
8·0-9·9	7·3	1·5818	1·6696	0·1850	0·0925	1·6758
10·0-11·9	9·1	2·4581	2·5947	0·2875	0·1438	2·3616

Note: Based on Table 2 Columns 8-10.

I Cant conversion by frame and/or circular saw

II Cant conversion by band resaw.

Table C.4. EXAMPLES OF CONVERSION PATTERNS ON CANT AND CHIP RECOVERY FOR A 4·5 to 5·9 inch DIAMETER CLASS SAWLOG, 7·5 Ft. LONG.

Set No.	Log Length (ft.)	S.E.D. (ins.) UB (D.)	Cant Sectional Area (ft.^{2}) (a^2)	Percentage of cant length with wane	Percentage of single cant face with wane	Percentage of cant lumber recovery on log volume UB	Volume (ft.^{3}) solid: Cant (nominal)	Volume (ft.^{3}) solid: Chips (Nominal)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1.	7·5	4·1	·0584	0	0	45·5	0·438	0·524
2.	7·5	4·1	·0757	50	14·0	59·0	0·568	0·404
3. (a)	3·75	4·1	·0584	0	0	48·8	0·469	0·464
(b)	3·75	4·7	·0757	0	0			
4. (a)	3·75	4·1	·0757	100	14·0	65·8	0·633	0·309
(b)	3·75	4·7	·1050	100	17·7			

Note: Figures for the percentage of wane in column (6) as defined by F.P.R.L. (1955).

Table C.5(a). EX-MILL PRODUCT PRICES

Product	Ex-Mill Prices per ft.^{3} (solid measure) Shs.
1. Lumber (a) From Sawlog Diameter class < 6·0 ins. (OB)	7·5
(b) " " " classes $\geq$ 6·0 ins. (OB)	10·0
2. Chips	2·0
3. Sawdust	0·5
4. Bark	0·0

Table C.5(b). PRODUCT VALUE COEFFICIENTS FOR A 4·5 to 5·9 (ins.) DIAMETER CLASS SAWLOG.

Product (1)	Log Volumes (Ft.^{3}) Conversion & recovery percentages I (2)	II (3)	Ex-Mill prices per ft.^{3} (solid measure) Shs. (4)	Product Value Coefficients I (5)	II (6)
1. Lumber	32·6	34·4	7·5	2·445	2·580
2. Chips	41·4	41·1	2·0	0·822	0·822
3. Sawdust	3·8	1·9	0·5	0·019	0·010
4. Bark	16·2	16·2	0	0·000	0·000
5. Subtotal	93·7	93·7	-	- -	-
6. Loss (lumber shrinkage and chip waste)	6·3	6·3	-	-	-
7. Total	100·0	100·0	-	3·286	3·412

Sources: Tables 2,3 and 5(a). Note: I. Cant conversion by frame and/or circular saw.
II. Cant conversion by band resaw.

Table C.6. ESTIMATED FEED RATES FOR A LINCK CANTER CHIPPER

1. Standard Model (V40) Designed Rate	220 fpm.	
2. Effective Running Rate (75 per cent of (1))	165 fpm.	
3. Effective working rate (80 per cent of (2))	132 fpm.	
	Log Length (ft.)	
	7·5	10
4. Number of logs processed per minute (Rounded down to nearest whole log): Single Pass	17	13
	Log length (ft.)	
	7·5	10
5. Number of Logs processed per hour (a) Single pass	1020	780
(b) Double pass	510	390

Sources: Designed and Effective Running Rate (Kunz, 1969).

Note: Effective Working Rate assumes a 20 per cent delay time.

Table C.7. INPUT-OUTPUT PROCESSING RATES WITH A LINCK CANTER CHIPPER

S.E.D. UB classes (ins.)	Percentage of supply volume in the respective S.E.D. classes.	Hourly Sawlog Input OB.		Hourly Output Volumes in Ft.^{3} (solid measure)					
				I			II		
		H.ft.	ft.^{3}	Lumber	Chips	Sawdust	Lumber	Chips	Sawdust
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. 4·1	51	459	585	191	241	22	202	241	11
2. 5·5	33	821	1046	350	431	41	370	431	21
3. 7·3	13	1353	1723	617	654	72	651	654	36
4. 9·1	3	2017	2570	959	921	112	1012	921	56
5. Mix: Per Hour		741·4	944·7	321·9	377·7	37·5	340·1	377·7	18·9
6. Mix: Per 2000 Hrs.		1,482,800	1,889,400	643,800	755,400	75,000	680,200	755,400	37,800

Sources: Tables 1,2,3 and 6. Note: I. Cant conversion by frame and/or circular saw
II. Cant conversion by band resaw.

Table C.8. ALTERNATIVE MILL UNITS AND APPROXIMATE CAPACITIES OF LINCK CANTER CHIPPER INSTALLATIONS

Mill No. (1)	Installed Processing Equipment (2)	No. of Units (3)	Approximate Input Capacity Millions ft.^{3} per annum. (4)
1.	Canter Chipper	1	1·25 - 1·75
	Band Resaw	1	
2.	Canter Chipper	1	2·0 - 2·25
	Vertical Frame Saw	1	
	Edgers	2	
	Undercut Cross-cut Saws	2	
3.	Canter Chipper	1	2·0 - 2·25
	Log Band Mill (Quad Saws)	1	
	Edger	1	
	Undercut Cross-cut Saws	2	
4.	Canter Chipper	2	4·0
	Vertical Frame Saw	1	
	Double Log Edger	1	
	Band Resaw	1	
	Edger	1	
	Undercut Cross-cut Saws	3	

Source: Kunz (1969).

Table C.9. PERSONNEL REQUIREMENTS IN LINCK CANTER CHIPPER INSTALLATIONS; WAGE & SALARY COSTS

Mill No.	1		2		3		4	
Approximate Input Capacity (Millions ft.[3] per annum) OB	1·25 - 1·75		2·00 - 2·25		2·00 - 2·25		4·0	
	Nos.	Wage(£)	Nos.	Wage(£)	Nos.	Wage (£)	Nos.	Wage(£)
1. Administrative, Technical and Clerical Personnal.								
(a) Managing Director	1		1		1		1	
(b) Mill Manager	1		1		1		1	
(c) Accountant	)1		1		1		1	
(d) Book Keeper	)		1		1		1	
(e) Sales & Shipping Clerk	-		-		-		1	
(f) Secretary	1		1		1		1	
(g) Master Mechanic	-		1		1		1	
(h) Saw Doctors	1		1		1		2	
(i) Wood Yard Foreman	1		1		1		1	
(j) Storage and Dispatch Foreman	1		1		1		1	
Total Number & Total Average Weekly Earnings[1]	7	210	9	270	9	270	11	330
2. Workmen								
(a) Production Labour	2	40	4	80	4	80	6	120
(b) Woodyard and Mill Labour	8	) 198	9	) 248	9	) 248	9	) 281
(c) Storing, Sorting & Dispatch Labour	4	)	6	)	6	)	8	)
Total Number and Total Average Weekly Earnings[2]	14	238	19	328	19	328	23	401
3. Grand Total								
(a) All Personnel	21		28		28		34	
(b) Wages & Salaries per week		448		598		598		731
(c) Wages & Salaries per annum		23,296		31,096		31,096		38,012

Sources: 1. Dept. of Employment & Productivity (1969, Table B.20, p. 53; Timber Industries).
2. Dept. of Employment & Productivity (1969, Table B.7a, p. 17; Sawmilling and Timber Industries).

Table C.10. NET WORKING CAPITAL REQUIREMENTS

Mill No.	1		2		3		4	
Approximate Input Capacity (Mill. ft.^{3} P.A.) OB	1·27 - 1·75		2·0 - 2·25		2·0 - 2·25		4·0	
(1)	Quantity H.ft. (2)	Value £ (3)	Quantity H.ft. (4)	Value £ (5)	Quantity H.ft. (6)	Value £ (7)	Quantity H. ft. (8)	Value £ (9)
Current Assets								
1. (a) Sawlogs (1 month's supply at 3/6 per H.ft.)	100,000	5,000	150,000	7,500	150,000	7,500	260,000	13,000
2. (b) Lumber (3 month's stock at 10/- per ft.^{3})[1]	116,000	58,000	176,000	88,000	186,000	93,000	352,000	176,000
3. (c) Chips (3 month's stock at 2/- per ft.^{3})[1]	123,000	12,300	197,000	19,700	197,000	19,700	393,000	39,000
4. (d) Opening up Expenses (equivalent to 3 month's pay in wages and salaries)	-	5,800	-	7,800	-	7,800	-	9,500
5. (e) Cash Reserve (5 per cent of total production costs)	-	3,100	-	4,600	-	4,800	-	6,400
6. (f) Total Current Assets		84,200	-	127,600		132,800		244,200
Liabilities								
7. Trade Credit and Bank Overdrafts (20 per cent of total current assets)		-15,100		-23,000		-24,000		-45,700
8. Total Net Working Capital		69,100		104,600		108,800		198,500

Note: 1. Includes Value of Debtors' Stock.

Table C.11. TOTAL MILL CAPITAL INVESTMENT REQUIREMENTS IN LINCK CANTER CHIPPER INSTALLATIONS

Mill No.	1		2		3		4	
Approximate Input Capacity (Mill ft.^{3} P.A.)OB	1·25 - 1·75		2·0 - 2·25		2·0 - 2·25		4·0	
1. Investment Grants and Allowances:	Without £	With £	Without £	With £	Without £	With £	Without £	With £
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
2. Mill Site (£5,000 per acre)	10,000	10,000	10,000	10,000	10,000	10,000	15,000	15,000
3. Pre Planning Costs	2,000		2,000		2,000		3,000	
4. Site Preparation	2,000	16,484	2,000	32,163	2,000	32,163	2,000	33,771
5. Buildings (a) Mill (£2 per ft.^{2})	12,000		31,000		31,000		31,000	
6. (b) Office (£10 per ft.^{2})	4,500		5,000		5,000		6,000	
7. Machinery and Equipment	122,000	75,256	191,000	117,818	204,000	125,837	309,000	190,607
8. Subtotal	140,500	101,740	229,000	159,981	242,000	168,000	348,000	239,378
9. Construction Period Interest'		3,813		6,025		6,350		9,150
10. Total Mill Capital Investment		105,553		166,006		174,350		248,528
11. Total Net Working Capital		69,100		104,600		108,800		198,500
12. Total Capital Investment		174,653		270,606		283,150		447,028

' Based on ½ the capital cost for a 6 month period = ½ capital cost × 5 per cent interest rate.

Table C.12. PRODUCTION COSTS (EXCL. WOOD) FOR LINCK CANTER CHIPPER INSTALLATIONS

Mill No.	1		2		3		4	
Approximate Input Capacity (Mill ft.^{3} P.A.) OB	1·25 - 1·75		2·0 - 2·25		2·0 - 2·25		4·0	
Total Costs (1)	£.P.A. (2)	Percentage of total production costs (3)	£.P.A. (4)	Percentage of total production costs (5)	£.P.A. (6)	Percentage of total production costs (7)	£.P.A. (8)	Percentage of total production costs (9)
1. Electric Power	4,618	6·5	6,671	6·4	7,184	6·6	9,749	6·5
2. Maintenance	1,120	1·6	2,260	2·2	2,293	2·1	2,600	1·7
3. Insurance and Property Taxes	5,101	7·2	6,469	6·2	8,420	7·7	11,939	7·9
4. Wages and Salaries	27,023	38·1	36,071	34·6	36,071	33·0	44,094	29·2
5. Amortization and Interest	26,226	36·9	42,168	40·5	44,395	40·6	62,651	41·5
6. Working Capital Costs	6,900	9·7	10,500	10·1	10,900	10·0	19,900	13·2
7. Total Production Costs (Excl. Wood) P.A.	70,988	100	104,157	100	109,263	100	150,933	100
8. Total Production Costs (Excl. Wood) P.H.	35.494	-	52.078	-	54.631	-	75.466	-
9. Unit Production Costs (Excl. Wood) per ft.^{3} of Sawlog Input (OB)	shillings 0·8113 to 1·1358		shillings 0·9258 to 1·0416		shillings 0·97123 to 1·0926		shillings 0·7547	

Note: 1. Production costs are based on 2,000 working hours per annum.
2. Depreciable Assets i.e. Total Mill Capital Costs excluding site cost; are amortized over a 5 year period.
3. Capital costs receive the investment grants and allowances used in Table 11.

Table C.13. MAXIMUM DISPOSABLE WOOD PRICE AT MILL WITH DIFFERENT DIAMETER CLASS AND THE AVERAGE ANNUAL SAWLOG SUPPLY FROM POST 1900 THINNINGS

S.E.D. (ins.) UB	Hourly Sawlog Volume OB Input		Hourly Output Volumes in ft.^{3} (solid measure)						Total Output Value per hour £	Maximum Disposable wood price per unit volume (OB) in shillings	
			Lumber		Chips		Sawdust				
	H.ft.	Ft.^{3}	Quantity	Value £	Quantity	Value £	Quantity	Value £		Ft.^{3}	H.ft.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1. 4·1	459	585	202	75·8	241	24·1	11	0·3	100·2	2·2120	2·816
2. 5·5	821	1046	370	184·8	431	43·1	21	0·5	228·4	3·6883	4·695
3. 7·3	1353	1723	651	325·6	654	65·4	36	0·9	391·8	4·1358	5·265
4. 9·1	2017	2570	1012	506·0	921	92·1	56	1·4	599·5	4·3891	5·587
5. 'Mix'	741·4	944·7	340·1	148·4	377·7	37·8	18·9	0·5	186·7	3·2010	4·075

Sources: Tables C5(a), C7 and C12.

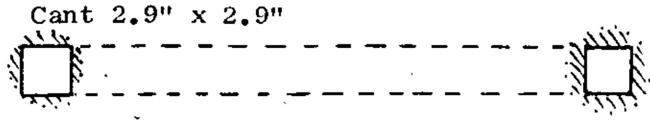
Note: (1) Output volumes based on cant conversion by band resaw (Table C7, Alternative II)
(2) Output values per hour in columns (5), (7), (9) and (10) expressed in £.
(3) Maximum disposable wood price in shillings per unit volume (OB) input
(4) Lumber values in row (1) are 7·5 shilling per ft.^{3}, in rows (2), (3) and (4) are 10·0 shillings per ft.^{3} and row (5) are the weighted average.

Table C.14. MAXIMUM DISPOSABLE WOOD PRICE SENSITIVITY TO A 5 PER CENT CHANGE IN COSTS, CONVERSION, AND PRODUCT PRICES

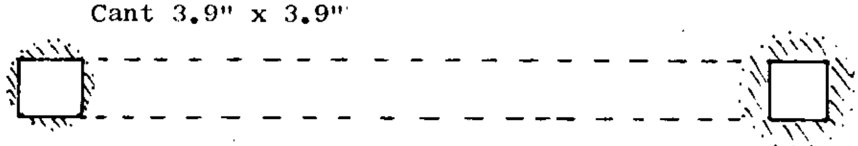
Main elements in which a 5 per cent change is considered (1)	Percentage change in Max. Disp. Wood price. (2)
1. Processing Costs (Excl. Wood)	1·1
2. Lumber Recovery	10·5
3. Lumber Price	4·9
4. Chip Price	1·2

FIGURE C.1
LOG CANT AND CHIP VOLUME PROFILES

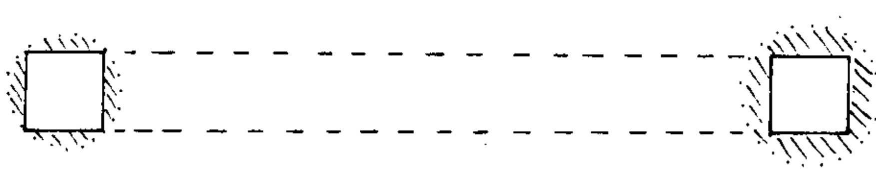
(1) S.E.D. 4.1 ins, Log length 7.5 ft.
Cant 2.9" x 2.9"



(2) S.E.D. 5.5 ins., Log length 10 ft.
Cant 3.9" x 3.9"



(3) S.E.D. 7.3 ins., Log length 10 ft.
Cant 5.2" x 5.2"



(4) S.E.D. 9.1 ins., Log length 10 ft.
Cant 6.4" x 6.4"

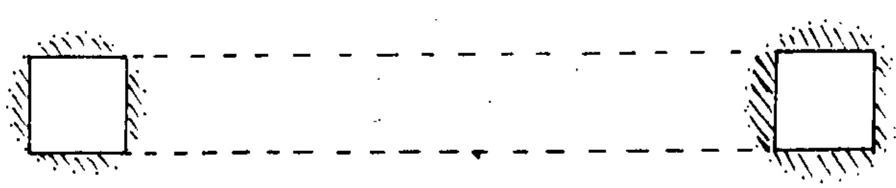
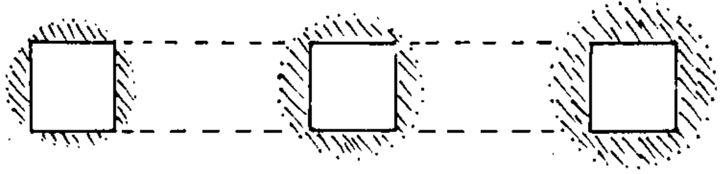
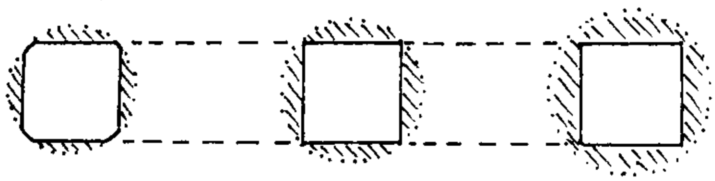


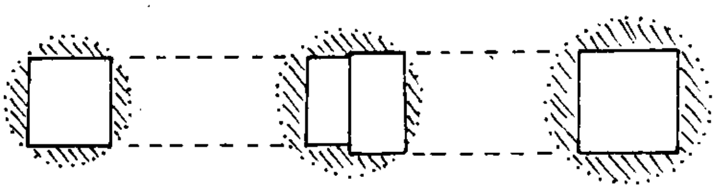
FIGURE C.2
EXAMPLES OF CONVERSION PATTERNS ON CANT AND CHIP RECOVERY FOR A 4.5 to 5.9(ins.) OB DIAMETER CLASS SAWLOG. 7.5 ft. LONG.



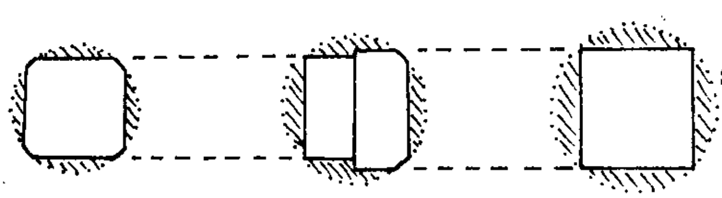
Set (1)
Log length 7.5 ft.
S.E.D(UB) 4.1 ins.
Cant 2.9" x 2.9"
No Wane
C.L.R. Percentage 45.5



Set (2)
Log length 7.5 ft.
S.E.D.(UB) 4.1 ins.
Cant 3.4" x 3.4"
Maximum Face Wane 14 per cent
Maximum length Wane 50 per cent
C.L.R. Percentage 59.0



Set (3)
Log lengths 3.75 ft.
1st Cant 2.9" x 2.9"
2nd Cant 3.4" x 3.4"
No Wane
C.L.R. Percentage 48.8



Set (4)
Log lengths 3.75 ft.
1st Cant 3.4" x 3.4"
2nd Cant 3.9" x 3.9"
Max. Face Wane 14-17 per cent
Max Length Wane 100 per cent
C.L.R. Percentage 65.8

Note: Cant Lumber Recovery (C.L.R.) is the nominal cant volume as a percentage of log volume (UB)