

CHAPTER 2: DEVELOPMENT OF THE MODEL

2.1 INTRODUCTION

In an even-aged forest there is only one age class present on any one small area whereas in an uneven-aged forest several age classes are present on any one small area (Malcolm and Taylor, 1979). However, the size of the "small area" is not fixed by any hard and fast rules. The distinction between small clearfelling areas and large group selection areas is not strong. In his model for management of hardwood forests for timber and other benefits (Dynast-TM) Boyce (1978) stated that:

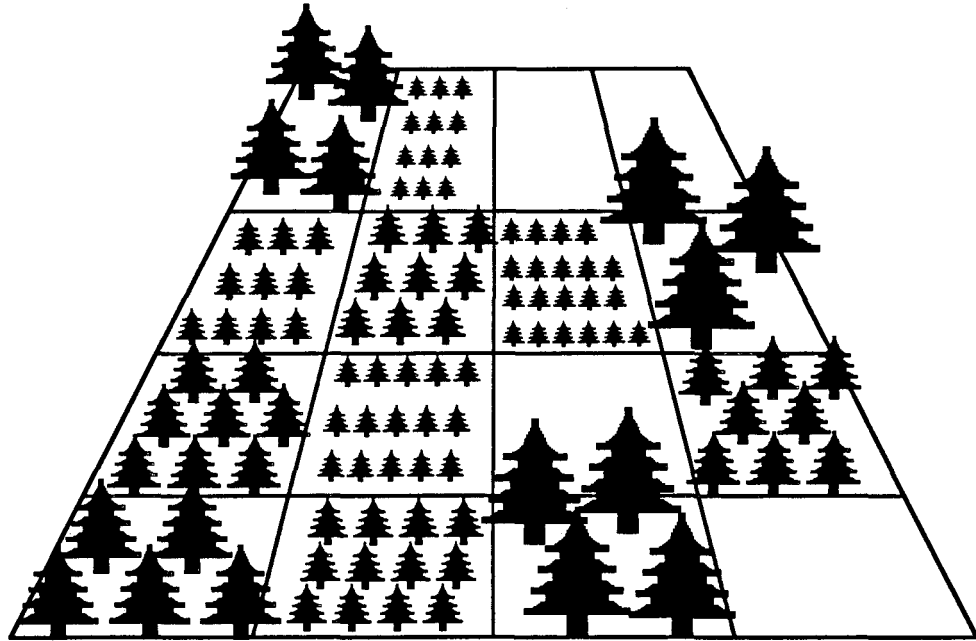
"The Dynast-TM model does not attempt to model any of the classical systems of silviculture...Rather, Dynast-TM is a model which includes and perhaps supersedes these systems. Dynast-TM explores the consequences of manipulating the period of rotation and the size of opening. Actually, the classical systems of silviculture can be described by these two variables, as modified by in place enhancements. Properly considered, such apparently antithetical methods as "clearcutting" and "selection" appear as points on a continuum."

The operational costs of uneven-aged systems versus even-aged systems are largely determined by the size of opening and thus also appear on such a continuum. The simulation model I have developed compares openings the size of single-tree removal at one end of the continuum, through group selection and group clearfelling, up to fairly large-scale clearfelling at the other end of the continuum.

Some silvicultural systems and variants of silvicultural systems are not represented by the model. *Femelschlag*, for example, is somewhat similar to the group selection system but it has a fixed rotation period and groups are only cut during the first felling period. In subsequent felling periods these groups are gradually enlarged until they coalesce. The basic structure of the model cannot handle this arrangement of fellings and the layout of the extraction routes needed for this system. Also, the various types of shelterwood systems are not included because they cannot be placed on this continuum from single-tree selection to clearfelling.

The forest block is represented by a series of square two-dimensional arrays, where each element of the array represents a group of trees which will be thinned, felled, and regenerated (See Figure 2.1).

Figure 2.1: Storage Of Information About The Forest Block



319	0	0	0
45	134	0	374
227	45	0	227
319	134	374	0

Sawlog volume array
(m^3)

Using this approach, distance calculations can be made simply. Data stored in this matrix form have implicit coordinates because location information is not specified for each element but is implicit in the method of storage. Therefore, distance calculations can be done using the row number and column number of a cell, and the cell size (MacDougall, 1976). In this way, machine extraction distances and movement

distances for workers can be calculated. Then, by calculating the time taken to carry out operations within each group and the time spent moving between groups, the total time taken for each operation can be found for a range of group sizes.

An alternative approach I considered was the development of a model using a range of group sizes and shapes, chosen to fit into an example of an actual forest, such as Glentress. By digitizing a map of the forest, distances between groups and the extraction network could be Calculated. However, I felt the extra cost and time needed for this approach were not justified in terms of the applicability of the results to other forests.

I did not feel it was necessary to consider irregularly shaped groups because they are not generally found in practice. Irregular-shaped working areas are intrinsically more expensive to work in, regardless of the size of the area, because planting lines are interrupted. Therefore, planting costs are higher and all machine costs are higher because more turns **are** needed (Guildin, 1983). I also did not consider different group sizes within one forest block because there are endless permutations of group size and arrangement, making generalizations about the relationship between increased costs and group size very difficult.

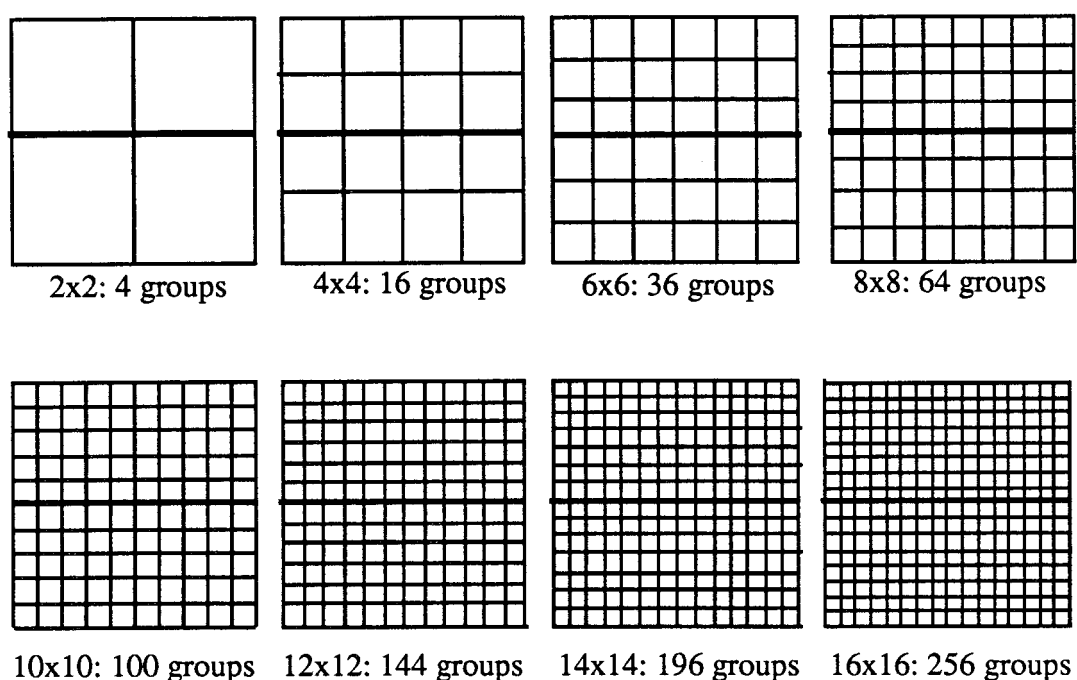
The geometric arrangement of the groups of trees is similar to that used at Tavistock (See Appendix **A**), but I am not advocating creation of uneven-aged forests set out with such mathematical precision. Rather, this approach allows straightforward, generalized comparisons of alternative management regimes (e.g. even-aged versus uneven-aged, and various scales of uneven-aged working) for the same area of forest, so that a manager can gauge the relative importance of different management variables. Harvesting models for clearfelling have been developed in several countries, notably Canada and although none of these models were used directly, the literature on the structure of these models was consulted during the development of the model.

2.2 DESCRIPTION OF CONSTRAINTS

The forest block can be managed either under an even-aged, clearfelling regime, where the whole block is felled in a single operation, or it can be transformed into an uneven-aged forest. If an uneven-aged transformation is selected, then the model allows a choice of four different group sizes for each of which operational costs are calculated. The **group size, forest block size, transformation period, and frequency of operations (felling period or felling cycle)** are all interrelated

and choosing a value for one of these variables restricts the values which the other variables can take. **Also**, I have assumed that a road runs through the centre of the forest block and this adds further constraints because it means that groups can only be arranged in squares (See Figure 2.2).

Figure 2.2: Possible Arrangement Of Groups Within The Forest Block



2.2.1 FELLING PERIOD

The Forestry Commission Yield Models (Forestry Commission, 1981) are based on a thinning interval of five years, and Forestry Commission management is planned on a five-year horizon. For these reasons a felling period of five years was chosen for the model. This may seem a fairly arbitrary decision, but it is consistent with felling periods determined by the Gurnaud-BiolleyCheck Method. Under the Check Method, a felling period is chosen after increment studies have been carried out to find the **Time of Passage** (the average time for a tree to pass through a 5cm. diameter class).

The felling period is then taken to be half the Time of Passage. Times of Passage for conifers have been found to be ten years at Corroul (Malcolm, **1971**) (See Appendix A) and twelve years at Glentress (Blyth and Malcolm, **1988**) (See Appendix A), giving felling periods of five to six years.

2.2.2 TRANSFORMATION PERIOD

In order to have an equal distribution of age classes in the transformed forest, an equal area of the block must be regenerated during each felling period. The relationship between felling period, transformation period and number of groups is:

$$T_t = (N_b \div N_f) \times T_f$$

where

T_t = Transformation period

N_b = Number of groups in the block

N_f = Number of groups harvested in each felling period

T_f = Felling period

The choices for transformation periods, based on the arrangements of groups shown in Figure 2.2 are calculated in Figure 2.3.

The next consideration is the fact that once the forest is transformed, the rotation length for each group of trees will be equal to the transformation period. Therefore, we can immediately rule out many of the transformation periods generated in Figure 2.3 because they will lead to trees which are far too young or too old at the time of their final felling. We can, in fact, sensibly restrict the range of transformation periods to **35-100** years, although the upper limit is perhaps more flexible, particularly in situations where the presence of older trees is an important management consideration. With this new constraint the choices of transformation period are reduced to those in Table 2.4.

Figure 2.3: Choices Of Transformation Periods Based On A Five-Year Felling Period

2x2: 4 groups

Number of Groups Harvested Each Felling Period	Transformation Period (yrs.)
1	20
2	10

4x4: 16 groups

Number of Groups Harvested Each Felling Period	Transformation Period (yrs.)
1	80
2	40
4	20
8	10

6x6: 36 groups

Number of Groups Harvested Each Felling Period	Transformation Period (yrs.)
1	180
2	90
3	60
4	45
6	30
9	20
12	15

8x8: 64 groups

Number of Groups Harvested Each Felling Period	Transformation Period (yrs.)
1	320
2	160
4	80
8	40
16	20
32	10

10x10: 100 groups

Number of Groups Harvested Each Felling Period	Transformation Period (yrs.)
1	500
2	250
4	125
5	100
10	50
20	25
25	20
50	10

12x12: 144 groups

Number of Groups Harvested Each Felling Period	Transformation Period (yrs.)
1	720
2	360
3	240
4	180
6	120
8	90
9	80
12	60
16	45
18	40
24	30
36	20
72	10

14x14: 196 groups

Number of Groups Harvested Each Felling Period	Transformation Period (yrs.)
1	980
2	490
4	245
7	140
14	70
28	35
49	20
98	10

16x16: 256 groups

Number of Groups Harvested Each Felling Period	Transformation Period (yrs.)
1	1280
2	640
4	320
8	160
16	80
32	40
64	20
128	10

Table 2.1: Final Selection Of Transformation Periods

Number of Groups	16	36	64	100	144	196	256
Arrangement	4x4	6x6	8x8	10x10	12x12	14x14	16x16
Transformation Periods	40	45	40	50	40	35	40
	80	60	80	100	45	70	80
		90			60		
					80		
					90		

As one of the objectives is to compare different scales of working in the uneven-aged forest, I had to choose transformation periods which gave me the greatest range of group sizes. It is clear from Table 2.1 that transformation periods of 40 or 80 years appear most often across the widest range of group sizes, and therefore, these are the two choices of transformation period included in the model.

The 40-year and 80-year transformation periods are not perhaps ones which would be chosen by a forest manager because they dictate rotation ages of 40 years and 80 years respectively once the forest is transformed. The first is really too short, except in fairly exceptional circumstances with very high Yield Class sites and the second is too long, unless dealing with very poor sites. However, these two choices do cover the range of sensible transformation periods, assuming that values for these other transformation periods lie on the line between these two extremes. **In** order to test this, the length of the transformation period was altered with the group size staying constant for the 12x12 arrangement of groups. From figure 2.3 it can be seen that this arrangement allows a transformation period of 60 years (the transformation period being implemented at Glentress, for example) in addition to the 40 and 80-year transformation periods.

2.2.3 GROUP SIZE

With the two choices of transformation period, the choice of group sizes is limited to four. It would be possible to include a fifth choice by introducing the arrangement of **20 groups x 20 groups**, but an array size of 400 elements would make the model very slow to run. The group sizes **are** generated **as** follows:

Group Size **1** = Block Size ÷ **256**

Group Size **2** = Block Size ÷ **144**

Group Size **3** = Block Size ÷ **64**

Group Size **4** = Block Size ÷ **16**

2.2.4 BLOCK SIZE

Block size is chosen by the user and in theory could be any area, but in the model it is restricted to between **12** hectares and **23** hectares. Various proponents of uneven-aged forestry have suggested optimum block sizes for the uneven-aged forest (See Table 2.2) based on factors such as statistical reliability in estimating production and efficiency of working (Newton, 1985).

Table 2.2: Suggested Block Sizes (ha)

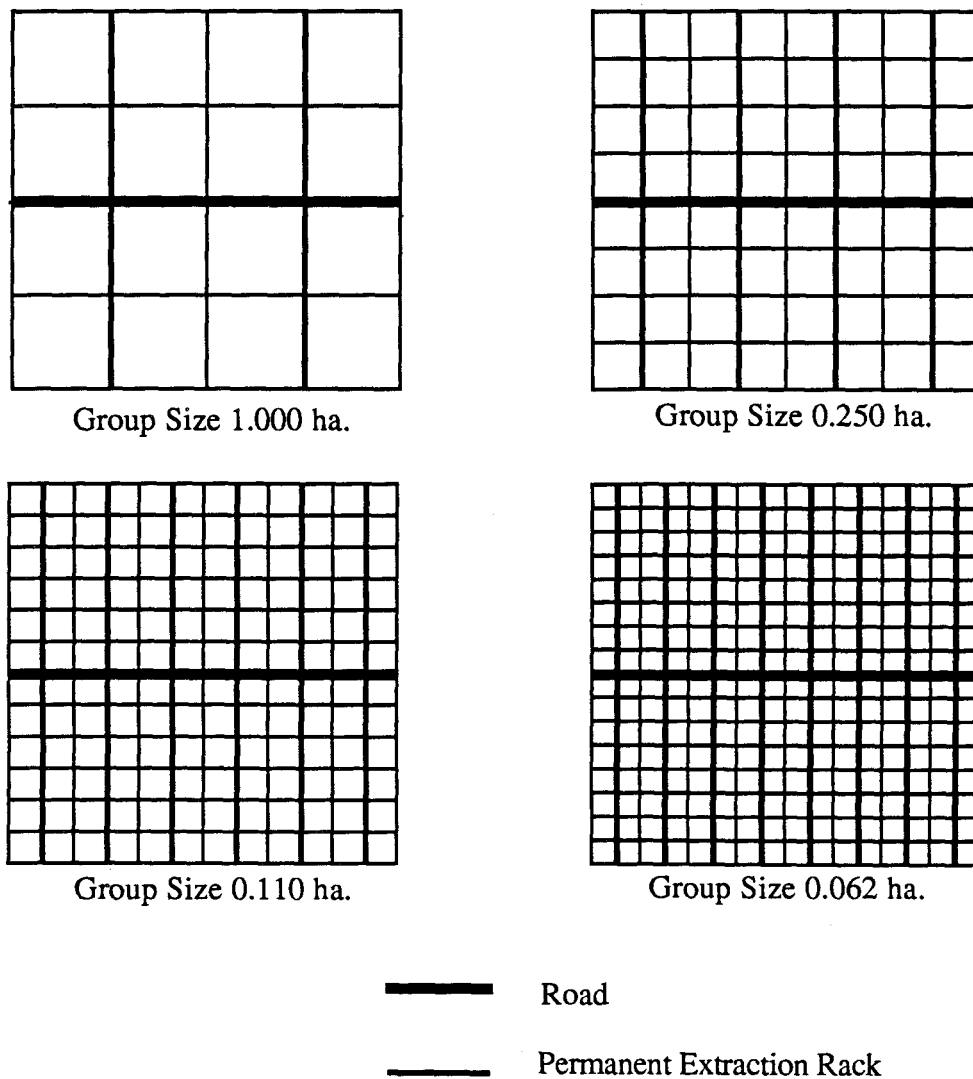
Minimum	Optimum	Maximum	Source
6.25		12.50	Paterson (1958)
4.00		10.00	Newton (1985)
	12.00-15.00		Biolley (1920)
	6.00-15.00	20.00	Knüchel (1953)
	10.00-12.00		Osmaston (1968)

Setting limits on the block size in the model was introduced purely to reduce the amount of programming, and the block size could be changed if necessary.

2.2.5 PERMANENT EXTRACTION RACKS

The forest transport network in the forest block also includes a series of permanent extraction racks placed between every other column of groups. This arrangement ensures that every group **has** direct access to an extraction route and is again based on the management system at Tavistock (See Appendix 1). Figure 2.4 shows the arrangement of groups and the transport system for an example 16 hectare block.

Figure 2.4: Extraction Network For A Sixteen Hectare Forest Block



The extraction racks are four metres wide and the area covered by each rack is treated as unproductive ground. This assumption is based on a cancelling-out of the positive and negative effects of cutting extraction racks in a forest. The main positive effect is an increase in the growth of trees alongside the edge of the rack, which benefit from the increased growing space and have greater volumes than trees on the inside of the groups. Isomäki (1986) collected data from temporary sample plots in Southern Finland, in order to examine the effects of line corridors on the development of edge trees. The measurements were taken over ten years after the corridors were cut and the edge trees had significantly higher volumes (+27%) than the inner trees. However, other factors which reduce volume or reduce the value of edge trees must also be considered. These include development of poor form in the edge trees and a reduction of increment caused by damage to the soil and the remaining trees, caused by extraction machinery. The group size which has been chosen by the model user is reduced by a two metre strip along one edge, for all the volume calculations, to take into consideration the area occupied by the extraction rack. In the results chapter, the group size shown is the gross group size, before this adjustment is made.

2.2.6 POSITIONING OF GROUPS TO BE FELLED

The groups which will be felled during any one felling period must be spread throughout the block, either in some systematic pattern or randomly. A random distribution was chosen because this represents the flexibility which is such an important feature of uneven-aged management: The forest manager chooses groups of trees to harvest, or patches of bare land to regenerate, based on the condition of the trees, or the presence of windblow etc. However, a constraint was added so that contiguous groups (but not those groups which are diagonally adjacent) could not be harvested in consecutive felling periods. This is a policy followed at Glentress with the aim of maximizing the irregular appearance of the forest. This will also mean that groups will generally stay as distinct units once the forest is transformed, because the age difference between groups will discourage amalgamation of parts of groups for final felling.

2.2.7 SPECIES AND YIELD CLASSES

The model assumes that transformation starts with an even-aged block of a single species. However, during the transformation new species, with associated new Yield Classes, may be chosen. In any one felling period only one species can be planted and individual groups may contain **only** a single species. In the uneven-aged forestry trials initiated by M.L. Anderson at forests such as Glentress, each group usually contained

two species: a shade tolerant species was planted at the southern end and a less tolerant species at the northern end. In the post-Anderson period this was discontinued as it was considered to be unnecessarily complicated.

The early uneven-aged trials were based on the central European montane irregular forests and the main species planted were Norway spruce, European silver fir, and beech. Planting of European silver fir and beech had to be discontinued because of heavy browsing by sheep and deer, and other species such as Sitka spruce, Douglas fir, Noble fir, larch, and Western hemlock have now been introduced. Species choice for the model has been restricted, for practical reasons (mainly paucity of data) to Norway spruce, Sitka spruce, Douglas fir and larch. Also, for each species-Yield Class-Spacing combination a large number of values must be calculated (See **2.2.3**) and so again choices are restricted to two-metre spacing (the current norm for conifers) and the following Yield Classes:

Norway spruce: YC **8**, YC 16, YC **20**

Sitka spruce: YC **8**, YC 12, YC **20**

European larch: YC 10

Douglas fir: YC 10, YC16

The species and Yield Class combination is chosen by the user of the model. The initial assumption is that the block contains a single species of one Yield Class, but as each group is replanted, a new species and Yield Class may be selected. The range of Yield Classes for Norway spruce and Sitka spruce was chosen to represent poor, average and good sites. The data for these two species are the most comprehensive and, therefore, most of the results have been generated using them. The other two species have been included for comparison with Norway spruce and Sitka spruce in order to see if the results are affected by the species planted.

2.2.8 AGE OF CROP AT START OF TRANSFORMATION

The Forestry Commission Yield Tables do not show values from the time of planting, but only begin with the five years prior to the age of first thinning for each species and Yield Class. Therefore, yield data for trees younger than this could only be obtained by extrapolation of the tables. Given that these trees would not be of merchantable size, it was not felt necessary to include them in the model. However, in order to

examine the effect of site **quality** (in terms of Yield Class) the results for different Yield Classes had to be compared with transformation starting at the same age. Therefore, the tables for the lower Yield Class sites were extrapolated back to age fifteen (the age when values for the spruces at Yield Class 20 are presented in the yield tables). (see Appendix D)

2.3 SOURCES OF DATA USED IN THE MODEL

2.3.1 INTRODUCTION

The data can be divided into three sections:

- Data on the time to carry out various forest operations
- Data on yields from the forest
- General information on the management of uneven-aged forests

Most of the "time" data have been obtained from the Work Study division of the Forestry Commission in the form of Work Study Reports, Standard Time Tables, and Output Guides. Standard Time Tables and work study experiments from other countries have also been included if they have been developed under similar conditions and are the only source of information on a specific operation. In some cases, no information could be found about specific operations, and in these cases I set up small-scale work study experiments to collect the necessary data. A final source of time information was the machine specifications for machinery included in the model, obtained from the manufacturers of the machinery.

The yield data have, again, mostly come from Forestry Commission sources. These include the Forestry Commission Yield Models, Volume Assortment Tables, Single Tree Length Assortment Tables, Sawlog Tables, and Smallwood Tables.

Managers of uneven-aged forests in Britain and Germany provided information on day-to-day management of uneven-aged forests. They provided valuable inputs in highlighting specific problems associated with uneven-aged forestry, their own solutions to these problems, and general information on costs of operations.

2.3.2 WORK STUDY DATA

The most detailed Work Study data are obtained from Work Study Reports, which describe actual work study experiments. A work study experiment begins with division of the operation being studied into several elements. This breakdown into elements is needed for several reasons (Wittering, 1973):

- Some parts of a job are invariable, while other parts **are** very variable, so breakdown into elements allows this to be taken into consideration.
- *Workers may not work at the same speed during different elements of the operation.
- *Similar elements from different operations can be compared and possibly interchanged, thus reducing the number of measurements needed.

An example of the elements in an operation is given here for Shortwood felling of Sitka spruce:

- Walk
- *Brash
- Fell
- *Takedown
- Sned
- *Move top aside
- *Measure and cross cut
- Extract

Once the time measurements have been taken for each element, regression equations are calculated, relating the time to carry out an element of the operation to some attribute of the trees and/or the stand. In the case of the shortwood felling example equations are calculated to relate the time taken for each element to the volume of the tree. Where equations give poor explanations of time mean element times are used.

Using the same example as above, we have the following equations (Muhl, 1984):

•Walk	Mean time
•Brash	Mean time
•Fell	Time= $0.174+3.71V-0.59V^2-0.070V^3$
•Take down	Time= $0.264+0.664V-0.527V^2+0.216V^3$
•Sned	Time= $2.139+5.29V-0.07V^2-0.252V^3$
•Move top aside	Mean time
•Measure and Cross cut	Time= $1.377+0.27V+1.21V^2-0.486V^3$
•Extract	Mean time

Where:

V=Tree volume in cubic metres

The **Basic Times** obtained by the procedures described above are converted to **Standard Times** by the addition of a percentage **Rest Allowance**. Rest allowances are added to the basic times so the worker can "recover from the physiological and psychological effects of carrying out specified work under specified conditions and to allow attention to personal needs" (Wittenng, 1973). Work Study Reports are not published, but the results are synthesized to form Standard Time Tables which are generally in the following form:

Shortwood Clearfelling of Sitka spruce	
Mean Tree Volume	Standard Time Per Tree
m3	S.Min.
0.10	9.70
0.15	11.45
0.20	13.10
.....

Standard Time Tables also include detailed job specifications such as the assortment of products to be cut from each tree, the presentation of the produce, treatment of cut stumps, and diameter at which tops should be cut off. The final section of the table contains modifications to the Standard Times which are applied when the prevailing conditions or job specifications differ from those set out in the first sections of the

tables. This section may include allowances for factors such as difficult ground conditions or extra time needed for snedding of unusually coarse trees. The allowances are usually percentages which must be added to or subtracted from the Standard Times. In cases where it has not been possible to gather enough data on an operation Output Guides are produced. These are similar to Standard Time Tables, but are less precise.

2.3.3 YIELD DATA

Yield models for uneven-aged forests in Britain are not presently available. Developing such models is difficult because there are so many variables involved, e.g. site, species, frequency of operations, length of transformation and pattern of felling. The productivity of uneven-aged forests versus even-aged forests is a controversial subject, but as total stand leaf area is the factor influencing productivity and is site determined, the differences in productivity between the two stand structures are probably small (Blyth and Malcolm, 1986). Malcolm and Taylor (1979) concluded that comparisons of productivity between different stand structures are almost impossible because of factors such as site and timescale of operations. In 1985, Helliwell called for the setting-up of experimental stands in order to make these comparisons, but as far as I know, this suggestion has not been followed up.

As alternative data were not available I assumed that groups of trees in the uneven-aged forest behave as even-aged units, and I therefore based my calculations on the Forestry Commission's Normal Yield Tables (1981). I feel this is a reasonable assumption for the larger group sizes and for determination of yields during the transformation period when many of the trees being harvested have essentially grown in an even-aged system. However, it is probably more difficult to justify for very small groups which contain only a few trees. In this case, the influence of shelter and shading must then play a larger part in influencing tree growth.

The yield tables have been incorporated into the model in such a way that if yield models for uneven-aged forests become available, they could easily be added to the model. Similarly, if a correction factor for the "edge effect" (i.e. the changes in growth of trees on the edge of each group) was developed, this could readily be included as a modification to the normal yield tables. The Forestry Commission yield tables also had

to be extended because the maximum age of trees included in these tables is not great enough to allow for the 80-year transformation option in the model. Therefore, I extrapolated the values in the tables **up** to age 105, which covers an 80-year transformation period starting with trees up to age 25. (see Appendix **D**)

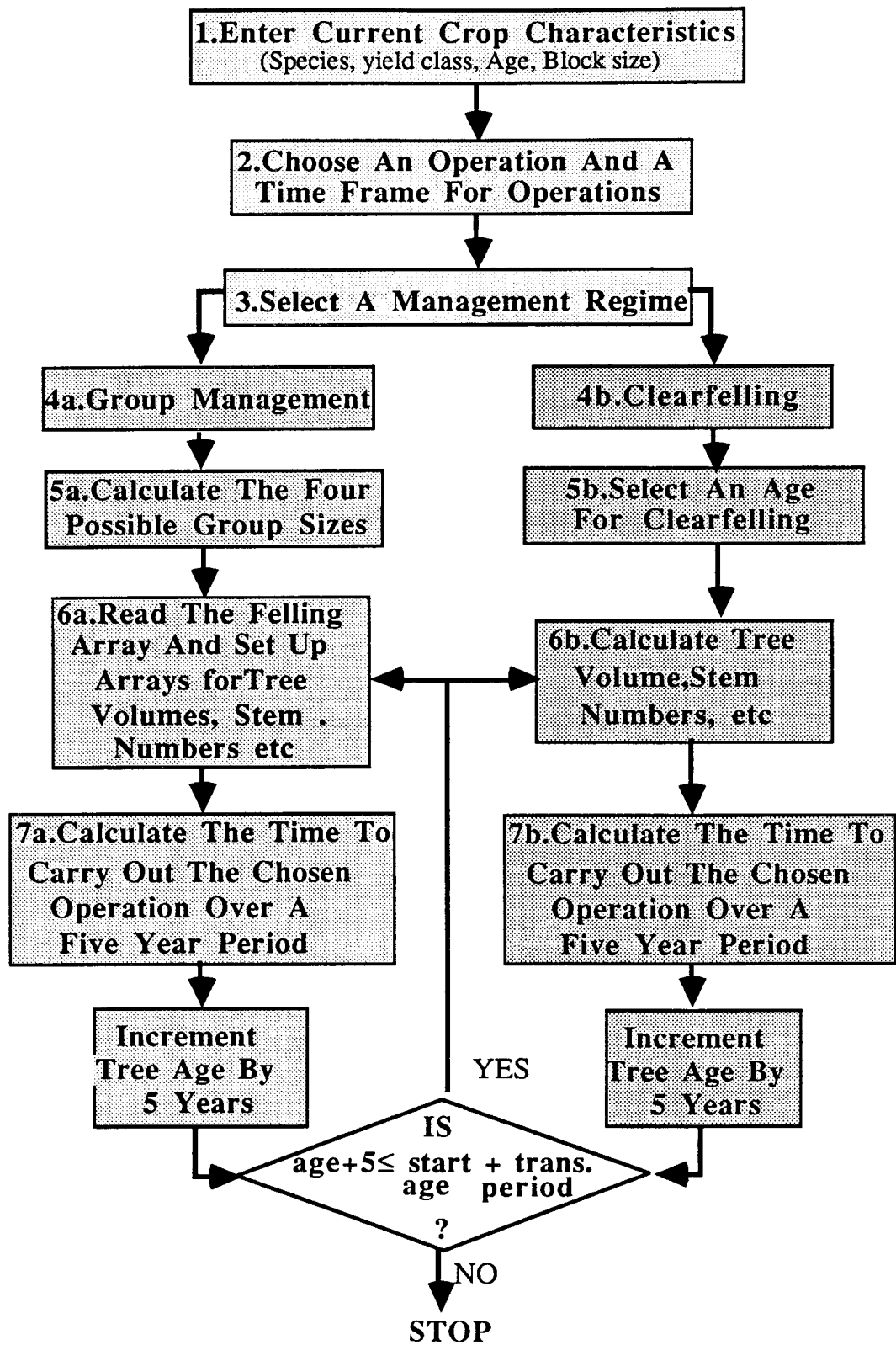
The values for stand volume, volume removed in thinnings, tree height, tree diameter, and number of stems **are** read directly from these extended yield tables. However, for operations such as forwarder extraction and for calculations of revenue from the forest, information was needed on the dimensions and quantities of sawlogs and pulpwood. Pulpwood volume and sawlog volume for each group (final fellings and thinnings) were obtained from a Stand Overbark Volume Assortment Table, using 16 cm as the specified top diameter. The mean sawlog volume and mean sawlog length were calculated as follows:

- Mean stand diameter (read from the yield tables) was used to access a Stand Table for conifers (Table 57, Forestry Commission, 1985a) in order to find the distribution of stems in each diameter class.
- The diameter class and the tree height were then used to access a Single Tree-length Assortment Table (Table **54**, Forestry Commission, 1985a). The sawlog specifications used were maximization of number of 8-metre logs with a 3-metre minimum sawlog length and 16 cm top diameter. These specifications are appropriate for the 10-tonne forwarders. Assortments of 4.5-metre logs were also calculated to be used in the 7-tonne forwarder operation.

2.4 STRUCTURE OF THE MODEL

The flowchart showing the structure of the main body the model is shown in figure 2.5. The following two sections describe steps **6a** and **6b** from the flowchart, for the two management options: uneven-aged management and even-aged management.

Figure 2.5: Flowchart showing the structure of the main section of the model



2.4.1 GROUP FELLING OPTION

The first step of the model is to read the array containing the sequence and arrangement of groups to be felled, in order to determine the type of operation appropriate for each group. During each felling period a group could be in one of five possible phases:

1. The group is selected to be felled and replanted
OPERATION=FELLING
2. The group has not been felled and the trees have not reached the age of first thinning
OPERATION=NONE
3. The group has not been felled but the trees have reached the age of first thinning
OPERATION=THINNING
4. The group has been felled and replanted but the second crop of trees has not reached the age of first thinning
OPERATION=NONE
5. The group has been felled and replanted and the second crop of trees has reached the age of first thinning
OPERATION=THINNING

This process is illustrated by the following example for Sitka spruce, Yield Class **20**, starting with trees aged 15 (Figure 2.6 and Figure 2.7). The age of first thinning, as specified in the Forestry Commission Yield Tables, is **20**.

Figure 2.6: Sequence in which the groups will be felled

1	4	6	3
5	1	8	5
2	8	3	7
7	4	6	2

FELLING ARRAY

Figure 2.7: Implementation of felling sequence

fell			
	fell		

period 1

	thin 20	thin 20	thin 20
thin 20		thin 20	thin 20
fell	thin 20	thin 20	thin 20
thin 20	thin 20	thin 20	fell

period 2

	thin 25	thin 25	fell
thin 25		thin 25	thin 25
	thin 25	fell	thin 25
thin 25	thin 25	thin 25	

period 3

	fell	thin 30	
thin 30		thin 30	thin 30
	thin 30		thin 30
thin 30	fell	thin 30	

period 4

thin 20		thin 35	
fell	thin 20	thin 35	fell
	thin 35		thin 35
thin 35		thin 35	

period 5

thin 25		fell	
	thin 25	thin 40	
thin 20	thin 40		thin 40
thin 40		fell	thin 20

period 6

thin 30			thin 20
	thin 30	thin 45	
thin 25	thin 45	thin 20	fell
fell			thin 25

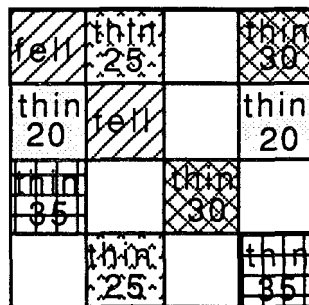
period 7

thin 35	thin 20		thin 25
	thin 35	fell	
thin 30	fell	thin 25	
	thin 20		thin 30

period 8

After the eighth felling period the forest block has been transformed into an uneven-aged structure with an even distribution of age classes. From this point on, the final felling groups will always be the same age (in this example 40 years) and the number of groups thinned in each age class will be equal.

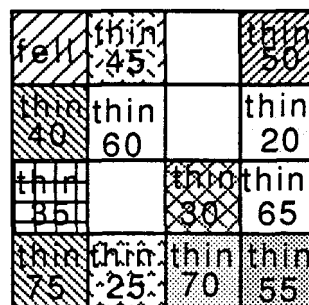
Figure 2.8: Transformed block (40-year transformation period)



Transformed Block

With an 80-year transformation period the number of age classes is greater and the number of groups in each age class is halved (See Figure 2.9).

Figure 2.9: Transformed block (80-year transformation period)



Transformed Block

During each felling period a set of arrays is created containing information on the trees and/or produce in each group. The arrays for the above example are shown below (Figure 2.10), for the final felling period of the forty-year transformation period (based on a 16 hectare forest block).

Figure 2.10: Information contained in two-dimensional arrays

2	2	0	2
0	2	1	0
2	1	2	0
0	2	0	2

Operation (1=fell
2=thin)

70	70	0	70
0	70	568	0
70	568	70	0
0	70	0	70

Total Volume To
Be Harvested (m³)

110	1130	0	364
0	110	286	0
179	286	364	0
0	1130	0	179

Number Of Stems
To Be Harvested

0.64	0.06	0	0.19
0	0.64	2.03	0
0.39	2.03	0.19	0
0	0.06	0	0.39

Mean Tree Volume
(m³)

28	14	0	18
0	28	46	0
23	46	18	0
0	14	0	23

Diameter Breast
Height (cm)

62	7	0	30
0	62	497	0
53	497	30	0
0	7	0	53

Total Sawlog Volume
(m³)

8	63	0	40
0	8	71	0
17	71	40	0
0	63	0	17

Total Pulpwood
Volume (m³)

0.35	0.12	0	0.14
0	0.35	0.61	0
0.29	0.61	0.14	0
0	0.12	0	0.29

Mean Sawlog Volume
(m³)

7.1	4.2	0	3.9
0	7.1	7.5	0
6.9	7.5	3.9	0
0	4.2	0	6.9

Mean Sawlog Length
(m)

Two one-dimensional arrays store the species which is replanted as each group is harvested and the associated Yield Classes, and two final arrays hold the number of stems to be brashed and the number of stems to be pruned, if these operations are selected as part of the management strategy.

2.4.2 CLEARFELLING OPTION

If clearfelling is selected as the alternative management option, the forest block is treated as a single unit, although the position of the road in the centre of the block is still fixed. Once the option has been selected, an age for clearfelling must be entered and costs are calculated over the same time period as the group management (i.e. 40 years or 80 years).

The forest block again **may** be in one of several states **and** this must be determined in order to choose the appropriate operation:

1. The forest block has not reached clearfelling age and the trees have not reached the age of first thinning.

OPERATION=NONE

2. The forest block has not reached clearfelling age but the trees have reached age of first thinning.

OPERATION=THINNING

3. The forest block has reached clearfelling age.

OPERATION=FELLING

The sequence of operations for clearfelling, using the Sitka spruce, Yield Class 20, age 15,40 year period example, is shown in Figure 2.11 below.

Figure 2.11: Sequence of operations for the clearfelling option

