COMPUTER SIMULATION

OF THE

WOOL SALE ROSTER

A Thesis Presented in Partial Fulfilment

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CHAPTER I

INTRODUCTION

1.1 New Zealand Wool Production and Disposal

New Zealand is the third largest producer, and second largest exporter, of wool in the world. Over the past thirty years New Zealand's wool production has more than doubled. Since 1967/68, however, a marked decline has occurred in the rate at which wool production was increasing. This decline may be attributed primarily to present economic and managerial advantages of expanding beef production, rather than sheep production, in many parts of the country.

Wool provides an important source of export earnings for New Zealand. Wool exports in 1970, valued at $204.5 million, constituted 19% of the total New Zealand earnings from export produce.[1] This places wool third in importance, after meat and dairy produce, as an export earner.

The bulk of the New Zealand wool clip is sold at auction in New Zealand and exported in the greasy state. The major markets for New Zealand wool are the United Kingdom, the U.S.A., Japan, Belgium, France, Italy, and the U.S.S.R. Local mill purchases take only a small proportion of the wool clip.

1.2 Wool Marketing in New Zealand

In New Zealand there is no controlled marketing of wool. Growers may market their own individual clips at auction in New Zealand or the United Kingdom, or they may sell their wool privately. The major proportion of the clip is sold at auction in New Zealand.

When growers sell their wool at New Zealand auctions they are assured

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1. Source: Department of Statistics (3), p.567.

of at least receiving the floor price for their wool, through the operation of the floor price scheme administered by the New Zealand Wool Commission. Provision also exists for the application of floor price protection to wool sold privately, provided certain conditions are met. Growers can put their own reserves on their wool offered at auction, and they can withdraw the wool from sale and offer it later. Reasons for only a limited amount of New Zealand wool being sold by auction in London include the delay in receipt of payment, and the general convenience of supplying local sales. Private selling has developed very strongly from the 1968/69 season. The proportions of the seasonal clip sold through the various marketing channels are given in Table 1.1 below.

TABLE 1.1 THE MARKETING OF NEW ZEALAND WOOL

Method of Sale	Percentage of Total Production			
	1967/68	1968/69	1969/70	1970/71
New Zealand Auction	75.14	71.04	68.69	66.07
United Kingdom Auction	0.27	0.27	0.28	0.22
Private Sales	7.99	10.91	13.17	15.81
Others*	16.60	17.78	17.86	17.90
Total	100.00	100.00	100.00	100.00

* Composed largely of slipe wool but includes sheep skins and stock changes also.

Source: Primary data from New Zealand Wool Commission (6), p.11.

Table 1.1 above indicates that the importance of the New Zealand wool auction outlet is declining. Most of this decline is being taken up by increases in private selling. However, the auction of wool in New Zealand provides a means of sale for about two thirds of the clip. Unless private selling, or, some other means of disposal, can accomodate this two thirds of production the New Zealand auction system will retain a major marketing role.

Because of the variability in wool offerings buyers require that wool be available for appraisal prior to auction. This appraisal function of the auction marketing system could become redundant if one (or both) of the following technological changes occurred. These are:

i. if manufacturing techniques for wool develop such that variability in the fibre characteristics of wool become of little disadvantage, or,

ii. if a practical means of grading wool fibres into acceptably homogenous lines becomes available (homogeneity of a degree sufficient to satisfy manufacturers).

Either, or, both, the required changes above would favour the introduction of an industrial system of marketing for wool; a system whereby samples of wool, with specified prices, would be presented to manufacturers. Otherwise, samples[2] could be made available to buyers for evaluation, in lieu of the present method of appraisal. In this situation the auction system could retain its function as a pricing system but lose its function as a means of wool appraisal.

These technological changes are likely to develop and effect the future of the auctioning system. The rate at which these technologies develop may determine how long the auction system remains.

At present the New Zealand Wool Marketing Corporation is being established, following recommendations made by the Wool Marketing Study Group (10), the Wool Marketing Committee (9), and, the Battelle Report (2) on wool marketing in New Zealand. The policies of the Corporation are not known as yet. To obtain wool the Corporation could buy privately, buy at auction, or operate an acquisition scheme (as does the Dairy Board). The Coporation could sell

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2. Some wool is appraised on a sample basis at present. The situation referred to implies that <u>all</u> wool is appraised on the basis of samples.

wool to buyers and merchants in New Zealand, and/or, directly to overseas merchants and manufacturers, and/or, through the auction system.

In conclusion, the immediate future of the auction system cannot be assessed at this stage; the most important controlling factors are the policies decided on by the New Zealand Wool Marketing Corporation.

1.3 The Auction System in New Zealand

1.3.1 The Auction Sale Procedure

There are eight wool auction selling centres in New Zealand; four in the North Island (Auckland, Napier, Wanganui and Wellington) and four in the South Island (Christchurch, Timaru, Dunedin and Invercargill). A roster of wool auction sales, for each season, is drawn up by an official body called the Wool Auction Sales Committee. The roster prescribes dates for the sales at each centre and the quantity of wool to be offered at each sale. Teams of buyers in the North Island and South Island, totalling about eighty buyers, travel from selling centre to selling centre.

The roster of New Zealand wool sales covers a series of winter sales in August[3] as well as main sales starting at the end of September and finishing in June. At the winter sales most crutching wools are sold; also any early shorn wool available at the time, and any wool left over from the previous season.

Wool producers sort their wool into lines with some semblence of homogeneity and press it into 145 - 160 kilogram bales in the shearing shed. They may skirt, and/or, class their wool in the shearing shed, or, arrange for a wool broker to do this. Wool brokers are firms that prepare, handle, and offer producers' wool for auction (or for private sale). Growers brand their bales with their identification mark, description of contents, and bales are numbered consecutively. Transportation of wool to their broker, at the

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3. Winter sales form part of the roster but are not considered in the roster problem. They do not effect the rostering of main sales. Main sales are rostered on the basis of estimates of new seasonal wool arrivals.

centre where their wool is to be auctioned, is arranged by the producer. At this time any instructions for the broker regarding preparation of his wool are given.

Producers usually send their wool to their broker immediately after shearing. One possible reason for this is the belief that there is a downward trend in prices over the season. The main reason is probably because producers are foregoing interest on the value of unsold wool. Because different wool types are shorn at different times of the season, the quantitative composition of wool types being offered at auction varies over the season.

On arrival at the wool brokers store, bales may be separated for specific pre-sale operations, to be carried out by the broker, as instructed by the wool producer. Pre-sale optional operations carried out are important determinants of labour and time requirements of brokers. The most important of these optional operations are binning, reclassing, skirting and interlotting. About 40% of wool offered at auction sales in New Zealand is binned or reclassed by brokers. This proportion varies between auction centres from around 20% in Wanganui to about 50% in Christchurch.[4]

Because the bulk of the National wool clip is shorn before Christmas, there is a rush of wool into brokers' stores between the beginning of the main selling season in October and the end of December. Brokers adopt a system of "first into store first into sale". This is necessary because of the time required to prepare wool for auction by brokers, and, because of a quantitative upper limit on the wool that can be sold at individual auction sales.

Wool brokers and wool buyers are parties to agreed regulations covering:

i. the procedure for display of wool,

ii. the sampling of wool by buyers,

iii. the auction sale rules,

iv. the after-sale procedure regarding confirmation of purchases and rebranding of bales for export,

v. documentation,

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4. Source: New Zealand Wool Commission (6), p.18.

vi. shipping instructions and payment for wool purchases,

vii. the Press market reports of each sale.

Daylight lighting is required for wool displayed for sale by auction. Bales are displayed in brokers' wool stores to which buyers are given access for valuation. A limited number of bales are opened to allow inspection. Wool brokers and buyers regulations cover the stacking of bales, and, the proportion of each lot to be opened. Bales opened for inspection must be representative of each lot, to the best of the broker's knowledge.

The rules settled between wool buyers and wool brokers provide that wool must be displayed for valuation by the buyers during an agreed number of days prior to the sale. Brokers supply buyers with catalogues in which they can mark their valuations for lots to be offered for sale. Hence buyers are ready on the sale day to compete in their bidding for lots offered. Brokers also make valuations of wool before the sale and generally communicate their valuations to the producers. Producers may then instruct brokers to place a reserve price on their wool.

Wool auction sales in New Zealand are legally public auctions but are attended only by recognised wool buyers. i.e. firm representatives resident in New Zealand, who buy wool at the sales in fulfilment of orders of their principals, or, on their own behalf. Seating is arranged suitably for the buyers at these auction sales, the seats being allocated at the beginning of the season by the Wool Brokers' Association on the basis of quantities of wool purchased during the previous three seasons.

After the sale, bales which were opened for the purpose of display are sewn up and countermarking requested by buyers is put on the bales. Space in ships is booked to ensure prompt shipment of wool overseas. Buyers pay for their purchases on or before "prompt date", that is, eighteen days after the sale.

In summary the wool buyer's function consists of inspecting and valueing wool, bidding for it at auction, arranging for payment for purchases, and the despatch of wool purchased. The wool buyer is the major link between the auction for wool and the raw wool user.

Wool Commission activities at auction effect the auction system in two ways. Firstly there is an effect on demand due to Commission bids operated on the floor price scheme. Secondly, the re-offering of any stocks of wool accumulated by the Commission effects supply.

Insofar as the roster problem is concerned Commission activities are not important. The Commission may offer stocks at any auction where these offerings do not increase the sale sizes to unmanageable levels.[5] Rosters are made before the season commences so little consideration can be given to demand shifts over the season.[6]

1.3.2 Efficiency of the Auction System

Two criteria which may be used to establish the efficiency of any marketing system are:

i. efficiency as a pricing system,

ii. efficiency as a distribution system.

A marketing method which is efficient from a pricing point of view is one in which consumers' wants are accurately transmitted to producers by the pricing mechanism. The Wool Marketing Committee (9) pointed out that the auction sale system for wool has inefficient aspects from this point of view. Short-term wool price fluctuations, and lack of consistency in the prices of individual wool types, do not give an accurate indication of consumer demand to growers.

A marketing system which is efficient from a distribution point of view

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5. Overrostering (see Section 1.4.1) occurs. Overrostering provides some flexibility to auction sale sizes, allowing the Commission to offer stocks if they wish.
6. The Wool Marketing Committee (9) agreed that "the major cause of fluctuation in raw wool prices is demand for, rather than supply of, wool". The effect of the roster on wool prices, in that it supplies wool to the market, is not considered important.

is one in which goods are moved from producer to consumer at minimum cost. While the wool auction sale system effectively disposes of two thirds of the national wool clip, it forms part of the distribution system described by the Transport Department (5) as being "fragmented and costly". The Wool Marketing Study Group (10) pointed to areas in which further cost savings could be made.

However, the Wool Marketing Committee (9) observed that before the wool auction sale system could be abandoned, there must be clear evidence of a method, better suited, for the sale of some 1,600,000 bales of wool per annum.

The continuation of the auction system, in a major wool marketing function, depends on whether a more efficient marketing system can be introduced. Inefficiency of auction selling as a pricing system is the major disadvantage of this system. The floor price scheme, operated by the Wool Commission, was aimed at improving this aspect of efficiency. Partly because of the limited success of the floor price scheme, the Wool Marketing Corporation (see Section 1.2) is being set up. Insofar as the roster is concerned, proposals to improve the pricing efficiency of the auction system are not important. The reason for this lies in the belief that demand, not supply, is the important determinant of wool prices and wool price fluctuations.

Proposals aimed at improving the auction system in its distribution function do effect the roster. Most of these proposals effect the rostering constraints. Sale by sample,[7] dense baling,[8] containerisation,[9] and unitisation,[10] have implications in terms of the time constraints in rostering.

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7. Sale by sample involves presenting wool samples for inspection by buyers rather than stacking bales in their respective lots and opening some of them.
8. Dense baling involves pressing wool into dense units. These bales cannot be opened for buyer inspection. Therefore dense baling must be associated with sale by sample.
9. Containerisation involves packing and shipping wool bales in containers.
10. Unitisation involves combining a number of bales into one unit for greater ease of handling. The bales of the unit may be held together by wire or steel straps.

The proposal that the number of selling centres be reduced would require vast changes in the roster format.

Attempts to improve the efficiency of the auction system by introducing one or more of the proposals discussed would produce associated changes in the roster format. The extent of these format changes, and the change in efficiency of the auction system, should be accurately evaluated before any proposal is implemented.

1.4 The Wool Sale Roster

The wool sale roster is perhaps the most important component of the auction system. The roster effects every party involved with the auction system; therefore it effects many important performance parameters[11] of the system. Furthermore the roster is one of the most flexible components of the wool auction system. This flexibility makes the roster amenable to alterations and adjustments aimed at improving the performance of the auction sales procedure as a marketing system.

1.4.1 Drawing Up the Roster

The wool sale roster is drawn up by an official body named the Wool Auction Sales Committee. The composition of the Committee is:

Three members nominated by the N.Z. Woolbuyers' Association
Three members nominated by the N.Z. Woolbrokers' Association
Two members nominated by the N.Z. Wool Board
One member nominated by the N.Z. Wool Commission
One member (without vote) to be Chairman of the Committee

A Sub-Committee, (composed of representatives of the wool brokers, the wool buyers, the Wool Board and the Wool Commission), has the function of

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11. Performance parameters represent goals, or, objectives, of individuals or parties. Measurement of performance parameters measures the extent to which these goals are fulfilled, (see Section 1.4.3).

drawing up tentative rosters for submission to the Wool Auction Sales Committee. This Sub-Committee has six members.

Before a roster can be formulated, estimates of expected wool arrivals for each centre must be made. The auction sales roster for the 1969/70 season, originally drawn up by the Wool Auction Sales Committee in November 1968, was revised by the Committee in May 1969 in the light of amended estimates of the quantities of new clip wool likely to be available in the eight selling centres throughout the season. Due to inaccuracy in the quantities offered for sale, compared to new clip wool actually available for sale, the system for rostering has been altered. Future rosters will set firm quantities for the first half of the season only. Tentative quantities will be given for the remainder of the season, and will be reviewed in mid-season.

The estimates of quantities of wool rostered for sale, when the roster is drawn up, need to be reasonably close to what will actually be offered at sale because:

i. shipping space for wool is made available (booked) according to the wool sale roster. Hence inaccuracies in estimates result in excess, or, deficits in, shipping capacity for each sale,

ii. buyer inconvenience is caused by inaccurate rostering.

Generally the Wool Auction Sales Committee overrosters in most centres. i.e. the amount of wool rostered for sale exceeds total seasonal arrivals.[12] Overrostering provides both brokers, and the Wool Commission, some flexibility in their operations.

The current sales programme is known in the trade as a two-island roster. It requires buying firms to have buyers for each island. This type of roster has proved flexible in meeting current demands and, particularly,

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12. The 1970/71 roster (as amended August, 1970) rostered 1,435,000 bales for auction from September. Total arrivals for that season (excluding winter sales) numbered 1,305,000 bales. Total rostered/total arrivals equals approximately 1.1. i.e. overrostering by about 10% occurred.

in ensuring that there is no undue delay in the early part of the season in scheduling sales where there is wool awaiting sale.

1.4.2 Restrictions in Rostering

Five basic restrictions must be considered when rostering wool sales. These restrictions are required in the roster by buyers and brokers so as they may fulfill their functions in the auction system without undue hardship.

Lower sale size limits are required to give a full days auctioning. Upper sale size limits keep the sale to a manageable size. The sale size limits are determined by the rate of selling wool and the length of the sale. The auction selling rate is generally between 300 - 350 lots per hour. Sales commence at 8.00 a.m. and finish at about 6.00 p.m. Wool auction sales may be either single or double sales. Single sales comprise one auction day; double sales are held over two auction days.

There are time restrictions on the minimum period between sales in a centre. A minimum period is required to allow brokers to break down the previous sale and prepare for the next sale. The sizes of these periods depend on the sizes of the two sales and the amount of preparation required for wool that is arriving in brokers' stores.

Brokers give notice of closing dates for sales. The closing date is the last day that new wool arrivals will be included in the next sale. A minimum value for the closing to sale date period is required to allow late arrivals to be processed and presented for appraisal by buyers prior to auction.

Buyers require minimum periods between sale dates in the same and different Islands. The within Island restriction allows buyers to organise shipping arrangements for purchases, to communicate with principals and associates, and, to evaluate wool being offered at the following sale. The between Island restriction is required by buyers for similar purposes though they seldom attend sales in different Islands.

The fifth basic restriction is that sales must be held only on trading days. This excludes weekends and public holidays. A Christmas break is included in this restriction.

1.4.3 The Performance of a Wool Sale Roster

The performance of a roster is some measure of the degree to which the roster fulfils the goals of parties involved. Due to areas of conflicting interest, however, a roster considered to have a high performance by one party may be considered of low performance by another party. Furthermore, a roster may be regarded as having high performance with respect to one goal of an individual (or party) and low performance in terms of another of his goals. Generally it is easier for an individual (or individual party) to compromise his (or its) conflicting goals, and arrive at a decision, than it is for more than one individual (or party). The problem of compromisation, between the conflicting goals of parties devising the roster, detracts from the use of optimising analytical techniques for the roster system.[13]

The wool producer would consider a high performance roster as one which sold his wool as soon as possible and at a good price. For some producers the wool cheque is the first source of revenue after winter, and may be required to meet operational expenses.

The wool broker wishes to shift as much wool as possible without extensive peak handling periods. Peak handling periods entail high costs of overtime work. They are caused by pre-sale rushes of wool arrivals and post sale shipping rushes.

Wool buyers need time to evaluate potential purchases and attend sales. Their main costs are in travelling and accommodation. Time is required after sales to organise the disposal of purchases.

The roster effects the activities of the Wool Commission in two ways. Firstly the roster effectively supplies wool to the market, and therefore has

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13. The problem of conflicting goals is expanded in Section 2.2.1.

implications to the floor price scheme. Secondly, stock offerings by the Commission must fit in with the roster. Stock offerings at a sale must be such that the resulting sale size is within prescribed limits.

The Wool Board acts in a co-ordinating function. Their aim, as representatives of producers, is to co-ordinate the system so as to minimize costs due to peak handling periods, yet sell wool at a rapid rate over the season. Shipping must be well organised to keep shipping and wool handling costs down.

In attempting to fulfil these objectives, the Wool Auction Sales Committee devises rosters which tend to have a monthly pattern of single sales. i.e. a single sale is held each month in each centre. The pattern cannot be rigidly adhered to because of holidays and differences in wool arrivals in different centres; smaller centres may not have enough wool for monthly single sales, whereas in larger centres so much wool may accumulate that a double sale must be held.

From the goals of the parties involved, a list of performance parameters for the roster can be drawn. The performance parameters are:

i. the accuracy of the forecasts of quantities offered at sales,

ii. the length of time bales are held in store prior to being sold,

iii. the storage requirements for wool,

iv. the extent of peak handling periods caused by the roster,

v. the time buyers have for wool appraisal, and disposal of purchases,

vi. the ease with which shipping can be made available.

In the list above many of the performance parameters are seen to be interrelated. The length of time bales are held in store prior to sale, obviously determines pre-sale storage requirements. The ease of organising shipping is related to sale size forecasts, and peak handling periods. Further in the study these performance parameters are made more specific to remove some of these interrelationships. Performance parameters relating to wool prices are not included in the list. The reason for this is the belief that the roster plays only a limited role insofar as wool prices are concerned.[14]

1.4.4 Changes to the Roster

Proposed changes to the auction system could produce significant changes in rostering. Most of these changes would be reflected in alteration of the rostering constraints.

Proposals that would improve the distribution efficiency of the auction system would often allow the minimum period between two sales to be reduced; less time may be required to set up and break down sales.

A study conducted by Peirse and Beggs (7) indicated that advantages would accrue in terms of wool handling and wool prices if smaller lot sizes were abolished from the auction system. The average lot size at auction is important in that the rate of selling wool (in bales per day) is limited by the rate of selling lots. If the rate of selling lots of wool was constant, then the rate of sale of wool at auction would be directly dependent on the average lot size.

Peirse and Beggs give a broad distribution of lot sizes over the 1964/65 season in the following table.

TABLE 1.2 DISTRIBUTION OF LOT SIZES SOLD AT AUCTION - (1964/65 SEASON)

Lot Size	Number of Lots	Percentage of Total Lots	Number of Bales	Percentage of Total Bales
1 - 6	64,360	48.8	287,747	21.8
7 - 10	31,618	23.9	260,368	19.9
11 - 15	16,166	12.3	204,714	15.8
16 - 20	7,313	5.5	129,705	9.8
21 - 25	4,949	3.8	114,805	8.7
26 & over	7,610	5.8	315,036	24.0
TOTALS	132,016		1,312,375	

Source: Peirse and Beggs (7), p.1.

14. For further discussion on this point see Section 2.1.4.

Assuming that the rate of selling lots is independent of lot size it can be seen from Table 1.2 that 48.8% of the selling time is taken to sell 21.8% of the wool offered at auction by the 1 - 6 lot size class. At the other extreme only 5.8% of the selling time was required to sell 24% of the bales. Abolishing smaller lots would probably increase the average lot size. This would mean that more wool could be sold in a days auctioning. The result on the roster would be to increase the sale size limit restrictions.

At present there are eight selling centres in the roster. It has been argued that this number could be decreased, to economic advantage, by removing some of the smaller centres. Such a proposal has important implications for parties effected by the roster. Producers in areas where centres were abolished would incur higher transport costs for their wool. Average brokerage costs may decrease due to economies of scale. Wool buyers would have less centres to attend sales in. Shipping could probably be organised more easily. However, as the quantity of wool channelled through a centre increases, more peak handling periods, and higher storage costs, are likely to occur. Because of all these factors, a full investigation into the performance of the auction system with less centres is required before such a proposal is implemented.

To facilitate the organisation of shipping an even monthly disposal pattern for wool could be introduced. This proposal could improve the operational efficiency of wool brokers and buyers but may incur higher wool storage costs. The roster would change in format, from tendencies to maximise monthly wool disposals, to a format promoting an even monthly disposal rate.

1.5 The Rostering Problem

Devising feasible wool sale rosters is time consuming, due to the restrictions that must be observed. Furthermore, rosters may be feasible but not acceptable. An acceptable roster must satisfactorily fulfil the goals of parties effected by it. It is difficult to devise acceptable rosters due to the problem of conflicting goals (see Section 1.4.3).

Different feasible rosters vary in their performance for different goals. It would be desirable to devise a great range of feasible rosters from which one can be chosen by the Wool Auction Sales Committee. At present, rosters are devised by a Sub-Committee of six members. The time required to draw up feasible rosters limits the range that can be produced. Consequently only a limited range of rosters can be studied and modified to find one which is satisfactory. Because of this limited range much time may be used to modify rosters. If a wider range of rosters was made available, then it is likely that one of these would be acceptable with little modification.

Due to the time required to draw up feasible rosters, and additional time that would be needed to measure performance parameters of the roster, no measures of performance parameters are made. In accepting a roster the Wool Auction Sales Committee must appraise the performance of the roster; but this appraisal is not in quantitative measures of performance parameters. However, quantitative measures would improve the appraisal function.

Furthermore, the present system of devising and evaluating rosters makes it very difficult, and, time consuming, to evaluate the performance of the roster sub-system for new roster formats; formats which would result from the introduction of proposed changes to the auction system.

1.6 Objectives of the Study

The main aim of the study was to devise a means of generating a wide range of feasible rosters. It was imperative to observe the rostering restrictions, and, desirable to measure the performance parameters of each roster quantitatively. The advantages of producing a wide range of feasible rosters, each with a measured set of performance parameters, have been explained in the previous section.

Because of the number of restrictions and performance parameters in the rostering problem, and the number of rosters required, it was felt necessary to use a computer. Consequently a representative mathematical model of the roster sub-system had to be devised. Formulation of a representative mathematical model of the roster sub-system requires that all components of the system be included in the model. Variation of the action of the system's components, or the relationships between components, makes experimentation with the model possible. Consequently, in fulfilling the main aim of the study, a means is provided by which the performance of the roster sub-system can be studied for proposed changes to the auction system.

1.7 Thesis Guide

In Chapter II a full description of the rostering problem is given in the broad categories of wool arrivals, constraints and performance parameters. Within these categories assumptions and refinements are made to establish components and relationships of the roster system. A description of operations research is given with special emphasis on the problem of conflicting goals. Following this a mathematical model of the roster sub-system is devised, and techniques of analysing the roster problem, by means of the mathematical model, follow.

Chapter III presents the computer simulation model and its validation. The estimation and computer input of wool arrivals is described initially. This is followed by the specifications for rostering restrictions, and their inclusion in the programme. Performance parameters measured by the model, and decision making processes of the model, are described next. Finally, a range of rosters, based on three sets of wool arrivals estimates, and varying model decision rules, are presented. These rosters are for the 1971/72 season; they are compared to the actual roster devised by the Wool Auction Sales Committee for that season.

In Chapter IV experimentation with the model is carried out to evaluate the effect of proposed changes to the auction system on the performance parameters of the model. The layout for each experiment conducted is as follows. Firstly, the implication of the experiment, in terms of proposed changes to the auction system, is discussed. Then the results for the experiment are presented and conclusions drawn. Further in the Chapter the sensitivity of the experimental results under conditions of changing wool arrivals and decision processes is studied. Inconsistent rosters are discussed, and finally a summary of the experimental results is presented.

Chapter V presents the conclusions drawn from the study. Initially the validity of the model, and model produced rosters, is discussed. Experimental results and policy suggestions are presented next. Finally a summary of the usefulness of the study in view of future changes to the wool marketing system is presented.

CHAPTER II

THE WOOL SALE ROSTER PROBLEM AND APPROACHES TO ITS SOLUTION

2.1 The Rostering Problem

2.1.1 Outline

The problem to be solved is that of rostering wool sales for the eight selling centres throughout the auction season. Consideration must be given to constraints on the timing and sizes of sales. Interaction of these constraints with wool arrivals determines the formulation of rosters. For each different roster that can be formulated within these constraints, for the same estimates of wool arrivals, there is likely to be a different relative performance,[1] as measured by the goals in rostering. Hence there are three areas to look at in the wool rostering problem. These are:

i. estimation of wool arrivals over the season in each centre,

ii. constraints on the timing and sizes of sales,

iii. the performance of a roster.

A fourth problem concerns the effect of changes in the parameters of the wool marketing system on the roster. Some relevant changes were discussed in Section 1.4.4. This problem area is studied further in Chapter IV.

2.1.2 Wool Arrivals for Auction

Wool is supplied by producers on a seasonal basis. Throughout the season both the quantity and type of wool arrivals, per unit of time, vary within and between centres. For the purposes of rostering, wool arrivals are assumed to be homogenous. Some allowance for heterogeneity is made insofar as processing by brokers, prior to auctions, effects the between sale restrictions for the

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1. Performance is explained in Section 2.1.4.

different centres (see Section 2.1.3). The period over which wool arrives in the different centres varies, with Auckland usually having the longest season and Timaru the shortest. The rostered period continues some short time after the last wool arrivals for the season reach brokers.

Estimates of wool arrivals for auction in the eight centres are made separately by the wool brokers, the wool buyers and the Meat and Wool Boards' Economic Service. The first two groups do this through their members. Brokers, in the separate geographical areas, build up an estimated total for one centre for the period of the main wool sales. These estimates do not include wool received and sold in the winter sales.

The Meat and Wool Board's Economic Service, provides estimates of the weight of wool that will be shorn by growers who patronise the auction sales at the different centres. Information to base these estimates on is provided by their Field Officers. Judgement must be used in some areas where there are insignificant economic differences for producers between supplying more than one centre.

The Wool Roster Sub-Committee takes out final estimates for each selling centre from these three sets of data, and then proceeds to develop wool sale rosters (or a roster) for the forthcoming season.

Auction sales are set with relation to the new clip only. If the Wool Commission wishes to offer any wool from its stockpile, it may use space in an auction sale where the new clip offerings (first time offered) are less than the upper single, or, double, sale size limit, as the case may be, provided total offerings remain within the relevant limit. The Wool Commission has the right to offer stockpile wool without reference to the Wool Auction Sales Committee. Notice is given to the trade of intended stockpile offerings.

Inaccuracies in estimates of wool arrivals for auction can be attributed mainly to production fluctuations caused by seasonal climatic variability, and, in more recent years particularly, to fluctuations caused by private sales of wool. Variability caused by changing production policies on farms, should be directly related to sheep numbers, which are estimated annually.

It is not possible to accurately forecast estimates of wool that will be available for auction with elements of uncertainty due to climatic effects, hinterland producers, and private sales. Hence it would be advantageous to estimate several rosters, subject to the same constraints, but using different estimates of wool arrivals. The sensitivity of the roster to varying estimates of wool arrivals could then be studied to aid decisions on the final form of the roster. Estimation of arrivals is further discussed in Section 3.2.1 where the model formulated looks at rosters for the 1971/72 season using estimated data.

The pattern of wool arrivals is not entirely independent of the roster itself. Wool arrivals between sales tend to arrive at an accelerating rate up until a short time before a sale. The result of this is a tendency for peak handling periods to arise in wool brokers stores shortly before a sale. However, unless drastic changes in the roster format were made, little control of this feature by the roster is possible. The type of drastic change envisaged, is one whereby the roster prescribes a selling pattern approximating continuous selling. Otherwise, incentive measures outside the roster would be required to decrease the incidence of these peak handling periods. Restrictions in the system are such as to make allowance for peak handling periods resulting from the pattern of wool arrivals between sales. The specific restrictions concerned are the between sale within centre time constraints (see following section).

2.1.3 Rostering Constraints

There are five basic constraints in the wool sale roster problem. These are:

i. upper and lower constraints on the sizes of sales,

ii. the minimum period between sales within a centre,

iii. the minimum period between sales in different centres,

iv. the minimum period between closing and sale dates,

v. the feasible sale days.

The length of the rostered season could be considered as a further constraint, however, it was found that within the assumptions, constraints, and goal evaluations of the model developed, that restriction or expansion of the rostered season around that length chosen would serve little purpose.

Upper and lower constraints on single and double sales are required. Lower constraints serve to ensure that auction sales are of reasonable size. This means sales must be of a size warranting the time and expense brokers and buyers put into preparation for the auction. Upper constraints on sale size are determined by the rate at which wool can be sold at auction. Hence the constraints are set such that a full day's (or two days in the case of double sales) auctioning results.[2] The major variable controlling these limits is the average lot size of wool offerings at sales. Changes in the average lot size, methods of achieving such changes, and the consequent effect on sale size limits and the roster, are discussed further in Chapter IV.

The minimum period between sales within a centre is determined by the nature of the previous sale (whether single or double), and the nature of the proposed sale (whether single or double). Consequently there are four values of this restriction[3] for each centre. These are for sale sequences of:

i. single - single
ii. single - double
iii. double - single
iv. double - double

Comparative between sale within centre restrictive values for different centres vary, due to disproportionate degrees of broker processing. For example Auckland, with a low percentage of arrivals requiring reclassing, should be able to set up a sale more rapidly than a centre such as Timaru or Dunedin where wool requiring reclassing comprises a considerable proportion of total arrivals. These differences in broker processing requirements are reflected in the size of the between sale within centre restrictions. For sale sizes

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2. For greater detail refer to Section 3.3.1.
3. For greater detail refer to section 3.3.2.

within the upper and lower limits of the double and single sale categories, the values of these restrictions are assumed unchanged. Probably the constraint levels should increase as sale sizes increase, within the single and double limits, but no data was available to develop an appropriate relationship. The hypothesis that such a relationship exists is supported by the fact that past rosters have violated these constraints.

The minimum amount of time that must elapse between sales in different centres depends on whether the sales being considered are in the same, or, different Islands. This difference is due to the existence of virtually two teams of buyers; one in the North Island and one in the South Island. The minimum period between sales in different centres within an Island is larger than its counterpart above, as buyers require time not only to arrange for disposal of wool purchased in one sale, but also to evaluate the wool being offered in the next sale. Between Islands the minimum difference requested by buyers is one day. This allows communication between buyers in different Islands, head office processing of orders etc.[4]

A minimum period between the closing and sale dates of a sale is requested by brokers.[5] This period is required for several reasons. Firstly, it gives brokers time to set up the sale bales in the appropriate fashion without having to contend with processing new wool arrivals. Wool arrivals after closing date are generally channelled into storage until after the sale; they can, however, be put into the sale at the brokers discretion provided sale size constraints are not violated. Secondly, it allows the broker to get out a catalogue of wool to be offered earlier, (i.e. the longer the sale is closed the earlier the catalogue can be prepared). It is assumed that a first in first served situation faces wool producers. This assumption is not necessarily correct in practice. However, it is shown in Section 2.3 that such an

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4. For greater detail refer to Section 3.3.4.
5. For greater detail refer to Section 3.3.3.

assumption is required to measure one performance parameter of the roster. Thirdly, with reference to wool buyers, some period is required over which they can evaluate wool offered for sale. With present methods of wool display, the brokers requirement, in this context, is much greater than the wool buyers requirement; the respective requirements being minimums of about five days, and one to two days.

Simple restrictions on infeasible sale days exist. Infeasible sale days comprise:

i. weekends,

ii. public holidays,

iii. local or regional holidays, (anniversaries).

The roster model must be such that these infeasible sale days are not rostered for sales.

Furthermore, the model must be formulated such that double sales have one day only between the two auctioning days. In a week of five feasible days, only Monday, Tuesday, and Wednesday are available for the first day's auctioning of a double sale. Failure to include this constraint could result in the programme rostering double sales with the two auction days separated by a weekend or, possible, the Christmas break. Such breaks between the two days of a double sale are undesirable, as they incur higher costs of travel and accomodation for wool buyers. Furthermore, with such breaks, wool brokers may find it necessary to set the double sale up as two single sales to avoid lost time in breaking down the wool sold on the first day of the double sale. Consequently, inefficiencies in wool handling occur, when double sales are rostered with more than one day's break between the two auction days.

'Monday'[6] sales in some centres are considered somewhat undesirable by wool buyers, as they necessitate buyers spending part or whole of the weekend away from home. The majority of North Island buyers are based in Wellington;

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6. 'Monday' refers to the first feasible trading day in any week.

South Island buyers in Christchurch. In Section 4.6 the sensitivity of the model to prohibiting 'Monday' sales in centres other than Wellington and Christchurch is investigated. Also, further investigation prohibiting all 'Monday' sales is carried out.

This section has given a descriptive coverage of the major constraints of the system. Other restrictions are more important to the model than in giving a general description of the system. All restrictions on the system are considered in greater depth in Chapter III where the model is developed.

2.1.4 Performance of the Roster

The performance or "worth" of a roster is measured by the degree to which it achieves, or goes towards achieving, the goals of those effected by the roster. Narrowing this down to those directly effected by the roster, there are three distinct groups; the wool growers, the wool buyers, and the wool brokers. Wool buyers, here, refers to those agents or merchants in New Zealand, assuming that their action reflects the desires of their principals. Between these three groups are a number of conflicting goals. For example, the obvious conflict between growers and buyers regarding their preferences for the level of wool prices. The problem of conflicting goals is discussed in greater depth later in this chapter. In this section various measures of performance of a roster, without regard to conflicting goals, are discussed.

The main goals of those parties directly involved with the roster, where these goals are governed or partially governed by the roster, are summarised below. These goals are subject to the qualifications given in the explanations following:

The Producer:-
i. maximizing the average price paid for his wool clip in the long term,
ii. minimizing interest foregone on the value of his wool, due to his wool having to await sale,
iii. minimizing wool brokerage costs for his wool,
iv. minimizing sales costs (other than brokerage) for his wool.

The Broker:- i. minimizing peak handling periods,

ii. minimizing pre-sale wool storage,

iii. minimizing double handling of wool.

The Buyer:- i. minimizing the prices paid for wool in the long term,

ii. maximizing the ease with which he can attend sales,

iii. maximizing the ease with which he can evaluate wool offered for sale,

iv. maximizing the ease with which he can communicate with principals and associates in other places,

v. maximizing the ease and speed with which he can ship purchases.

The Nation:- i. maximizing long term overseas earnings from wool,

ii. minimizing delay in receipt of overseas earnings.

Throughout this section instances arise where the goal under consideration is better included as a restriction in a model. The interchangeability of goals and constraints is a feature of model building. Often, a goal which may be represented as a model constraint, shows very low marginal returns to goal achievement once a certain minimum or maximum condition has been satisfied. In the roster problem many situations arise where a minimum period must elapse between certain operations. A lesser period than the minimum is highly undesirable, a greater period only slightly more desirable. Consequently the model is restricted so that it is impossible to go into the "highly undesirable" region yet the goal itself is not a determinant of whether the "slightly more desirable" region is entered.

The goals of the producer are to maximize his long term earnings from wool, subject to the physical and productive limitations of when he can present his wool for sale. Consequently, maximization of short term wool prices, where such maximization could lead to the suppression of long term demand for wool due to synthetic fibre substitution, is not a goal of wool producers. Insofar as the roster is concerned three questions must be answered affirmatively before consideration of wool prices should effect the roster. These questions are:

i. Does the roster effect wool prices at auction?

ii. Is it known how the roster effects wool prices?

iii. Is it known how much the roster effects wool prices?
i.e. can the effect of the roster on wool prices be quantified?

Intuitively the first and second questions posed above can be answered affirmitively. Taking the extreme situations, very small sales would accrue added expenses in buyers activities here, and added handling expenses (shipping etc.) by overseas receivers, which would result in a lowering of demand and decrease in wool auction prices. Very large sales would accrue stockholding costs by overseas wool users, which would probably be reflected in decreased demand, despite some compensation from lower buyers' costs, and lowered shipping and handling costs.

The third question posed above is practically impossible to answer for extremes of small and large sales, and is impossible to answer for comparatively small changes to the roster. There has been much conjecture as to whether an evenly spaced presentation for sale of wool in total, and wool in its various class types, would be advantageous. Peirse and Taylor (8) conducted a study with the aim of assessing:

> "the extent of the reduction to wool price variations that could be achieved if the different classes of wool were to be offered evenly throughout the selling season and to assess whether such a course would be worthwhile."7

Peirse and Taylor observe on price - supply relationships studied:

> "(a) the relatively low and inconsistent value of the percentage of the total price variation explicable by considering alone the different quantities of each wool sold at each sale throughout the season...
> (b) the inconsistant effect on each group of additional quantities of wool on price; only second shear wool was consistent in a rational way..."8

It should be noted that this study by Peirce and Taylor was looking primarily at price variability in individual wool types sold at auction. Cumulating these individual effects showed little consistent effect of supply on

7. Peirse and Taylor (8), p.1.
8. Peirse and Taylor (8), p.8.

average prices received at auction for the year's study. It appears that factors other than supply play an important part in wool price formation. These factors react with supply in forming prices, and unless they can be quantified there is little hope of quantifying the effect of supply alone on wool prices.

The supply of wool to the market would be an important determinant of wool prices if the demand for wool was of low elasticity. McKenzie et al (4) estimated high elasticities of demand for raw wool on a quarterly basis. The study indicated that wool prices are not greatly effected by quarterly supply changes of raw wool.

Because of the inability to accurately quantify the effect of wool supply on prices, and, the belief that supply plays only a small part in determining prices, it was decided that this aspect would be disregarded in the model. Consequently, the producers' goal of maximizing the average price for their wool was not included as a performance parameter of the model.

The producer's goal of minimizing the opportunity cost of interest foregone on the value of his wool may be broken into two performance parameters:

i. Pre-sale storage (in the brokers store),

ii. Bales held over, (i.e. bales in brokers stores that are excluded from a present sale and must await a later sale).

The storage argument rests on the fact that pre-sale storage of wool by brokers is associated with a delay in the sale of the wool, which is associated with an opportunity cost due to interest foregone by the producer on the value of his wool. Minimization of pre-sale storage will minimize this opportunity cost. Secondly, storage is tied up with brokers costs, due to long term costs of facilities for storage, and short term costs of double handling in wool stores. Consequently, this goal of the producers is related in part to their goal of minimizing brokerage costs.

The second parameter concerns mainly a redistribution of income problem. Wool brokers work on a first come first sold basis largely (although late arrivals may be put ahead of earlier arrivals to achieve a desirable average lot size for the sale). When the bales available for auction in a centre outnumber the sale size rostered, some bales must be carried over until the next sale. A producer who gets his wool in just in time for the sale, will have a lower per bale opportunity cost of interest foregone, than a farmer whose wool arrives just too late for the sale. Hence, on an equality argument, it would be desirable to minimize the degree of bales being held over. Apart from the equality argument there are added costs of s torage, and double handling of wool in wool stores, associated with bales held over. The distinction between storage and bales held over is a fine one; it lies in the equality argument mainly but also manifests itself in double handling in wool stores.

The third goal of a producer, to minimize wool brokerage costs for his wool, is largely covered above by arguments on storage and double handling. Further costs are associated with processing of wool and peak handling periods in wool stores. Processing costs are a direct function of the producer's policies and need not be included in the roster model, except insofar as they effect between sale within centre restrictions. Peak handling periods are a function of the roster in two instances. Firstly, those peaks caused by pressure to break down sales and get wool shipped. Secondly, peaks due to the setting up of sales. Peaks caused by a rush for shipping are a function of the roster, as shipping can be organised to fit in with the roster, and may be made available close to the sale day. Possibly, changes to the roster and shipping organisation could be made to improve wool flow (i.e. decrease handling peaks). Moves in this direction include the suggestion that ships be organised to arrive at even intervals. If such a pattern of shipping was introduced then the roster could be altered to give a more even supply of wool for shipping. However, unless rather drastic changes are made to the rostering pattern then it appears that the organisation of shipping around the roster, not the organisation of the roster around shipping, is the main determinant of these peaks.

Peak handling periods for setting up sales are controllable by the roster to a degree. Such peaks may arise from the necessity to prepare late wool arrivals for a sale to be held in a few days. To avoid extreme peaks, brokers specify a minimum period between closing and sale dates for a sale. This period was explained in the previous section on model restrictions. The longer the period between closing and sale dates, the less likely it is that a pre-sale peak handling period will occur.

Minimizing sale costs other than brokerage costs is the fourth summarised producer goal. With regard to the roster, the main variable effecting the variability of sale costs is the number of sales rostered. The type of costs associated with organising an auction sale are:

i. hire of theatre (fixed cost/day),

ii. preparation of a catalogue (fixed cost/sale),

iii. accommodation costs (fixed cost/day).

These costs, when compared to the value of product sold, the variability in the value of this product, and the interest earning potential of this product, are considered to be insignificant. Consequently, the inclusion of the number of sales rostered as a performance parameter, would appear valueless. However, the number of sales rostered in each centre, and in total, is some use as an indicator of the size distribution of the sales rostered.

From the goals of wool producers relating to the roster, four performance parameters can be obtained. These performance parameters are:

1. Pre-sale storage of wool (measured in bale-days).
2. Bales held over (measured in bale-days).
3. Mean closing date to sale date period (measured in days).
4. Number of sales rostered.

Applying the arguments used in obtaining the performance parameters of importance to the wool producer, to the wool broker's goals, yields the same performance parameters. A brief summary relating to broker's goals follows.

Minimizing peak handling periods in wool stores has cost advantages due to minimization of overtime work and greater ease of management. As argued above the roster can effect peaks due to setting up sales. Here, the constraint relating to the closing to sale date period, and the mean of this period over a number of sales, are important. Post sale peaks lose their importance to the roster model following the argument used earlier in regard to shipping.

Minimizing pre-sale wool storage, where such storage involves no double handling, has cost saving implications to the broker in the long term. This long term cost arises from providing facilities for such storage. Storage involving double handling is largely a function of bales held over.

Minimizing double handling of wool has cost advantages to the wool broker. Double handling, as effected by the wool sale roster, is largely attributable to bales being held over from sale to sale. Such bales must be put aside as they arrive, as the wool store is fully involved in preparing for the immediate sale. After this sale these held over bales must be taken out of storage and processed in preparation for the next sale. Consequently, double handling costs are associated with these bales.

Hence the performance parameters which measure the goal achievements of the brokers, in reference to the roster, are the same as those for the producer. Only the relative importance of these performance parameters has changed. Bales held over, and, the mean closing date to sale date period, are more important performance parameters to the wool broker than is pre-sale wool storage; especially in the short term.

A further consideration of peak handling periods pertains to the period between sales within a centre. This aspect has been discussed in the preceding section on model restrictions, but deserves mention as a possible performance parameter. A suitable performance parameter would be the mean between sale within centre period. Short term variable costs associated with this mean value would be mainly attributable to variability in wool store labour costs. In the long term, costs would include machinery and facilities for wool handling. It was felt that this goal was adequately covered by the between sale within centre restrictions.

Wool buyers' goals, as effected by the roster, may similarly be reduced to a number of measurable performance parameters, by expansion of the summary of their goals given earlier in this section.

It would be expected that wool buyers wish to obtain their purchases at the lowest price possible, providing the prices are not so low as to depress supply below that desired in the long term. This goal of buyers is considered unimportant to the rostering problem. The argument in support of this supposition, is the same as that used earlier to exclude the producers goal of maximising average long term wool prices, from the rostering problem.

The buyer's two goals of maximising the ease with which he can attend sales, and, with which he can evaluate wool offered for sale, are interrelated in the context of rostering. Firstly, there is the requirement that buyers have one or two days to evaluate wool offered for sale. This requirement is overshadowed by the brokers requirement of a minimum closing date to sale date period, and so is never a problem in rostering single sales, although, the request forces double sales to be separated by a day. Secondly, there is the undesirable aspect of 'Monday' (or first business day of week) sales in some centres. These goals give rise to one performance parameter, other goals being covered by restrictions. That is:

5. The number of 'Monday' sales in the roster where such sales are not held in a base centre.

'Monday' is in quotation marks as it may refer to any day of the week where this day is the first day after a public holiday; (i.e. the first feasible trading day of the week).

Buyers request four days between single sales within the same Island. This allows them to arrange the disposal of purchases from the first sale, to communicate with principals and associates in other areas, and to evaluate wool offerings at the next sale. This four day minimum is more suited to a constraint than a performance parameter. The contribution of the performance parameter to the goals of buyers would decline sharply once the four day minimum period was observed.

The fourth goal of wool buyers listed is that of "maximizing the ease with which they can communicate with principals and associates in other places". As mentioned above this forms part of a within Island constraint. It also forms the whole of a between Island constraint. That is, buyers require one day between wool sales in different Islands. This allows them to communicate with their counterparts in the other Island, or, if necessary, to attend sales in both Islands. Again a constraint rather than a performance parameter is more appropriate for this goal.

Buyers wish to be able to ship their purchases easily and as early as possible. Consequently they would wish for a quick breakdown of sales by brokers and an early availability of ships. This goal conflicts, in this respect, with the goals of producers and brokers pertaining to minimization of peak handling periods. However, as argued earlier regarding post sale peaks, it is the organisation of shipping around the roster and not the organisation of the roster around shipping which determines post sale handling peaks. Consequently the goal is not directly relative to the rostering problem.

In considering the effect of the roster on goals of the nation, only those goals directly related to earnings of overseas exchange by wool are listed. Obviously the well being of producers, brokers, buyers and indeed all parties involved in the wool industry are of some importance to the nation as a whole. However, an evaluation of national and international socio-economics, as effected by the wool sale roster, is outside the limits of this study.

The first goal of maximizing long term overseas earnings from wool, insofar as this goal is effected by the roster, can be dismissed from the model on the argument presented for the producer's goal of maximizing the price received for his clip. The second goal of minimizing the delay in receipt of payments for wool warrants consideration. Due to the large amount of overseas exchange involved in New Zealand wool auction sales, marginally earlier receipts for wool sold overseas, give significant financial benefits in terms of interest alone. Earlier payments for wool sold at auction result from a more rapid rate of sale of wool over the season. A more rapid rate of wool selling is reflected in decreased pre-sale storage requirements for wool.

An estimate of the relationship between foregone interest receipts and pre-sale wool storage is given below:

	1968/69	1969/70	1970/71
Average price paid per bale of wool (greasy) at auction in New Zealand[9]	\$95.98	\$88.11	\$84.08
Average price paid for the three seasons	= \$89.39		

9. Source: New Zealand Wool Commission (6), p.9.

1,000 bale-days storage	=	2.74 bale-years storage
This represents 2.74 x 89.39	=	$244.93 per year in storage
At 7% interest	=	$17.14 per 1,000 bale-days

For every 1,000 bale-days of pre-sale wool storage approximately $17.14 is foregone in interest. Total pre-sale wool storage is of the order of 50 to 60 million bale-days. It is estimated that a 1% decrease in the total storage of wool sold at auction could yield over $30,000 in interest (assuming a 7% interest rate) on overseas exchange holdings. This is worthwhile investigating if significant variability in pre-sale storage can result from different rosters. Internally, the figures are just as significant to wool producers.

2.1.5 Summary

In summarising it appears that the nature of the restrictions for the rostering model are such that the model must include a day to day time sequence. A shorter time sequence would complicate the model without contributing anything in the way of accuracy or significance. A longer time sequence would approximate results from a model to such a degree as to make the model useless both as an aid to rostering and as a means of experimenting with the system. The model would certainly be useless for studying the effect of marginal changes in the time constraints.

The performance parameters found to be of use for evaluating a roster are:

1. the extent of pre-sale storage of wool,
2. the extent to which bales are held over,
3. the mean closing date to sale date period,
4. the number of sales rostered,
5. the number of 'Monday' sales.

These performance parameters should be measured for each centre individually and for the system as a whole.

At first glance it may appear that five performance parameters are insufficient to cover all the implications of the wool sale roster. Some performance parameters were excluded due to either their inestimatability, or, their insignificance. Others were excluded as actual performance parameters but were included as restrictions. Performance parameters included as restrictions generally show low marginal returns to performance once some specified minimum or maximum value of the parameter is reached.

Question may be raised as to why a performance parameter measuring the difference between rostered quantities and actual sale offerings was not included. This has in part been answered in the section on wool arrivals. Here it was suggested that wool arrival estimates be varied parametrically to study the stability of the roster to changes in estimates. Furthermore, it is assumed that the estimates of wool arrivals available to the Wool Auction Sales Committee are as accurate as can be estimated under the circumstances. It is outside the range of this study to attempt to improve the forecasting of wool arrivals.

2.2 Operations Research : A Brief Description

Operations research, or management science, emerged in the period after World War II; it incorporates scientific methodology with an understanding of managerial problems, and attempts to solve those problems by various analytical means.

An important aspect of operations research is that it looks at the system as a whole. Rather than isolating the components of the system and making these as efficient as possible, operations research methods attempt to fit together these components in the most efficient manner. The method of operations research involves making a mathematical model of the system under study. This model can then be manipulated, in lieu of the real world system, to seek an optimal combination of components of the system; optimal, that is, with respect to some stated performance measure. The problems encountered in using operations research techniques are in:

i. the formulation of a representative mathematical model of the system which can be manipulated to optimise,

ii. finding what to optimise - what performance parameters and the importance that should be placed on each.

In formulating a mathematical model of the system some degree of realism is immediately lost. Operations research models are usually very complex if realistic. This complexity may leave the model insolvable for extreme values of performance parameters. Simplification of the model may ensure solvability of the model. But, the solution obtained may not be the best real world solution, as realism of the model decreases with increased simplification. The operations research team have three possible approaches to the problem, if it is such that no solvable and perfectly realistic model can be made of the system under study. They may:

i. Simplify the model which can then be solved for an optimum. This optimum may or may not hold for the real world system.

ii. Complicate the model, to obtain realism, and experiment with the model. There is no guarantee that optimisation will occur (unless all possible situations are looked at) but areas of high performance can be looked into.

iii. Complicate the model, but simplify or approximate the data input to the model if this will give an optimal model solution. (i.e. a representative model with non representative data.)

Whether to use methods i. or iii. above depends on the problem at hand. Both give approximate answers through approximating the model in i. and approximating the data in iii.

Method ii. above should be used where a high degree of model realism is required to give results any practical significance. When realism decreases sharply with simplification, it may pay to look at certain results following model manipulation, with no guarantee that an optimal solution can be effected, rather than find the optimal solution for a non-realistic model of the system. For some problems an optimising analytical technique may be applied while retaining realism. But the assumptions of many optimising analytical techniques are such that if the mathematical formulation of the problem is realistic, then the problem is a fairly simple one. An example of this is the feed mix problem in which a realistic optimum can often be obtained by formulation of the problem as a linear programme.

In the final analysis there are three broad alternatives in selecting a method of analysis for any operations research problem. These are to:

i. Select an optimising analytical technique where the assumptions of the model used are not such that realism is lost.

ii. Select an optimising analytical technique with some loss of model realism, accepting that application of the optimal solution to the problem will be approximate in terms of the real world problem.

iii. Select a non-optimising analytical technique which retains realism, and experiment with the model to obtain realistic and quantifiable measures (in terms of the problem) of responses of the model to various manipulations.

2.2.1 Conflicting Goals

The problem of conflicting goals occurs in most managerial decision problems. The goals of an individual may conflict; the goals of parties with dissimilar interests conflict. In the roster problem serious conflicts between goals of parties involved in deciding on the format of the roster occur. These parties are:

i. the Wool Board (representing the growers),

ii. the wool brokers' representatives,

iii. the wool buyers' representatives,

iv. the Wool Commission.

Table 2.1 below indicates the relationships between the goals summarised in Section 2.1.5, in terms of whether they conflict with, or complement, one another.

TABLE 2.1 THE RELATIONSHIPS BETWEEN ROSTERING GOALS

PARAMETER	Pre-Sale Storage (Min)	Bales Held Over (Min)	Closing to Sale Date Period (Max)	Number of Sales (Min)	'Monday' Sales (Min)
Pre-Sale Storage (Min)	•	+	–	–	–
Bales Held Over (Min)		•	–	–	–
Closing to Sale Date Period (Max)			•	o	+
Number of Sales (Min)				•	+

Min = minimization
Max = maximization
\+ indicates complementary goals
\- indicates conflicting goals
o indicates little or no relationship between the goals

With reference to Table 2.1 above, it is important to note that the relationships indicated between goals are felt to be indicative of the general case. Exceptional instances may and do often occur. For the indications of the relationships of the relevent goals with the 'Monday' sales goal, it was assumed that the periods between sales, and, between closing and sale dates, are increased to reduce the incidence of 'Monday' sales. Furthermore, the indication that some measure of achievement of these goals is to be minimized or maximized is not always intended. The words "decrease" and "increase" could be substituted for minimization and maximization respectively, where the decreases and increases envisaged are within realistic limits.

When some of the goals effected by a decision are in conflict, then the decision made is generally a compromise. The best decision is that which gives the most favourable compromise. The problem is to find the solution which gives the most favourable compromise.

To find the best solution to a problem by analytical means, an objective function must be formulated. An objective function is a mathematical function which measures in some way the performance of the system as a whole. This requires that the objective function include all the important goals relevant to the problem. Often these goals must be weighted in some fashion so as the more important of them dominate. If the objective function, and the constraints on the problem, are such that an analytical solution can be derived which optimises the objective function, then this analytical technique is probably the best method of approach to the problem. If it is impossible to solve the problem for an optimal solution, or if the goals comprising the objective function are such that no meaningful weights can be attached to them, then experimentation via simulation procedures can be employed.

When an adequate objective function can be formulated, yet the problem is not amenable to optimising analytical techniques, then simulation can be used to give solutions with single value performance outcomes. This technique requires that performance parameters (if there are more than one) be of the same dimension. Otherwise, simulation may be used to produce feasible solutions for which the performance of the solution with regard to individual goals is measured. These feasible solutions can be presented to management, who will assign weights to the performance parameters (or goals) ex poste. This assignment of weights by management may not be explicit; it will, however, be reflected in their attitudes towards the various solutions presented to them.

Unless appropriate goal weights can be estimated the problem of conflicting goals is generally ignored by the analytical technique of solving the problem (i.e. the operations research analytical procedure). The problem is handled after analytical solution by subjective appraisal of the solution. The strength or weight of this subjective appraisal is reflected in the final course of action taken by management. Generally, the greater this weight, the less the course of action decided on coincides with the optimal model solution.

In presenting management with a number of solutions, obtained by experimenting with the model, the operations analyst is in effect simplifying the management task of decision making following subjective appraisal of the analytical solutions. If enough solutions are presented to management they will find one that they like best. Including a wide range of measured performance parameters in each solution eases the burden on management. Much of the work involved in evaluation of decisions may be done by having the model measure these parameters. Further evaluation and subjective appraisal by management, is simplified as the measured parameters may be used to base such appraisal on.

To provide a number of alternative model solutions the operations analyst must have a means of varying the decision processes of the model. If the problem can be solved for an analytical optimum then variation can be introduced by having the model base its decisions according to varying goals; i.e. have the model optimise for different goals in different runs. Further solutions can be effected by having the model base its decisions on more than one goal. However, expansion of the model is generally in an exponential fashion with the number of goals considered. Increasing complexity of the model ultimately limits the number of goals that can be controlling the models decision processes. In non-optimising simulation procedures, the decision processes of the model can be varied in a similar fashion. The decision processes may be based on many, one, or no goals (a random choice may be made).

In conclusion the operations analyst must weigh up the advantages of having as many goals as possible controlling the decision processes of the model, against the disadvantages of loss of realism where inclusion of more goals, and, restrictions, adds such complexity that the model must be simplified. When this decision is made the analyst should have the model measure as many non-decision controlling goals as possible, as well as optimising (if possible) for the decision controlling goals.

2.3 A Mathematical Representation of the Problem

Before discussing methods of analysis of the roster problem note should be made of the mathematical similarity of apparently dissimilar problems. Ackoff (1) describes such problems as having "analagous mathematical structures". Many problems when represented, mathematically turn out to be of the same mathematical type, and can be solved analytically by the same technique. Quite probably this occurs because the problem is mathematically stated so as it can be solved by the technique. A problem can often be represented in as many mathematical forms as there are techniques for solving these mathematical models. This suggests analagous model structures, in that the models can be solved to optimise for the same objective function by different techniques. The problem then is where does the analyst start in solving a problem? Should he select a technique and formulate the problem mathematically to fit the technique, or, should he select a mathematical model and formulate a technique of solving it? The answer again depends on the realism required by the model. Ideally the problem should be mathematically formulated, as realistically as possible, and a technique found to solve it. Choosing a technique, and formulating the problem so that it is amenable to solution by that technique, frequently leads to loss of realism of the model, as the mathematical model is restricted by the assumptions of the technique used. (Loss of realism, and the consequences of the loss, is discussed in Section 2.2)

2.3.1 The Mathematical Model

The mathematical model developed below includes the performance parameters:

i. pre-sale storage of wool,

ii. bales held over,

iii. the mean closing date to sale date period,

iv. the number of sales,

and the restrictions that:

i. wool available for sale must be in store by or before the minimum closing date to sale date period allowed,

ii. the between sale within centre restrictions be observed,

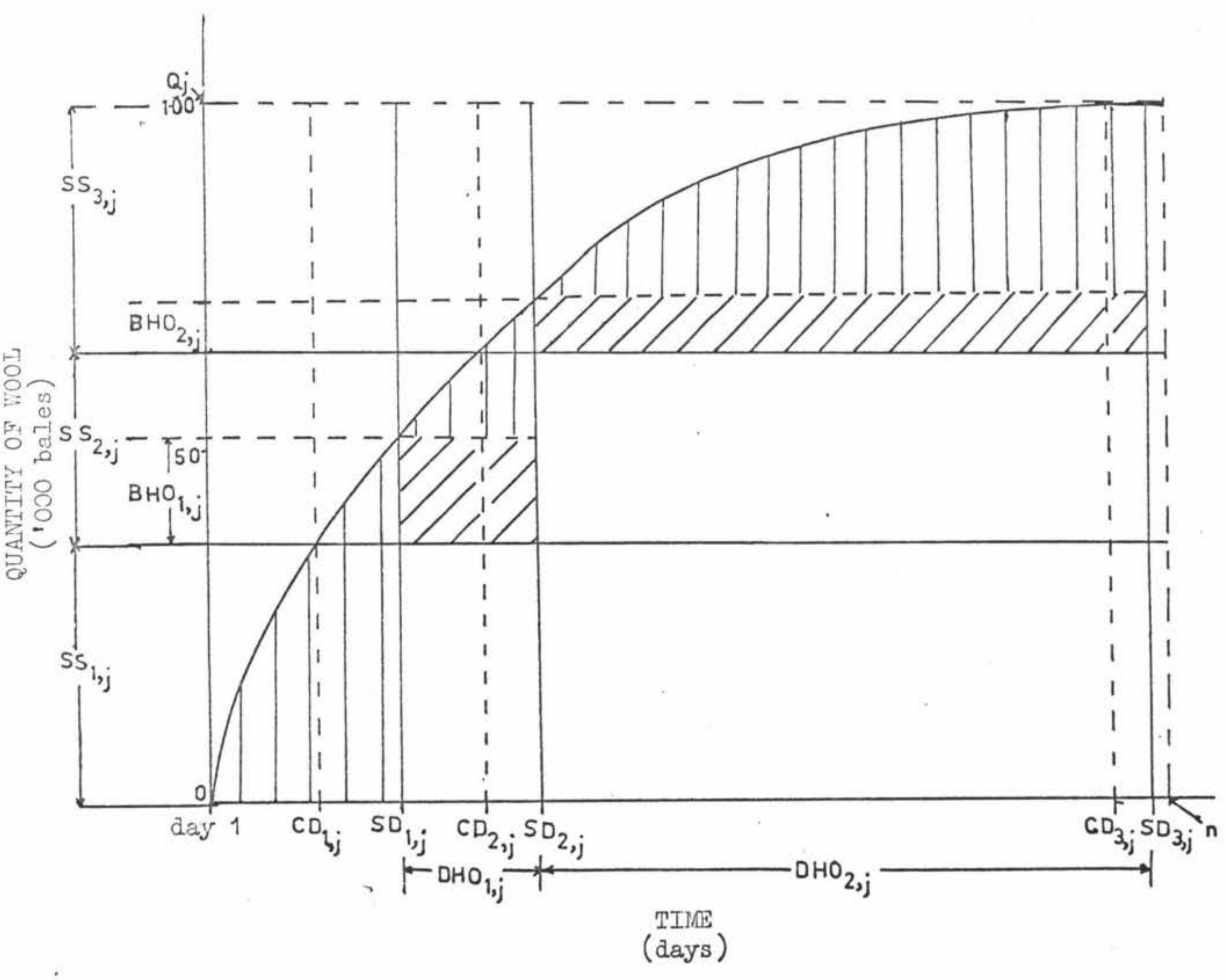
iii. the sale size restrictions be observed,

iv. the between sale between centre restrictions be observed,

v. sales are only rostered for realistically available days of the rostered period.

To facilitate understanding of the mathematical model graphical illustration is used where appropriate. This graphical illustration relates to one centre only.

FIGURE 2.1 GRAPHICAL REPRESENTATION OF THE MATHEMATICAL MODEL



n = last day of season

j = centre identification ($j=1,\ldots.8$)

Q_j = total arrivals in centre j

S_j = total number of sales rostered in centre j

k = sales $1,\ldots.S_j$ in centre j

$BHC_{k,j}$ = bales in store but not sold at sale k in centre j

$DHO_{k,j}$ = period held over bales must await sale (from $SD_{k,j}$)

$SD_{k,j}$ = sale date for sale k in centre j

$CD_{k,j}$ = closing date for sale k in centre j

$SS_{k,j}$ = size of sale k in centre j

Figure 2.1 above includes a "cumulative wool arrivals" curve. This curve indicates the nature of wool arrivals over the season for a hypothetical centre; most centres show a pattern similar to this for wool arrivals over the season. Initially the rate of arrivals is slow (not shown in Figure 2.1), then the rate increases to become greatest around the November to February period. The flattening of the curve towards the end of the season indicates a tailing off in wool arrivals over the last stages of the rostered period.

PERFORMANCE PARAMETERS

i. Storage - (bale-days)

$$\text{MIN.} \sum_{j=1}^{8} \sum_{i=1}^{n} (B_{i,j}.(n-i)) - \sum_{j=1}^{8} \sum_{k=1}^{S_j} (SS_{k,j}.(n-SD_{k,j}))$$

i = day of roster ($i=1,\ldots.n$)

$B_{i,j}$ = number of bales that arrive in centre j on day i

The first statement above measures the sum of the areas under the cumulative arrivals curves for all centres. These areas measure total wool storage if no sales were held. The second statement decreases this total storage measure, by the reduction in storage resulting from holding sales. This reduction in storage (for one centre) is represented by the unhatched areas in Figure 2.1.

Resulting net storage is indicated in Fugure 2.1 by the sums of the vertical and diagonal cross hatched areas (for one centre).

ii. Bales Held Over - (bale-days)

$$\text{MIN.} \sum_{j=1}^{8} \sum_{k=1}^{S_j} (BHO_{k,j} . DHO_{k,j})$$

Diagonal cross hatched areas in Figure 2.1 indicate the weighted measures of this performance parameter for each sale in a centre; the weight being the period these bales are held over.

Figure 2.1 does not indicate why bales may be held over. Firstly, bales arriving after the closing date for a sale, must be held over until the next sale in that centre. Secondly, wool may be held over due to the sale size constraints. There may be more wool available than can be accomodated in a double sale, or, there may be too little wool for a double sale yet more than the upper sale size limit specifies. Thirdly, the time constraints between sales may cause bales to be held over. The time constraints may allow a single sale, but not a double sale, to be held in a centre. If there is more wool in that centre than the upper single sale size limit can accomodate, then the supplus wool will be held over until the next sale.

iii. Closing to Sale Date Period - (days)

$$\text{MAX.} \sum_{j=1}^{8} \sum_{k=1}^{S_j} (SD_{k,j} - CD_{k,j}) \quad \div \quad \sum_{j=1}^{8} S_j$$

Refer to Figure 2.1

iv. Number of Sales -

$$\text{MIN.} \sum_{j=1}^{8} S_j$$

$$\text{or, MIN.} \sum_{j=1}^{8} (ZS_j + ZD_j)$$

ZS_j = number of single sales in centre j

ZD_j = number of double sales in centre j

RESTRICTIONS

i. Closing Date to Sale Date Period

$$SAS_{i,j} \leq BIS_{i-cd,j} - \sum_{k=1}^{d} BS_{k,j}$$

i = day of rostered period (i=1,....n)

$SAS_{i,j}$ = sale size rostered on day i in centre j

cd = minimum period (in days) between the closing and sale date for a sale.[10]

$BIS_{i-cd,j}$ = cumulative arrivals, in centre j, cd days before day i

d = number of sales rostered previously in centre j

$\sum_{k=1}^{d} BS_{k,j}$ = sum of bales rostered for sale in centre j in sales 1,....d

This mathematical statement says that the size of a sale rostered in any centre, on any day, must be less than the cumulative wool arrivals in that centre a specified number of days prior to the day being considered. The specified number of days is the value given to the minimum period from closing to sale dates for wool sales. Furthermore, the cumulative arrivals value must be decreased by the number of bales which have previously been rostered for sale. This assumes that no carry over of rostered wool (as distinct from new arrivals)

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10. The value for cd will equal the $SD_{k,j}-CD_{k,j}$ value in sales where the closing date to sale date period restriction limits the sale size rostered. Where the upper sale size limits restrict the sale size, then cd will be less than the $SD_{k,j}-CD_{k,j}$ value; i.e. the closing to sale date period can be greater than the minimum (cd) specified in the restriction.

occurs. i.e. that wool rostered for sale is sold and can not be left for re-entry in a future sale.

ii. <u>The Between Sale Within Centre Restrictions</u>

(a) If $SMIN \leq SAS_{i,j} \leq SMAX$

then $SAS_{p,j} = 0$ $\qquad p = i+1, \ldots. i+SZ_j$

SMIN = single sale size minimum limit

SMAX = single sale size maximum limit

SZ_j = minimum single-single sale sequence period in centre j

i.e. if a single sale is rostered on day i in centre j then no further sales may be rostered in that centre for at least SZ_j days.

If $SMIN \leq SAS_{i,j} \leq SMAX$

and $SAS_{q,j} \geq DMIN$

then $q \geq i + SD_j$

SD_j = minimum single-double sale sequence period in centre j

DMIN = minimum double sale size limit

i.e. if the sale being considered on day q in centre j is a double sale, and the previous sale in centre j was a single sale, then the period between these sales must be greater or equal to the single-double sale sequence minimum restriction for centre j.

(b) If $SAS_{i,j} \geq DMIN$

then $SAS_{m,j} = 0$ $\qquad m = i+1, \ldots. i+DS_j$

DS_j = minimum double-single sale sequence period in centre j

If $SAS_{i,j} \geq DMIN$

and $SAS_{l,j} \geq DMIN$

then $l \geq i + DD_j$

DD_j = minimum double-double sale sequence period in centre j

The arguments in (a) for single sales explain mathematical statements in (b) for the double sale situation.

iii. <u>The Between Sale Between Centre Restrictions</u>

(a) If $SMIN \leq SAS_{i,j} \leq SMAX$

and 1) $j \leq 4$

then $SAS_{r,t} = 0$

$r = i, \ldots. i+4$

$t = 1, \ldots. 4$

and $SAS_{v,w} = 0$

$v = i, i+1$

$w = 5, \ldots. 8$

or 2) $j > 4$

then $SAS_{r,w} = 0$

$r = i, \ldots. i+4$

$w = 5, \ldots. 8$

and $SAS_{v,t} = 0$

$v = i, i+1$

$t = i, \ldots. 4$

If a single sale has been rostered in a centre, then no sale may be held in the same Island until a further four days have passed; no sale may be held in the other Island until the day after next.

(b) If $SAS_{i,j} \geq DMIN$

and 1) $j \leq 4$

then $SAS_{x,t} = 0$

$x = i, \ldots. i+6$

$t = 1, \ldots. 4$

and $SAS_{y,w} = 0$

$y = i, \ldots. i+3$

$w = 5, \ldots. 8$

or 2) $j > 4$

then $SAS_{x,w} = 0$

$x = i, \ldots . i+6$

$w = 5, \ldots . 8$

and $SAS_{y,t} = 0$

$y = i, \ldots . i+3$

$t = 1, \ldots . 4$

For double sales, the periods between sales between centres are two days greater (from the first auction day of the double sale) than for single sales. The values placed on these restrictions are those specified in Section 3.3.4.

iv. The Sale Size Restrictions for Non-Zero Sale Levels

$SMAX \geqslant SS_{k,j} \geqslant SMIN$

or $DMAX \geqslant SS_{k,j} \geqslant DMIN$

k = sales in centre j $(k=1, \ldots . S_j)$

DMAX = maximum size for double sales

v. The Feasible Days for Wool Sales

(a) General:

$SAS_{b,j} = 0$ $j = 1, \ldots . 8$

$b = Z_1, \ldots . Z_f$

$Z_i s'$ = a set of infeasible days for all centres

$SAS_{b,j}$ = the size of any sale rostered for day b in any centre j

(b) Specific:

$SAS_{h,j} = 0$ $j = 1, \ldots . 8$

$h = Z_{1,j} \ldots . Z_{g,j}$

$Z_{i,j} s'$ = sets of infeasible sale days specific to each centre

$SAS_{h,j}$ = the size of any sale rostered for day h in centre j

2.4 Methods of Analysis

In this section the methods of analysis of the rostering problem fall in two categories. Firstly, models used in operations research, insofar as they are connected with the problem, are looked at. Secondly, analytical techniques for solving models of the roster system are considered.

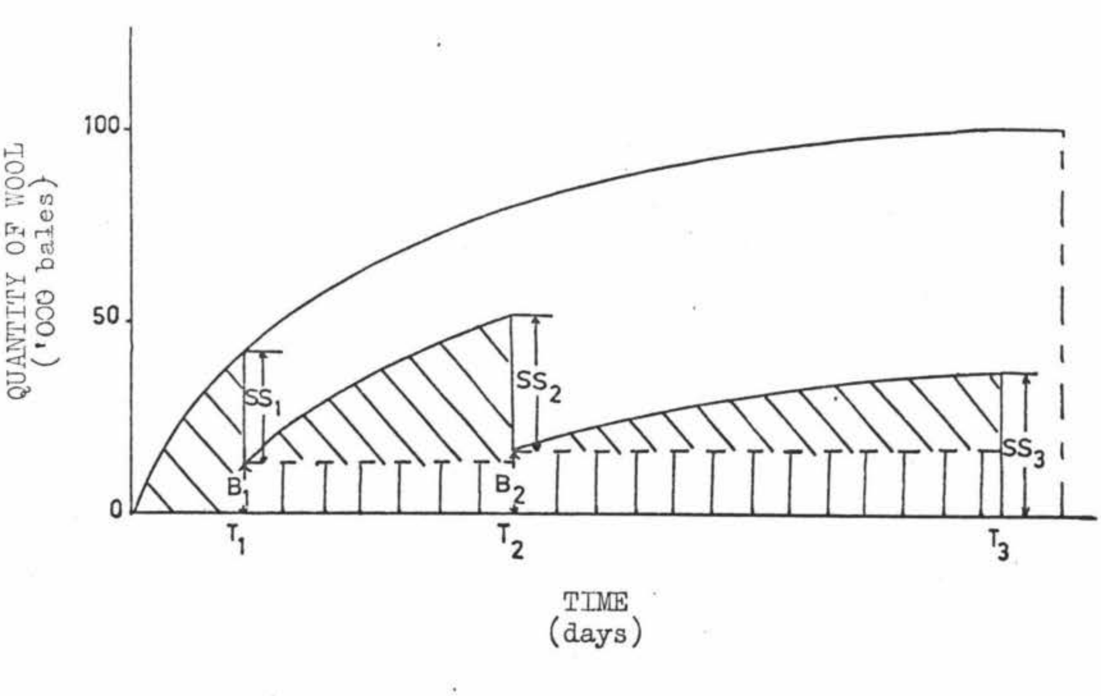
2.4.1 The Inventory Model Approach

The inventory model has been used in marketing problems such as analysing warehouse needs, in production problems such as scheduling operations, and to determine plant capacities. Generally the similarity of inventory problems lies in storing something to meet a future demand.

Basically the inventory model approach involves finding a compromise between set up costs and holding costs. In the roster problem the set up costs are dependent on the number of sales rostered; the holding costs can be measured in terms of wool storage and bales held over.

The inventory model of the rostering problem is presented graphically for any one centre in Figure 2.2 below.

FIGURE 2.2 THE INVENTORY APPROACH - ONE CENTRE



n = total number of sales

T_k = time of sale k (k=1,....n)

SS_k = size of sale k (k=1,....n)

B_k = bales held over from sale k (k=1,....n)

In Figure 2.2 total storage in the centre is indicated by the diagonally and vertically cross hatched area. Total storage of held over bales is shown in the vertically hatched area.

The lower sectional curves in Figure 2.2 represent wool available in wool stores over the season. Any point on these curves equals the cumulative wool arrivals value net of previous sales.

Solution of the one centre problem presented in Figure 2.2 involves finding that set of Ts which minimizes an objective function composed of the costs of sales, storage, and bales held over.

The problem could be solved for one centre at a time for a weighted objective function (including one or more performance parameters). However it is very unlikely that the optimal solutions for each centre individually, could be amalgamated to give a feasible overall optimal solution for the eight centres together. For example, the structure of the problem is such that sales are desirable immediately after the Christmas break, due to wool accumulating over this period. Consequently, optimal solutions for each centre would probably include sales immediately after the Christmas period. This is feasible for one centre, but not for more than one centre, due to the between sale between centre restriction (see Section 2.1.3). Hence, obtaining an optimal analytical solution, requires the solution of an eight dimensional problem.

2.4.2 The Queuing Model Approach

The queuing model approach is relevant to the wool rostering problem. Sasieni, Yaspan and Friedman (11) make the following observations on queuing problems or waiting lines:

> "Decision situations frequently arise in which units arriving for service must wait before they can be serviced. If the laws governing arrivals, servicing times, and the order in which arriving units are taken into service are known, then the nature of this waiting situation

can be studied and analyzed mathematically."

Further:

> "Arriving units may form one line and be serviced through only one station, as in a doctor's office; they may form one line and be serviced through several stations, as in a barber's shop; or they may form several lines and be served through as many stations, as at the checkout counters of a supermarket."11

Conceptually the problem of rostering wool sales could be treated as a type of queuing problem, and solved accordingly to optimise for certain performance parameters. The eight selling centres could be considered to represent eight servicing stations; a wool sale would then represent a service rendered at one of the facilities. To incorporate the time restrictions it would be necessary to constrain the frequency of services within and between centres.

Again the dimensions of the roster problem make the use of optimising analytical techniques impractical for representative queuing model of the system. A Monté Carlo simulation procedure could be used to simulate probabalistic wool arrivals over the season. Decisions, regarding places of sales and sale sizes, could be made in a random fashion. However, computer facilities would limit the number of experiments that could be carried out with a model incorporating probabalistic arrivals and random decision processes. In Section 2.4.4 it is shown that the range of feasible rosters that can be produced, for any one set of data and restrictions, is very large. A limited number of experiments over this range would yield little in the way of significant results.

2.4.3 Dynamic Programming

The dynamic programming procedure involves breaking a problem up into stages, and, solving each of these stages for an optimum, for any possible input to that stage. From these stage solutions, an overall optimal policy for the system can be found. The reason an overall optimum can be obtained from individual stage solutions, lies in Bellman's principle of optimality,

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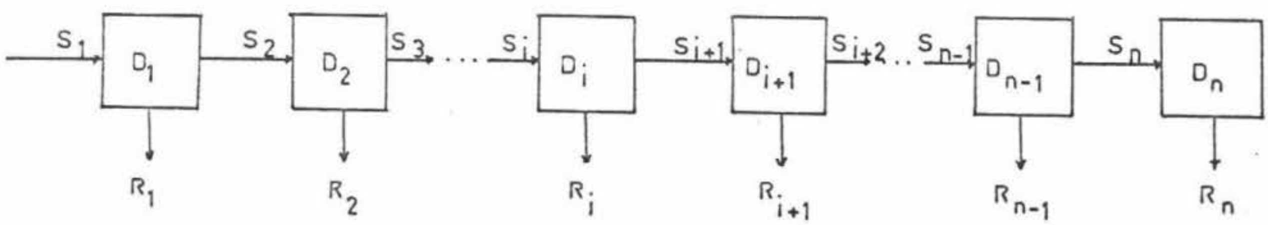
11. Sasieni, Yaspan and Friedman (11), p.125.

which states:

> "An optimal policy has the property that, whatever the initial state and initial decision are, the remaining decisions must constitute an optimal policy with respect to the state resulting from the first decision."

The dynamic programming approach is represented in Figure 2.3 below, and subsequent discussion.

FIGURE 2.3 STAGES IN DYNAMIC PROGRAMMING



i = stage identification $i=1,\ldots.n$

n = last stage of the problem

S_i = input to stage i

D_i = decision made at stage i

R_i = return (contribution to objective function) at stage i.

The objective function measured by R_i may be simple (one performance parameter), or, complex (more than one performance parameter, each of which may be weighted).

Three basic components make up the dynamic programming procedure. These are:

i. The Stage Return Function

$$R_i = f_i(S_i, D_i)$$

ii. The Stage Transformation Function

$$S_{i+1} = g_i(S_i, D_i)$$

iii. The Recurrence Relationship

$$V_i^*(S_i) = \text{Max.} \left[f_i(S_i, D_i) + V_{i+1}^*(S_{i+1}) \right]$$

$V_i^*(S_i)$ = the optimal return for the present, and all previously[12] evaluated stages for an input of S_i at stage i.

For the wool sale roster problem, for one centre, the variables used in the relationship would refer to the following:

i = day i of the roster

R_i = the return on day i, measured by an objective function comprising performance parameters for storage, bales held over, number of sales, etc.

S_i = the number of bales of wool available for sale in the centre on day i

D_i = decisions on the sale size to hold on day i (sale sizes rostered from zero to the upper size limit for double sales)

V_i = the cumulative return function for previous stages evaluated.

For the wool sale roster problem the dynamic programming method of analysis is suitable for a one centre study. For one centre, optimisation in terms of the performance parameters given (especially storage and bales held over) could be carried out. The optimal results for different performance parameters, and combinations of different performance parameters, could be compared. Consideration of all eight selling centres complicates the problem enormously.

At each stage there are eight wool arrivals figures making up each input (S_i) to that stage. If each of these wool arrivals figures could take a number of (say p) values at each stage, then there would be p^8 combinations for S_i. i.e. p^8 possible values for S_i at each stage. Obviously, p does not have to

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12. The recurrence relationship given is for backwards dynamic programming; i.e. start at stage n and work back to stage 1. Therefore, previously evaluated stages means stages i+1,....n.

be very large before computer storage capacity becomes limiting. Apart from this aspect of size of the problem, difficulties arise through interactions between the D_i's for each centre. Fairly complex programming would be required for the model to recognise these interactions. Consequently, the programme itself would occupy a large proportion of computer storage.

To use a dynamic programming procedure in the analysis of the wool roster problem, for eight centres, would require that very complex mathematical techniques be employed. Simplification of the model, representing the roster system, would need to be severe to keep the mathematical techniques used at manageable levels. It was felt that the loss of realism resulting from such simplification of the model would invalidate solutions; optimal analytical solutions, derived by the dynamic programming technique, may have had little or no application to the real world problem. Consequently simulation procedures were used to look into the wool roster problem.

2.4.4 Simulation

Simulation, in general usage, means to make a model or copy of some process or object. Formally simulation is "to duplicate the essence of reality without necessarily obtaining reality itself".

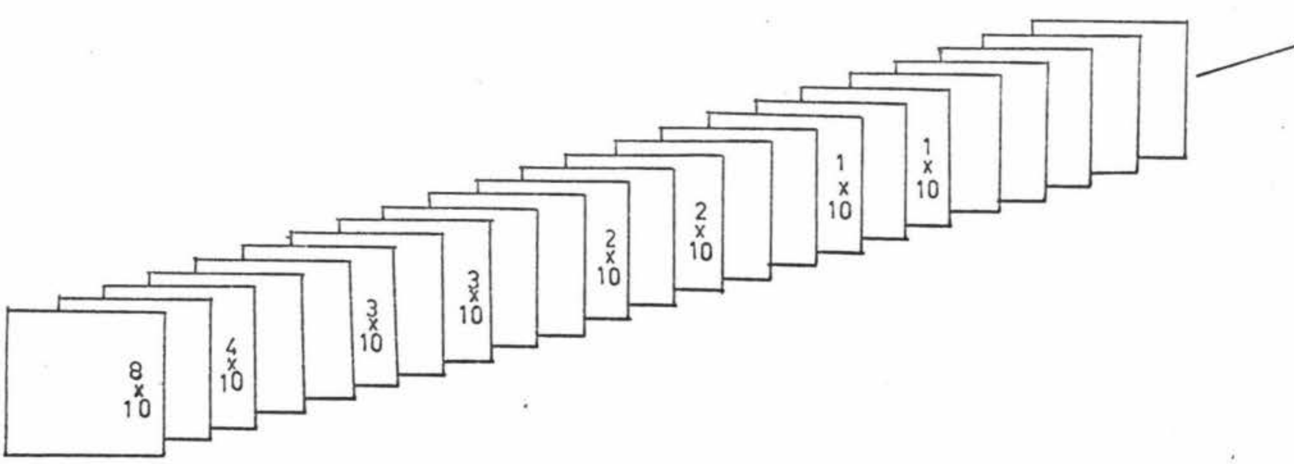
Digital computer simulation involves expression of the process or problem as a mathematical model. The model must retain similarity of properties and relationships with the real world problem. Experimentation with the model, in lieu of the real world situation, can be carried out to test plans, ideas, and designs, in order to aid decisions effecting the real situation. Use of the digital computer allows such experimentation to be done in hours.

The problem of realism (see Section 2.2) remains. The simulation model can be developed with varying degrees of realism depending on the required precision of results. In order to make inferences from model results to the real world problem, the model must be a valid representation of the system under study. Such a model will produce realistic results under a wide range of operating conditions.

One computer simulation procedure for the wool sale roster problem would involve devising a computer programme which could produce numerous feasible rosters, according to the inputs and restrictions operating for the run, and evaluate each of these rosters in terms of the performance parameters given in Section 2.1.5. The disadvantage of simulation without enumeration[13] is that often there is no guarantee that any one performance parameter is optimised. In some cases search procedures can be used in simulation to find optimal solutions; a reasonably "smooth" performance surface is required for this.

Enumeration of the simulation model derived rosters, for any one set of data and restrictions, is impractical due to the large number of feasible rosters involved.

FIGURE 2.4 THE NUMBER OF FEASIBLE ROSTERS



Referring to Figure 2.4. above, let each card represent a day of the

13. Enumeration involves obtaining every possible solution for a problem. One of these solutions must be optimal for the objective function being used.

roster (a stage). Assuming the roster starts when any of the eight centres can hold a sale, and, that there are ten possible sale sizes that can be chosen, then there are 80 possible decisions to evaluate in the first stage. This reduces by 40 two days later, as only four centres can have sales, (i.e. those in the other Island from that centre selected to have a sale in the first stage - assuming a sale was held).[14] The number of possibilities decreases from stage to stage due to the between sale within centre restrictions. However, the number of possible rosters is still immense. For the eighteen days above the possible combinations number -

$$8x10 \times 4x10 \times 3x10 \times 3x10 \times 2x10 \times 2x10 \times 1x10 \times 1x10 = 1152 \times 10^8$$

The complexity of a simulation programme for rostering wool sales requires that considerable computer time per run is required. Consequently computer costs alone inhibit enumeration.

Because it was impractical to enumerate feasible rosters, and, as no basis could be found on which to establish an orderly search procedure, it was necessary to include certain decision processes in the model; decision processes which were formulated to improve the performance of some performance parameters of the model. It appeared desirable to be able to vary these decision processes so as a range of rosters could be produced.

The method of simulation was chosen to analyse the wool sale roster problem for a number of reasons. The main reason was that it was felt that the approximations inherent in other analytical techniques, through their assumptions, were too severe when applied to the problem. Secondly, a simulation procedure appeared to lend itself more readily to experimentation around present levels of restrictions. Thirdly, the model could easily be adapted to evaluate any roster whatsoever in terms of the performance parameters of the model.

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14. It is assumed that a sale is held whenever it is possible to do so. Without this assumption, the estimate of the number of feasible rosters that can be formulated would be larger.

CHAPTER III

THE SIMULATION PROGRAMME

3.1 Contents

In this Chapter the simulation programme developed is explained in relation to the input data, restrictions, and performance parameters included in the model. Limitations of the computer programme, and, methods of adjusting rosters for these, are discussed.

Programme rosters for three sets of estimated input data for the 1971/72 season are compared with the actual roster formulated by the Wool Auction Sales Committee for this season. Finally, more general parallels and disparities between the programme and actual roster are made, and, conclusions drawn as to the adequacy of the computer programme in rostering wool auction sales.

3.2 Estimation and Computer Input of Data

3.2.1 Estimation of Wool Arrivals

Estimates of in-to-store wool arrivals for auction in the eight selling centres were made by taking unweighted and weighted averages of arrivals over the three previous seasons. It is in no way suggested that the best method of forecasting arrivals was used. The estimates made by the Wool Auction Sales Committee should be much more reliable as they have sources of information from men in the field, via the Meat and Wool Boards' Economic Service, and, a great deal of previous experience in estimating arrivals.

The first estimate made was an unweighted average of the three previous seasons arrivals at each centre, as provided by the wool brokers.[1] The

1. New Zealand Woolbrokers' Association Schedule of Weekly Receipts Into Store 1968/69 - 1969/70 - 1970/71 Seasons.

second estimation of arrivals was made by taking a weighted average of the arrivals for the previous three seasons. The weights, selected arbitrarily, were:

10% of the figure for the 1968/69 season

30% of the figure for the 1969/70 season

60% of the figure for the 1970/71 season

The unweighted estimation referred to as the "Unweighted Average" data in programme rosters, gives reliable forecasts if there is no trend in the seasonal data for wool arrivals, but, fluctuation in quantities occur. If there is no trend and no fluctuations then any year's data would do as an estimate of course. If there is no trend in wool arrivals over the season, and if fluctuations from season to season in arrivals are random, then the unweighted average technique, taking the average over as many seasons as possible, will give the best estimate. "Unweighted Average" data is contained in Appendix B1.

However, there appears to be a trend in seasonal wool arrivals. At present this is a downward trend due to increased private selling and a levelling of wool production. If the trend is a continuing one, then the unweighted average technique will not give an efficient estimate. Taking a weighted average, with progressively greater weights for more recent data, will improve the efficiency of the estimate. Using the "Unweighted Average" result and modifying it by a trend coefficient will also improve the efficiency of estimation, as may taking a weighted average and applying a similar trend coefficient correction. The trend coefficient for the latter estimate should be less than for the former, as the weighted average technique allows for trend to some extent. If no fluctuations occurred, then the best estimate is made by correcting the previous year's data by an accurately estimated trend coefficient.

In estimating wool arrivals, by applying statistical techniques to previous data, the problem of isolating random fluctuations from changing trends arises. A simple weighted average technique was used, which hopefully removes errors of fluctuations, yet allows trend to play a role in determining this estimate. Data corresponding to this method of estimation is referred to as "Weighted Average" data, (see Appendix B2).

A third estimate was made due to the disparity between the Wool Auction Sales Committee's estimate of total arrivals, and both the weighted and unweighted estimates. Consequently resulting programme rosters differed more from the actual roster than they may have done. The third estimate was made simply by multiplying the "Unweighted Average" estimate of arrivals, in each centre for each week, by a correction factor. This set of data is referred to as "Corrected Average" data. Total wool arrivals in each centre in the "Corrected Average" data are the same as estimates made by the Wool Auction Sales Committee. The correction factors for each centre are estimated as follows:

$$\text{Correction factor} = \frac{\text{Wool Auction Sales Committee estimate}}{\text{"Unweighted Average" data estimate}} \Big/ \begin{matrix}\text{total arrivals}\\ \text{for each centre}\end{matrix} \Big/$$

So multiplication of "Unweighted Average" estimates by the corresponding correction factor yields Wool Auction Sales Committee estimates. The values of these correction factors are given in Appendix B3.

3.2.2 Computer Input of Wool Arrivals

The simulation programme developed iterates day by day, whereas the data estimates are on a weekly basis. As these estimates can only be approximate, it seemed pointless to try to interpolate the weekly estimates to obtain daily increments. Consequently, in the model, it is assumed that the cumulative arrivals figures estimated for the beginning of the week, apply over the week; no further arrivals occur until the beginning of the next week. It is hoped that the errors associated with this approximation are no greater than the errors of approximating daily arrivals by weekly interpolation.

Link programme DISKIM (see Appendix A2) feeds estimated wool arrivals data into disk storage. In the programme this data is identified by the NB(J)s'. The wool arrivals data fed in is in the form of cumulative wool arrivals at each centre. The cumulative value is corrected for bales rostered as having been sold as the main programme progresses. The corrected value is shown in the NST(J)s' of output.[2]

One special feature of DISKIM is the programme's ability to handle the leap year situation When the second year of the roster season is a leap year then the brokers schedule of wool arrivals[3] includes an eight day week; this week being from 27th February to 5th March inclusive. By giving variable K a value of 2 this eight day week is rostered for as such. The inclusion of this special feature may appear trivial at first glance. It is not, however, as exclusion of this feature would mean that the whole roster became out of phase by one day after February when the second year of the season was a leap year. This one day is significant as it can mean the difference between rostering sales on feasible and infeasible days.

3.2.3 The Feasible Sale Days

The programme rosters over the period from the 5th September of the first year, to the 27th or 28th June of the second year of the season, depending on whether the second year is, or is not, a leap year. This comprises a period of 297 days.

In general, feasible sale days are from Monday to Friday of any week. Exceptions occur over the Christmas break and public holidays. For all centres the exceptions for the 1971/72 season are contained in Appendix B4.

Link programme DISKIM feeds all this information to disk storage. A -1 value is recorded if the day is infeasible; a 0, or +1, value if the day is feasible. +1 identifies days which are the first of the week, i.e. Mondays generally, Tuesdays when the corresponding Monday is infeasible, etc. The +1 value is used to identify 'Monday'[4] sales.

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2. An example of output is presented in Appendix C2.
3. New Zealand Woolbrokers' Association Schedule of Weekly Receipts Into Store 1968/69 - 1969/70 - 1970/71 Season.
4. For an explanation of 'Monday' sales refer to Section 2.1.4. Briefly, 'Monday' sales refer to sales rostered on the first feasible sale day of the week.

Link programme DISKMM (see Appendix A3) has the capacity to feed in the roster days' data for seasons where the second year is not a leap year. DISKMM was written to speed up the input process where the same wool arrivals data was being used for runs with different levels of restrictions.

DISKMM and DISKIM convert the general feasible days of the roster into specific sets for each centre. These specific sets are changed by the main programme on execution so must be reloaded for new runs.

Various infeasible days specific to certain centres, are handled by the INDMCM subroutine (see Appendix A8). The specific days included for the 1971/72 season comprise infeasible days due to regional anniversaries (see Appendix B5).

3.3 Rostering Restrictions and Their Programming

The restrictions included in the simulation programme are:

i. the sale size limits,

ii. the between sale within centre restrictions,

iii. the between sale between centre restrictions,

iv. the closing to sale date minimum period,

v. the infeasible days restrictions.

In following sections, the specifications for, and programming of, these restrictions are given.

3.3.1 The Sale Size Limits

These limits are:

			Programme Identification
Single Sales :	minimum	20,000 bales	NSL
	maximum	28,000 bales	NSU
Double Sales :	minimum	40,000 bales	NDL
	maximum	50,000 bales	NDU

The limits above are those quoted by the Wool Board, although rigid adherence to them is not maintained by the Wool Auction Sales Committee.

In Chapter IV the sale size limits are parametrically varied. Consequently, the limits are fed into the computer by means of a data card. This is achieved via subroutine INITNM (see Appendix A6).

Enforcement of the sale size limits is done within sections III and VI in link programme SELLEM (see Appendix A9).

3.3.2 The Between Sale Within Centre Restrictions

The between sale within centre restrictions effectively limit, in some instances, the period between sales in any centre. These restrictions are necessary due to the period required to break down the past sale and prepare for the next sale. Variables effecting this period, assuming fixed labour and equipment, are the size of the two sales and the extent of wool preparation required for them. Restrictions between centres vary, due mainly to the influence of the latter variable.

The restrictions made available by the Wool Board are summarised below in Table 3.1.

TABLE 3.1 THE BETWEEN SALE WITHIN CENTRE RESTRICTIONS

Centre \ Sale Sequence	Single to Single	Single to Double	Double to Single	Double to Double
Auckland	28	31	30	45*
Wanganui	28	40*	35*	45*
Napier	28	39	35	42
Wellington	28	40*	35*	45*
Christchurch	28	40	37	45*
Timaru	35	45*	40*	50*
Dunedin	28	40*	35	45*
Invercargill	28	42	33	45

* Estimated. Not available from Wool Board due to no experience of this sequence having occurred in the relevant centre.

These between sale within centre restrictions are recognised as variables in the programme. They are parametrically varied in Chapter IV. The values for any run are fed in via subroutine INITNM; the values on the data cards being one day less than the quoted restriction values in order to allow cycles of sales in a centre of the relevant restriction value. For example, 28 day sale cycles for single sales in Auckland can be achieved by feeding the restriction value in as 27 days. Feeding the value in as 28 days could only give a minimum of 29 day cycles.

The between sale within centre restrictions are enforced within sections IV, V, and XI of link programme SELLEM. Section XI closes off (or makes infeasible) the minimum period until a future single sale may be held in the centre for which a sale has just been rostered. Section IV and V check out the situations where the proposed sale is a double one to see if the period that has elapsed since the last sale in the centre is not violating the single to double or double to double minimum period (as the case may be).

3.3.3 The Minimum Closing to Sale Date Period

A closing date for the sale is set in order to allow wool brokers to make last preparations for a sale. Bales arriving after the closing date are not generally processed for inolusion in the sale.

The minimum period for this restriction was given by the Wool Board as five days. In the programme, however, this value was increased to seven days due to the structure of the programme. With a five day minimum, bales arriving on say a Friday, could be sold the next Wednesday. This effectively allowed only three days to process the Friday arrivals (if the weekend days were assumed non-work days). Increasing the minimum to seven days ensured, in most instances, that at least five work days were included in the closing date to sale date period.

Enforcement of this minimum period is effected in link programme SELLEM (see Appendix A9), by estimating bales available for sale, from those wool arrivals that were in store seven days previous to the day being considered. Section II of SELLEM includes the operation of this constraint. The minimum value placed on this restriction is initialised in subroutine INITNM and carried through as variable KL to SELLEM.

3.3.4 The Between Sale Between Centre Restrictions

These restrictions allow buyers time to evaluate wool in different centres, when they apply within an Island, and, allow communication between buyers in different Islands. Attendance of sales in both Islands is also made possible by this restriction.

The between centre between Island restriction requires that at least one day must elapse between sales in different Islands. For sales within an Island four days between sales must elapse. For double sales these periods must be between the last auction day of a previous double sale, and the first auction day of the next sale. Double sales comprise a day's auctioning, a space of one day, then the second day's auction. So the period between the first day of a double sale and the next auction day (in another centre), must be six days if the centres are in the same Island, and three days if they are in different Islands.

These restrictions are enforced in section V of link programme SELLEM (see Appendix A9), by making the appropriate future days in the relevant centres infeasible sale days. The restriction values are treated as variables in the programme and are initialised in subroutine INITNM. The values used were provided by the Wool Board.

3.3.5 Infeasible Day Restrictions

Infeasible day restrictions are handled in two ways in the programme, depending on whether the infeasibility relates to all or some centres. General infeasibility is covered by the MUN(I) variable, found in sections II and XIII of link programme SELLEM (see Appendix A9). A -1 value for this variable means that the day it identifies is an infeasible sale day in all centres.

Specific infeasibility is covered by the set of MC(J) variables where J identifies the centre. A zero MC(J) value indicates that the associated day is infeasible for a sale in that centre.

Identification of specific infeasibility was necessary to allow for the specificity of between sale restrictions (within and between centres). Specific infeasibility is first introduced in subroutine INDMCM to recognise regional anniversaries in various centres.

3.4 Performance Parameters in the Programme

Performance parameters measured or estimated in the computer programme for each centre and the total system are:

i. pre-sale wool storage in brokers' stores - measured in bale-days,

ii. bales held over, weighted by the period they are held over - measured in bale-days,

iii. the average closing date to sale date period - measured in days,

iv. the number of single and double sales,

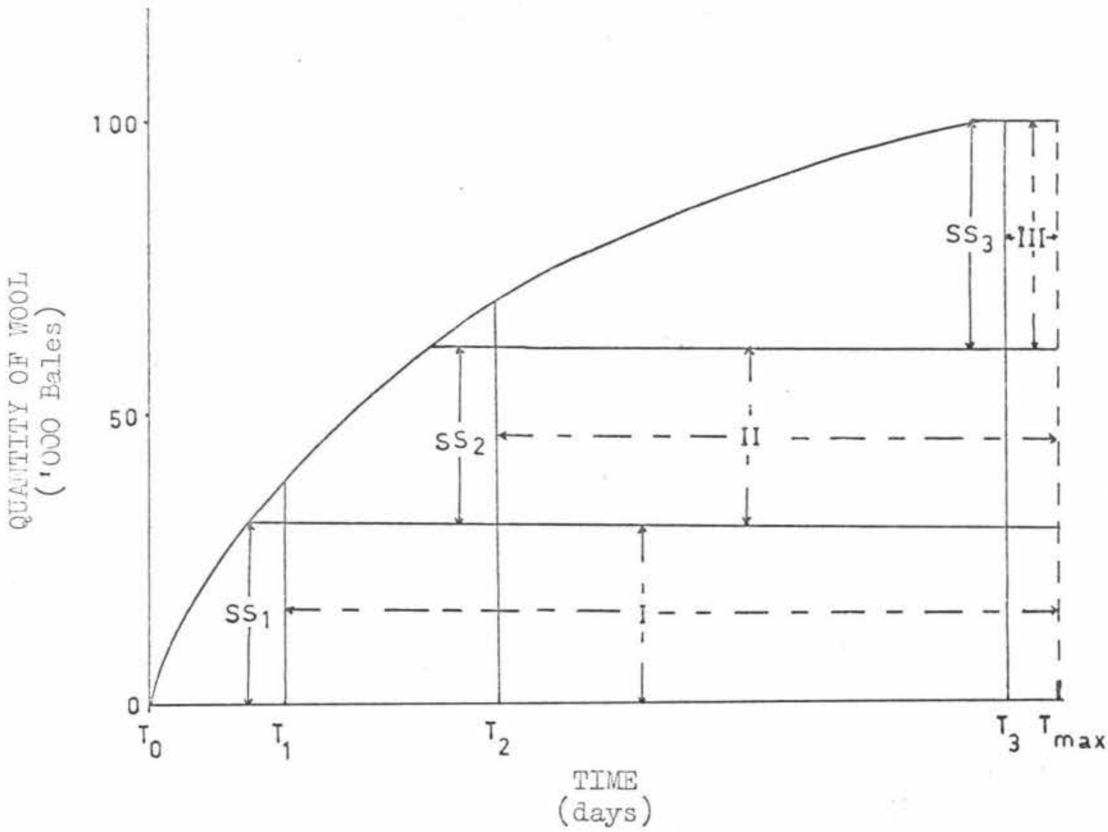
v. the number of 'Monday' (first feasible day of week) sales.

A full description and explanation of these parameters may be found in Section 2.1.4.

3.4.1 Pre-Sale Wool Storage

Pre-sale wool storage in each centre is estimated by subtracting the effective removal of storage due to sales, from total possible storage if no sales were held. This is explained in Figure 3.1 below for one centre.

FIGURE 3.1 WOOL STORAGE ESTIMATION : ONE CENTRE



T_1, T_2, and T_3 are the days for sales 1, 2 and 3.

SS_1, SS_2, and SS_3 are the sizes of sales 1, 2 and 3.

Total possible storage = area under cumulative arrivals curve

Storage removed = areas I + II + III.

Area I = $SS_1 \times (T_{max}-T_1)$ (bale-days)

Area II = $SS_2 \times (T_{max}-T_2)$ (" ")

Area III = $SS_3 \times (T_{max}-T_3)$ (" ")

$$\text{Net Storage} = \int_{T_0}^{T_{max}} f\ (\text{cumulative arrivals}) - \sum_{k=1}^{n} SS_k \cdot (T_{max}-T_k)$$

k = sales 1,....n

n = number of sales rostered in a centre.

In the programme the integral technique is not used due to the stepped nature of the cumulative arrivals curve, which results from the assumption in the model that arrivals for any week occur at the beginning of that week, (see Section 3.2.2).

Total possible storage for each centre in the programme is estimated by the equation:

$$S_i = (NB_i - NB_{i-1})(T_{max} - i) \qquad \text{(bale-days)}$$

i = day being considered $(i=1,\ldots.T_{max})$

S_i = storage on day i in the centre

NB_i = total (cumulative) arrivals by day i in that centre

NB_{i-1} = total (cumulative) arrivals by the day before i in that centre

T_{max} = length of the rostered period (in days)

$$\text{Total possible storage} = \sum_{i=1}^{T_{max}} S_i \qquad \text{(bale-days)}$$

$$\text{Net storage} = \sum_{i=1}^{T_{max}} S_i - \sum_{k=1}^{n} SS_k . (T_{max} - T_k)$$

Numerical Example:

Let total possible storage $\left(\sum_{i=1}^{T_{max}} S_i\right)$ = 30,000,000 bale-days

time of first sale (T_1) = 50 days

length of season (T_{max}) = 300 days

sale size of first sale (SS_1) = 40,000 bales

Storage removed by first sale = $SS_1 \times (T_{max} - T_1)$

= 40,000 x (300-50)

= 10,000,000 bale-days

Therefore net storage after first sale = 30,000,000 - 10,000,000

= 20,000,000 bale-days

This estimation of pre-sale wool storage is approximate for two reasons:

i. the assumption of stepped cumulative arrivals curves (in weekly increments)

ii. the method of estimating storage removed by sales assumes that pre-sale storage ends on the day of the sale, and for double sales this is assumed to be the first day of auction. Consequently storage removed for any centre is slightly over estimated for double sales.

Errors, due to assumptions i. and ii. above are not considered important. Error i. is a consistent error for all rosters made on the basis of the same data; the error would be quite small even if smooth cumulative arrivals curves were used.

Total possible storage is estimated in section XIII of link programme SELLEM (see Appendix A9). SELLEM starts seven days after the beginning of the season (September 5th), due to the constraint that bales must be in store seven days before they are sold (the closing date to sale date constraint). The storage occurring over these seven days is estimated in subroutine STARTM (see Appendix A7) prior to execution of the rostering programme SELLEM.

Storage removed due to sales is calculated in section VIII of SELLEM by the method indicated earlier in this section.

3.4.2 Bales Held Over

A weighted measure of bales held over is calculated. Bales held over from a sale are those bales which are in brokers' stores (in the relevant centre) on the day of sale, but are not included in the sale offerings.[5] The number of bales held over from a sale, is multiplied by the period they are held before being sold, to give a weighted measure of bales held over.[6] This weighted measure of bales held over is more appropriate with respect to goal

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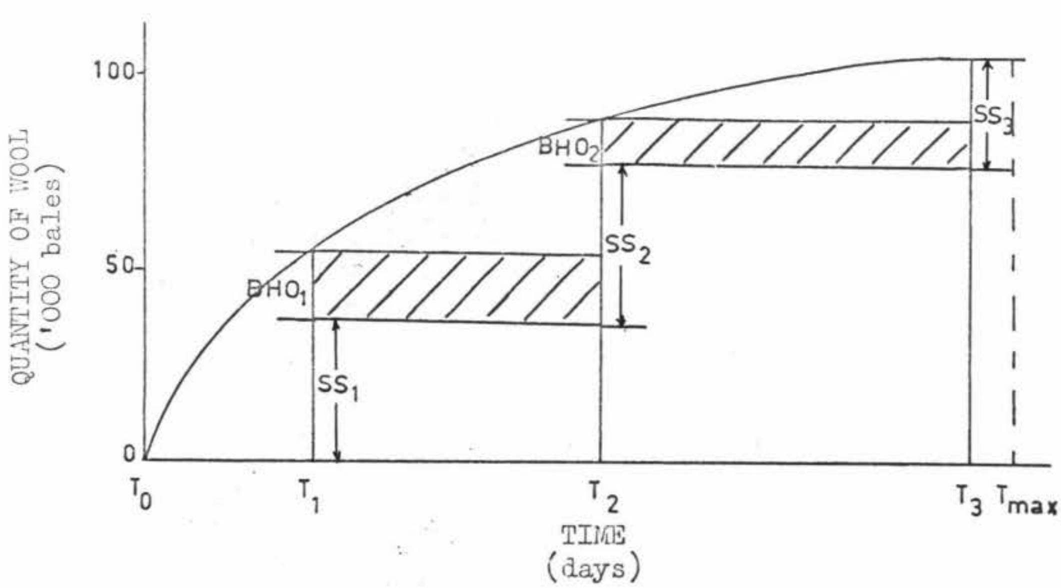
5. Bales held over comprise wool arrivals after the closing date but before, or, on the sale date for a sale, and, bales which cannot be included in a sale due to sale size constraints.
6. Figure 3.2 presents a graphical explanation of this weighting technique.

achievement of producers than to short term goal achievement of brokers. The weighted performance parameter is a determinant of the interest cost to growers resulting from delayed sale of their wool, and, a measure of the extent to which some wool producers are descriminated against by the roster in having their wool held over.[7] Costs to the brokers, assuming fixed long term storage facilities, relate only to the number of bales held over; this number being a determinant of double handling requirements. Consequently, the weighting of bales held over by the period they are held over, is not as directly significant in the short term to brokers. Though not summarised, the number of bales held over from each sale can easily be found by subtracting the number of bales rostered for each sale from the bales in store at the time of each sale. Hence the apparent shortcoming of weighting the bales held over parameter, in terms of brokers goals, is not severe.

Estimation of the weighted bales held over values for each centre is done by the method indicated in Figure 3.2 below.

FIGURE 3.2 ESTIMATION OF BALES HELD OVER : ONE CENTRE



Shaded areas represent weighted measures of bales held over from the respective sales.

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7. Descrimination occurs against producers whose wool is held over, as these producers incur higher costs in terms of interest foregone on the value of their unsold wool, (see Section 2.1.4).

$$BHO_k = NB_k - \sum_{p=1}^{k} SS_p$$

$$WBHO_k = BHOK \cdot (T_{k+1} - T_k)$$

BHO_k = bales held over from sale k

$WBHO_k$ = the weighted measure of bales held over for sale k

k = sale identification, k=1,....n

n = total sales rostered in the centre

SS_k = size of sale k in that centre

$\sum_{p=1}^{k} SS_p$ = sum of bales sold in sales 1,....k

T_k = day of sale k

NB_k = cumulative arrivals by sale day k

Total weighted bales held over in any centre equals

$$\sum_{k=1}^{n} WBHO_k = \sum_{k=1}^{n+1} BHO_k \times (T_{k+1} - T_k)$$

It can be seen from the equation above that no estimate of bales held over, (weighted by the period they are held over) can be made for the last sale (n), as there is no value for the day of the next sale (n+1). A value of T_{max} could have been put on T_{n+1}. This was not done, however, as it seemed to add nothing in terms of accuracy in measuring bales held over. The problem does not arise when total arrivals are rostered for sale (as in adjusted programmes). This is discussed further in Section 3.6.2 of this Chapter.

Numerical Example:

Let time of first sale (T_1) = 50 days

time of second sale (T_2) = 100 days

cumulative arrivals (NB_1) = 30,000 bales

size of sale (SS_1) = 25,000 bales

Bales held over from sale 1 (BHO_1) $= NB_k - \sum_{p=1}^{k} SS_p$

= 30,000 - 25,000

= 5,000 bales

Weighted measure of bales held over from sale 1 ($WHBO_1$) $= BHO_1 \cdot (T_2 - T_1)$

$= 5{,}000 \times 50$

$= 250{,}000$ bale-days

Bales may be held over for more than one sale. This situation would arise when:

$$BHO_{k-1} > SS_k$$

i.e. when more bales were held over from the previous sale, than are being sold in the present sale. The technique of weighting explained in Figure 3.2 (and discussion) requires no further refinement to handle bales which are held over for more than one sale.

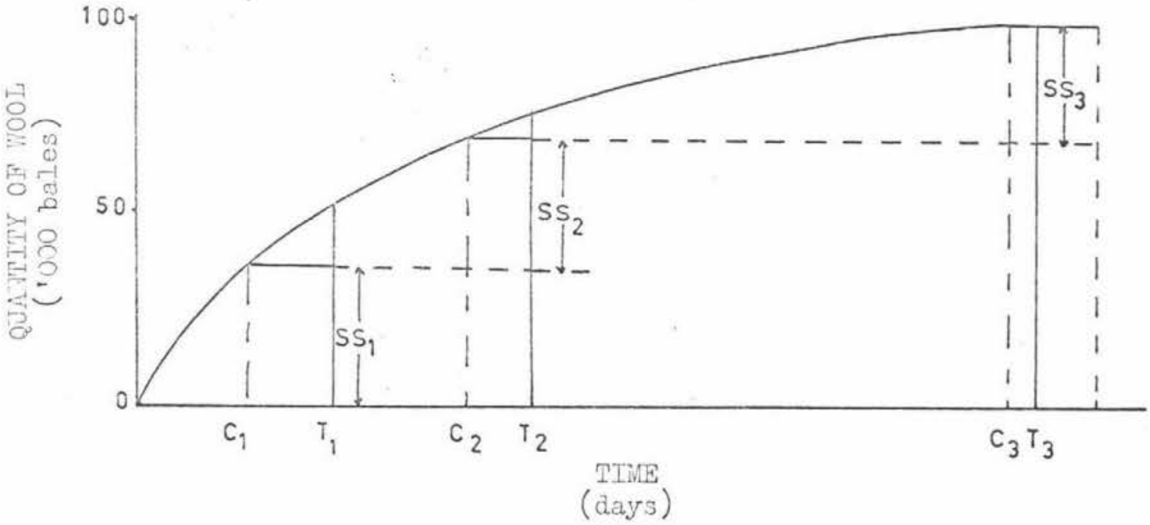
3.4.3 The Average Period Between Closing and Sale Dates

Estimation of the closing to sale date periods for sales is made by looking back to see how early a sale could have been closed, i.e. how long ago were there sufficient bales in a centre to allow a sale of the rostered size. As indicated earlier this period must be no less than seven days. Interest now lies in those sales unrestricted by this minimum restriction.

This performance parameter has implications in pre-sale storage, and, bales held over, for that period of the season when cumulative arrivals are increasing rapidly. Longer than minimal closing to sale date periods imply that more bales are available for sale, than have been rostered for sale.

Mathematically the programme estimates the closing to sale date period for any sale in a centre by the means indicated in Figure 3.3 (and discussion) below:

FIGURE 3.3 ESTIMATION OF THE CLOSING TO SALE DATE PERIOD : ONE CENTRE



Referring to Figure 3.3 above:

SS_k = size of sale k in the centre

T_k = time of sale k

C_k = closing date for sale k

Closing to sale date period = $T_k - C_k$

The objective of this performance parameter is to:

Maximize $T_k - C_k$

Subject to $NB_{C_k} = \sum_{p=1}^{k} SS_p$

NB_{C_k} = cumulative arrivals by day C_k

$\sum_{p=1}^{k} SS_p$ = sum of sale sizes rostered since the beginning of the season (including the sale under consideration)

In the programme the maximum value for $T_k - C_k$ (the closing to sale date period) is restricted to 15 days.[8] It was felt that periods longer than this would be of limited interest.

8. A maximum value of 15 days was specified to save computer time.

The sum of the closing to sale date periods for each sale in each centre, is divided by the number of sales in each centre, to give an average value for the parameter. Estimation of the period for each sale is made in section IV of SELLEM (see Appendix A9). Averaging is done in link programme PARAM (see Appendix A10).

3.4.4 The Number of Single and Double Sales

Sums of single and double sales in each centre are calculated in section VI of SELLEM and reported by link programme PARAM.

3.4.5 'Monday' Sales

As pointed out in Section 2.1.4 the placing of 'Monday' in quotation marks is used to indicate that it refers to the first feasible day of the week. These days are identified in the programme by a +1 value for their corresponding MUN(I) value. Estimation of sales in this category for each centre is made in section VIII of SELLEM.

3.5 Other Features of the Computer Programme

In this section special features of the programme pertaining to decision processes and double sales are discussed.

3.5.1 Sale Sizes

The programme maximizes the sizes of sales rostered within the constraints of the model. The method of maximizing sale sizes in a centre is as follows.

Initially the programme establishes whether the day (stage) being considered is a feasible sale day for the centre. If it is a feasible sale day, the amount of wool available for sale in that centre, seven days earlier (the minimum closing to sale date period), is estimated. If this quantity is greater than the double sale size minimum limit, the programme determines whether a double sale may or may not be held. When a double sale may be held then either the upper double sale size limit, or the amount of wool available at the latest possible closing date, is the maximum sale size that can be rostered in that centre. If it is not feasible to hold a double sale then the upper single sale size limit is the maximum sale size that can be rostered in that centre on that day.

If the quantity of wool available for sale (seven days before the day being considered), is less than the lower double sale size limit then only a single sale may be rostered. Either the upper single sale size limit, or, if less, the amount of wool available, determines the maximum sale size that can be rostered for that day in that centre.

Where wool available in the centre, on the latest feasible closing date, is less than the lower single sale size limit, then a sale cannot be held in that centre on that day, and, the centre is disregarded in further decision processes for that day of the roster.

On any day, sale sizes are maximized (as above) for all centres in which it is feasible to hold a sale. Section 3.5.3 contains an explanation of another decision process, by which one of these centres may be chosen as the venue for a sale on the day being considered.

The decision to maximize sale sizes was included as an attempt to include an implicit heuristic procedure in the model; heuristic with regard to the pre-sale storage and bales held over performance parameters. The ambitions of this decision process may not necessarily be realised due to interactions between sale size and time restrictions. The programming pertaining to this decision procedure is contained in sections II and III of SELLEM (see Appendix A9).

3.5.2 Double Sales

Double sales pose two special problems. The first lies in the between sale within centre restrictions. These restrictions require additional programming to handle a proposed double sale. This programming was mentioned in Section 3.3.2 of this Chapter. Secondly there is the problem of programming to include the second day's auctioning in a double sale. Double sales are composed of two days auctioning separated by a day of no trading. In rostering a double sale the programme must look ahead to ensure the second day of the sale (second auction day) is a feasible sale day for that centre. The period between the auction days must be one day and no more than one day i.e. a double sale separated by a weekend is not permitted.

Sections IV and V of SELLEM (see Appendix A9) implement the special features of double sales; most of the relevant programming is in the first half of section IV, however, other important pathways are found in the latter part of this section, and, in section V.

3.5.3 More Than One Feasible Sale Centre on Any Day

When it is feasible to have a sale in two or more centres on any one day, the procedure is to select that centre with the maximum number of bales available as the sale centre. When two centres have (say) 30,000 and 35,000 bales available for sale, yet only 28,000 can be sold due to the upper sale size constraint on single sales, then the centre with 35,000 bales would be selected by the programme. This decision can, however, be overruled by a further decision process discussed in the next section. When overruling occurs the centre with 30,000 bales available may have a sale rostered, although again the overruling decision process may intervene in this centre. The decision procedure explained above is aimed at lowering pre-sale storage by keeping the upper limit on bales in store as low as possible over all centres. This effect carries over to bales held over also.

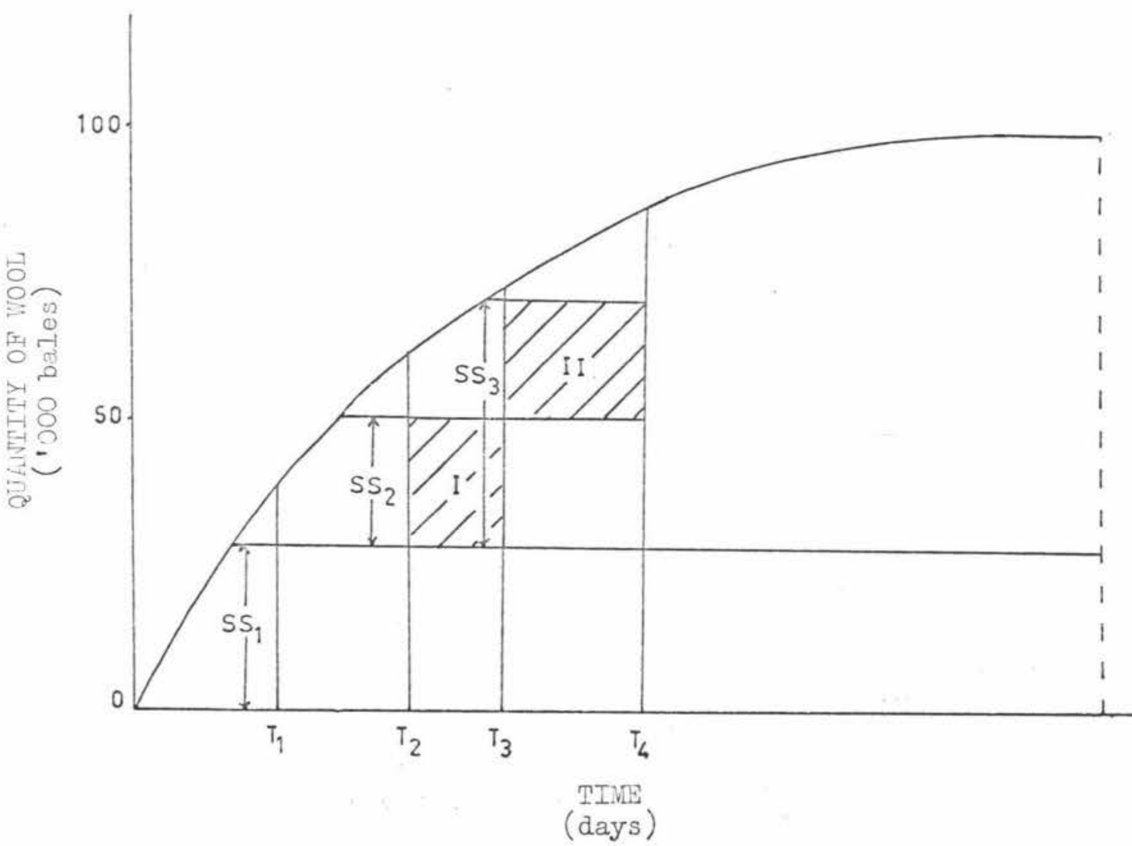
Sections II, IV and V of SELLEM (see Appendix A9) contain programming relevant to this decision procedure.

3.5.4 The Single/Double Sale Decision Procedure

The nature of the between sale within centre restrictions is such that it frequently becomes feasible to hold a single sale in a centre earlier than a double sale. This occurs when the restrictions referred to are effectively restrictive.

A procedure was developed which estimates, over a limited range of the roster, the pre-sale storage differences between holding a single sale now or a double sale later. Application of this decision process will also go some way to decreasing the extent of held over bales. The decision process is explained for one centre in the following figure. The procedure is referred to as the single/double decision procedure.

FIGURE 3.4 THE SINGLE/DOUBLE DECISION PROCEDURE



Referring to Figure 3.4 above:

- k = sales 1,....n
- n = total sales held in that centre
- T_k = the day of sale k
- SS_k = sale size of sale k

The decision to make is whether to have a single sale at T_2 or a double sale at T_3 where $T_3 > T_2$. The decision problem does not arise when $T_2 = T_3$ as a double sale will be rostered according to the decision process described in Section 3.5.1.

If a single sale is held at T_2 then the earliest possible date of the next sale in that centre is T_4 where $T_4 - T_2$ equals the minimum between sale within centre restriction for a single-single sequence in that centre. Storage saved between T_2 and T_4 for a single sale equals

$$SS_2 \cdot (T_4-T_2)$$

If no sale is held at T_2, but a double sale is held at T_3, then the storage saved to T_4 equals

$$SS_3 \cdot (T_4-T_3)$$

The common storage saving equals

$$SS_2 \cdot (T_4-T_3)$$

The net difference in storage saving between a double sale at T_3 and a single sale at T_2 is:

$$f\ (ST) = \text{area II} - \text{area I}$$

i.e. $f\ (ST) = (SS_3 - SS_2)(T_4-T_3) - SS_2(T_3-T_2)$

where f (ST) represents pre-sale storage saved.

If f (ST) is negative then a single sale is selected at T_2.

If f (ST) is positive then a double sale is selected at T_3.

When a positive f(ST) situation occurs no single sale is held in the centre concerned. However, a double sale in that centre may not be rostered until after T_3. This situation arises, when in the period from T_2 to T_3, other sales in other centres are rostered, and the time constraints resulting from these sales forces the postponment of a double sale in the relevant centre at T_3.

Experimentation showed that phasing out double sales that were marginal with respect to this decision procedure, gave improvements for some performance parameters.[9] The method of phasing out such double sales is described below.

This single/double decision procedure gives the model flexibility in rostering. By varying the operating rules of this decision process, rosters

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9. Relevant experimental results are presented in Sections 3.6.1 and 4.10

can be formulated with varying ratios of single to double sales. The operating rule described above involved comparing f(ST) to zero. More single sales are rostered if f(ST) is compared to some positive value. In Section 3.6.1, it is seen that comparing f(ST) to 100, 200, 300 and 400 thousand bale-days, in sequence, gives rosters with progressively higher single to double sale ratios, (because f(ST) must be greater than the value assigned for comparison before a double sale is held in place of a single sale).

The decision process mentioned in this and the previous section are included in SELLEM (see Appendix A9). The bulk of the programming for implementation of the decision process described in this section, is contained in sections IV and V of SELLEM, and, is only operational when sense switch 2 of the computer is on. The decision variable is named NETT in the programme.[10]

3.6 Rosters for the 1971/72 Season

Rosters were derived from the three data sets (see Section 3.2.1) using the restriction values given in Section 3.3. Some of these rosters were adjusted to be compared with the Wool Auction Sales Committee's roster for the season.

This adjustment involved two aspects. Firstly there was the adjustment of sale dates, within the constraints, to give what was felt to be better rosters. The programme rosters tended to favour one day of the week for sales. This favouritism occurred because of: the weekly increment assumption for arrivals, (see Section 3.2.2), the seven day closing to sale date restriction (see Section 3.3.3), and, because the between sale within centre restriction periods are often in weekly increments (see Section 3.3.2). These factors combined in

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10. Programme variable NETT corresponds to f(ST) above.

such a way as to give many sales in weekly increments, resulting in a large number of 'Monday' sales being rostered. These sale days are changed to other days of the week where this can be done without violating rostering constraints.

Secondly, the programme rosters do not roster all wool for sale. It is possible to adjust sale sizes and dates towards the end of the season, within the constraints of the model, to roster this unsold wool for sale.

These two aspects of adjusting programme rosters gave modifications which were such that fairer comparisons with the Wool Auction Sales Committee roster could be made. Link programme SELLEM (see Appendix A9), by means of sense switch 3, allows for rosters to be altered for both date and time of sale, and re-run to re-estimate performance parameter values.[11] Other than evaluating adjusted rosters, this capacity of the programme allows for evaluation of rosters derived independently of the programme, by perhaps different decision processes.

With regard to selling all the wool, it may be argued that it would be desirable for the programme to do this. At one stage the programme did have this capability (see Appendix A11) but this was later removed.[12]

3.6.1 Programme Rosters

Programme rosters for "Corrected Average" data were derived for five values of the single/double decision variable (see Section 3.5.4). The decision variable is referred to as "NETT" in the programme. The results of these runs are summarised in Table 3.2 below.

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11. Rosters obtained from the programme are referred to as "programme rosters". Programme rosters, which are adjusted by hand and re-run, are referred to as "adjusted rosters".
12. Mr. J.D. Fraser, Manager of the Wool Board, suggested that this refinement of the programme was of little practical significance, due to errors in estimation of wool arrivals giving wide variability in estimates over the latter part of the season.

TABLE 3.2 PROGRAMME ROSTERS FOR "CORRECTED AVERAGE" DATA

Performance Parameter	Single/Double Decision Variable Value				
	NETT : 0	NETT : 100	NETT ; 200	NETT : 300	NETT : 400
Pre-Sale Storage ('000 bale-days)	65,690	56,116	56,415	60,134	60,146
Bales Held Over ('000 bale-days)	27,044	22,126	23,080	29,609	29,971
Single:Double Sales	19:19	31:12	31:12	40:7	42:6
Average Evaluation Period (days)	11.55	10.97	11.20	11.34	11.12
'Monday' Sales	27	27	26	29	25

The results in Table 3.2 above indicate that the NETT : 100 decision rule was likely to give the best programme rosters, in terms of the pre-sale storage and bales held over performance parameters. Although the average evaluation period (closing to sale date period) is lowest for the NETT : 100 decision rule, it is still relatively high, and, well above the minimum requirement of seven days. Sale numbers are higher for the NETT : 100 than the NETT : 0 programme, but appear more realistic in terms of past rosters. Furthermore, the vast differences in storage and bales held over between these two rosters, were considered to outweigh the disadvantages in sale number differences. Table 3.3 indicates that the differences between the NETT : 0 and NETT : 100 rosters remained consistent for the other two data sets.

TABLE 3.3 PROGRAMME ROSTERS FOR "UNWEIGHTED AVERAGE" AND "CORRECTED AVERAGE" DATA SETS

Performance Parameter	"Unweighted Average" Data		"Weighted Average" Data	
	NETT : 0	NETT : 100	NETT : 0	NETT : 100
Pre-Sale Storage ('000 bale-days)	58,753	48,103	52,082	51,275
Bales Held Over ('000 bale-days)	20,866	15,716	18,233	17,309
Single:Double Sales	18:17	28:12	26:13[13]	25:14[13]
Average Evaluation Period (days)	11.02	9.97	10.76	10.07
'Monday' Sales	26	26	25	27

Tables 3.2 and 3.3 indicate relationships between performance parameter values and total expected seasonal arrivals.[14] As expected arrivals increase so do pre-sale wool storage and bales held over. This is expected as a greater quantity of wool is being processed through the system, under the same levels of constraints. Double sales would be expected to become more predominant, and, the average evaluation period would probably increase with more offerings. These latter hypotheses are not strongly supported by the results. They would probably be better supported if a wider range of expected wool offerings was

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13. In Table 3.3 an inconsistency occurs in the single:double sale number ratio for "Weighted Average" data rosters. This is not reflected so much in the direction of changes in other performance parameters, but is indicated by the extent of these changes. The values have changed in the right direction, but not by nearly so much as for comparative rosters based on other data. The cause of the discrepancy lies in decision processes other than the single/double process, having overriding effects on the roster format.

14. Total seasonal arrivals increase from "Weighted Average" to "Unweighted Average" to "Corrected Average" sets of data.

included in the experimentation.[15]

Appendix C2 contains an example of a programme roster as printed by the computer. The specific roster is for "Corrected Average" data based on the NETT : 100 decision rule.

3.6.2 Adjusted Rosters

Five of the programme rosters were adjusted for comparison with the Wool Auction Sales Committee's roster. The Committee's roster was corrected to fit the data used. This was done by assuming the same sale dates and sale sizes wherever possible, but decreasing the sale sizes where required by the data. Consequently, sales of only 3,000 bales are apparently rostered. In such cases the comparison is invalid due to breaching of constraints by the Committee's roster. A direct comparison is possible in the case of "Corrected Average" data rosters, as the data is such as to avoid breaching of sale size constraints by the Committee's roster. Results and comparisons are made in Table 3.4 below:

TABLE 3.4 ADJUSTED ROSTERS FOR THE 1971/72 SEASON

	PERFORMANCE PARAMETER				
ADJUSTED ROSTER	Pre-Sale Storage ('000 bale-days)	Bales Held Over ('000 bale-days)	Single: Double Sales	Average Evaluation Period (days)	'Monday' Sales
"Unweighted Average"					
NETT : 0	59,266	23,590	25:17	12.16	5
NETT : 100	50,669	20,213	35:12	12.08	6
Committee	50,238	23,816	45:9	9.79	15
"Weighted Average"					
NETT : 0	53,205	21,770	32:13	12.31	6
NETT : 100	53,126	21,102	30:14	11.45	6
Committee	46,337	20,306	45:9	8.96	15
"Corrected Average"					
NETT : 100	58,445	25,317	36:12	12.54	7
Committee	62,882	34,469	45:9	11.59	15

15. The NETT:100 programme roster for "Weighted Average" data does not fit the patterns indicated. This problem of "non-conforming" rosters is discussed further in Section 4.11.

Tables 3.2, 3.3 and 3.4 can be compared to see the effect of adjusting rosters on performance parameters. Adjusted rosters have higher pre-sale storage requirements than programme rosters. This is due to two activities in the adjustment process. Firstly, sales are often held later in adjusted rosters (on later days of the week). Secondly, sales towards the end of the season, may be delayed or reduced in size to allow all wool to be rostered for sale. These factors cause storage requirements to be higher in adjusted rosters.

Bales held over are higher in adjusted rosters than in programme rosters. The factors causing this are the same as those causing increases in storage. Furthermore, adjusted rosters include more sales generally; this means there are more sales from which bales can be held over.

The single to double sales ratio increases when rosters are adjusted, due to tidying up programme rosters at the end of the season. This process frequently involves rostering additional single sales at the end of the season.

The average evaluation period increase is somewhat less then two days. This is caused largely by shifting 'Monday' sales forward two days, where this is possible without violating constraints. In programme rosters not all sales fall on 'Mondays', nor, can all 'Monday' sales be shifted forward (as the results show). So the resulting increase in the average evaluation period falls somewhat short of two days when programme rosters are adjusted.

In comparing adjusted programme rosters with the Committee's roster, the point of validity of comparison mentioned earlier in this section is important. In Table 3.4, the Committee's roster is seen to perform differently when corrected for the various data sets. As estimated total wool arrivals figures decrease, the Committee's roster performs better (except for the average evaluation period parameter). However, this better performance is coupled with increased violation of sale size constraints. So although it is invalid to compare "Unweighted Average" and "Weighted Average" rosters with the Committee's roster, an important aspect has been brought out. This is the role of constraints in determining the performance of a roster. Quantitative measures of the importance of constraints on the system are made in Chapter IV.

Valid comparisons can be made between the adjusted programme roster derived from "Corrected Average" data, and, the Committee's roster. Using this data, the Committee's roster does not violate the sale size restrictions. Table 3.4 indicates that rostering with a lower single : double sales ratio improved the performance of the system for all measured performance parameters. Calculations in Section 2.1.4 suggest that the importance of savings in pre-sale storage, in terms of interest alone, are very significant. The adjusted programme roster involves 58,445,000 bale-days of pre-sale wool storage; the Committee's roster involves 62,882,000 bale-days. This difference in terms of added interest earnings, is in the vicinity of $80,000. The adjusted roster for the NETT : 100 decision rule, and the Committee's roster, are presented in Appendix C1.

3.6.3 Within Centre Performance Variability

In the previous two sections, the results indicated consistency in directional changes in performance parameter values, with changes in estimates of wool arrivals, and, operating rules. This consistency does not carry over for individual centres. An indication of the extent of centre inconsistency, is given in Table 3.5 below; the probable causes of discrepencies is discussed following Table 3.5.

TABLE 3.5 INCONSISTENCIES WITHIN CENTRES

CENTRE	PRE-SALE STORAGE ('000 bale-days)				
	"Weighted Average" Data				Committee Roster
	Programme Rosters NETT : 0	Programme Rosters NETT : 100	Adjusted Rosters NETT : 0	Adjusted Rosters NETT : 100	
	(1)	(2)	(3)	(4)	
Auckland	5,856	5,883	6,048	6,288	5,278
Wanganui	4,392	5,442	4,643	6,074	2,978
Napier	12,414	11,926	12,590	12,062	11,391
Wellington	5,699	6,883	5,935	7,059	4,928
Christchurch	6,435	6,387	6,528	6,380	6,935
Timaru	4,112	3,704	2,871	2,771	2,860
Dunedin	5,036	4,992	6,156	5,976	7,863
Invercargill	8,138	6,058	8,434	6,516	4,104
TOTAL	52,082	51,275	53,205	53,126	46,337

In Table 3.5 above the pre-sale storage performance parameter is used as an example of the inconsistencies that occur within centres in terms of performance parameter changes. This Table shows inconsistencies in performance parameter changes within centres, for rosters derived under different decision rules (columns (1) and (2), and, for rosters in the programme and adjusted states (compare columns (1) with (3), (2) with (4)). The performance parameter values are approximately in line with those for the Committee's roster. If anything the Committee's roster favours the smaller centres (Wanganui and Timaru) more than the larger centres, with regard to pre-sale wool storage. Table 3.6 indicates individual centre performances by the Committee's roster and the directly comparable "Corrected Average" roster.

TABLE 3.6 INDIVIDUAL CENTRE PERFORMANCES

Parameter and Roster	CENTRE								
	Auckland	Wanganui	Napier	Well-ington	Christ-church	Timaru	Dunedin	Invercar-gill	Totals
Pre-Sale Storage ('000 bale-days)									
"Corrected Average"(i)	7,743	4,315	15,601	6,316	6,811	3,337	5,702	8,620	58,445
Committee(ii)	8,559	3,856	16,067	7,590	8,069	3,161	9,699	5,881	62,882
Bales Held Over ('000 bale-days)									
"Corrected Average"	2,956	1,180	10,264	2,454	2,686	614	1,171	3,992	25,317
Committee	4,462	1,062	11,848	4,427	4,201	511	5,962	1,996	34,469
Single:Double Sales									
"Corrected Average"	5:2	5:0	3:4	3:2	6:1	4:0	4:2	6:1	36:12
Committee	6:2	6:0	5:3	7:0	6:1	4:0	6:1	5:2	45:9
Average Evaluation Period (days)									
"Corrected Average"	11.57	10.80	14.57	12.60	13.42	11.75	11.16	13.42	12.54
Committee	10.87	8.50	14.12	13.28	11.85	11.25	15.00	7.00	11.59
'Monday' Sales									
"Corrected Average"	1	1	3	1	0	0	0	1	7
Committee	3	1	3	1	1	0	3	3	15

(i) "Corrected Average" is the adjusted roster derived from "Corrected Average" data using the NETT : 100 decision rule.

(ii) Committee refers to the Wool Auction Sales Committee roster for 1971/72.

Table 3.6 gives a useful indication of the extent to which performance parameters can vary within centres, for rosters which are not vastly different in overall performance. The apparent reversals for Dunedin and Invercargill are of special note in this context. The difference is due largely to the "Corrected Average" roster including an early double sale for Dunedin. This small change in format, early in the roster, significantly effected the performance of that centre, and, is useful as an example of why within centre discrepancies occur.

The variability of performance parameter values within centres can be attributed to the "chunky" nature of operation of the system. When a sale is rostered in a centre over 25% of that centres total season arrivals may be involved. Consequently shifts in the timing of the sale, by only a few days, will radically change the performance parameters of that centre; especially the pre-sale storage and bales held over parameters. Because significant shifts in the rostering format occurs between different rosters, the within centre performances are rather unstable.

3.7 Summary

Insofar as the performance parameters of the model are concerned, the programme appears to be reasonably efficient at rostering wool sales. Furthermore, the inherent flexibility of the programme enables a variety of rosters to be generated. Control of the rostering format through the single/double decision procedure could perhaps be improved to give finer control of the roster format produced by the programme. Such improvements could include different decision rules for individual centres, and, varying degrees of imposition of the rule, (through the NETT[16] variable) at different times of the season.

Variability in performance parameter values for individual centres has undesirable connotations in terms of long term planning for storage facilities etc. However, the study was aimed at the system as a whole, with more emphasis on total system performance than on individual centre performances. In attempting to improve total system performance, the programme tends to improve all individual centre performances also. Individual centre performances would probably average out satisfactorily if runs over a wide range of data estimates were carried out.

The programme appears to be sophisticated enough to be used as an aid to rostering. Firstly, it is useful in establishing a range of bases from which the final roster can be derived. Secondly, it allows the measurement of some hitherto unmeasured performance parameters.

The results obtained indicate that better rosters may be formulated, (in terms of the performance parameters of the model), if more double sales were rostered, (than were rostered by the Wool Auction Sales Committee). On the basis of these findings the Committee considered rostering a higher proportion of double sales for the 1972/73 season.[17]

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16. The meaning of "NETT" is given in Section 3.5.4
17. This information was provided by Mr. J.D. Fraser, Manager of the Wool Board, and convenor of the Wool Roster Sub-Committee.

CHAPTER IV

EXPERIMENTATION WITH THE MODEL

4.1 The Purpose of Experimentation : Data Used

In Chapter I it was pointed out that the system under study is undergoing change. Proposals effecting the wool auction system need to be carefully evaluated, in terms of performance of the system, before being implemented. It was argued that measurement of performance of the system, under varying conditions and structures of the system, can be achieved by experimenting with a model of the system, in lieu of experimentation with the real world problem. The roster problem is a sub-system of the wool auction marketing system. Experimentation with a model of this sub-system, and measuring the performance of the sub-system under various experimental conditions, provides useful information for management to evaluate proposed changes to the system. Consequently, the simulation model of the roster problem was formulated with sufficient flexibility to carry out experimentation. The extent of this flexibility is indicated in the model development sections of Chapter III (Sections 3.2 to 3.5).

Experimentation in this Chapter is aimed at evaluating the performance of the roster for the following changes to the marketing system:

i. an increased rate of sale of wool at auction, (Section 4.2)

ii. changes in wool handling rates in wool brokers' stores, (Section 4.3)

iii. the interactions between changes in the rate of sale at auction and handling rates, (Section 4.4)

iv. increases in the upper size limits of wool sales, (Section 4.5)

v. the abolishment of 'Monday' sales, (Section 4.6)

vi. a decrease in the number of auction centres, (Section 4.7)

vii. an even rate of sale of wool (consistent quantitative offerings on a weekly, monthly, or quarterly basis), (Section 4.8).

The reasons behind these proposals are presented in the sections indicated with each experiment above. Each section includes the practicability of introducing the changes, and, the results and conclusions drawn in terms of the roster problem.

Most of this experimentation is carried out on a ceterus paribus basis, i.e. it is assumed that parametric variation of one restriction does not effect other restrictions. Obviously this is an unrealistic assumption. However, in isolating the effects of each restriction independently, insight is gained into the likely performance of the system if restrictions vary together. For example, the sale size limits can be varied independently of the between sale within centre restriction; then the between sale within centre restrictions varied independently of the sale size limits. On studying the effect of these restriction variations independently, insight should be gleaned as to how the restrictions would react together. It will be seen that the results obtained for these restrictions varied individually are used to base hypotheses for experiment iii. on, (where both restrictions are varied simultaneously).

The bulk of the experimental runs used the NETT : 0 decision rule (see Section 3.5.4). Rosters were not adjusted to give improved sale days or to sell all wool arrivals (as in Section 3.6.2). The reason for not doing so is because of the time that would be required to alter and re-run the experimental rosters (a total of eighty five programme rosters were obtained in this Chapter at $\frac{3}{4}$ hour computer time per roster). Section 3.6.2 indicated that quantitative, not qualitative, differences existed between programme and adjusted rosters. As experimentation is aimed at establishing trends only these quantitative differences are not important.

Further experimentation was conducted to find the sensitivity of trends in performance parameter values to changes in the amount of wool auctioned

(Section 4.9). In Section 4.10 the sensitivity of performance parameter trends to changes in the single/double decision procedure (see Section 3.5.4) was looked at.

Inconsistencies in the performance parameter values for some rosters are apparent throughout the experimentation. The reasons for, and consequences of, these inconsistencies are discussed in Section 4.11.

4.1.1 Experimental Year Data

The in-to-store arrivals data used for experimentation was an unweighted average of the weekly arrivals for each centre, for the most recent three seasons for which data was available. At this stage these seasons were:

1967/68

1968/69

1969/70

This data is contained in Appendix B6. The reasons that such data was taken are:

i. averaging out three years data decreases the influence of seasonal fluctuations so the data is more representative of the system over time,

ii. use of the most recent seasons data gives greater realism, in terms of now and the future, (insofar as it can be seen).

The season used for the experimental year covered the usual period of 297 days from 5th September to the 28th June.

Infeasible days were:

i. Saturdays and Sundays

ii. 31st October - Labour Day

iii. 21st December to the 7th January - Christmas break

iv. 1st Monday in April

v. 1st Monday in June.

Values of some of the restrictive variables were varied around their present day values. Where these values do vary from those given in Chapter III this is indicated.

4.2 Increasing the Rate of Sale of Wool at Auction

The rosters derived in Chapter III showed that sale size limits were effectively limiting the rate at which wool could pass through the marketing chain. The result of this restriction was detrimental to both the pre-sale storage and bales held over performance parameters. Furthermore upper limits on sale sizes requires a greater number of sales to sell all the wool.

In Section 1.4.4 it was shown that a large amount of time at auction is used in selling a small proportion of the wool. This is, the wool presented in small lot sizes. Peirse and Beggs (7) concluded that small lots show a discount when sold at auction; it would appear advantageous to amalgamate small lots into larger lots. In the next section it is shown that amalgamating small lots will generally increase the rate of sale of wool at auction.

Hypotheses on the effect on the performance parameters of progressively increasing the sale size limits are:

Hypothesis A :

Pre-sale wool storage will decrease initially as the upper sale size limits become less restrictive, but eventually storage will rise again as the lower sale size limits become restrictive.

The decreasing phase will be most apparent in large centres (centres where a lot of wool is sold) whereas the increasing phase will show more in smaller centres.

Hypthesis B :

The extent of bales held over will decrease initially but will level or rise with higher sale size limits.

In the first phase the raised upper sale size limits will cause less wool to be held over (noticable especially in the larger centres). In the second phase less bales (in number) will be held over but those bales that are held will be in store for a long time (due to lower sale size limits), and the weighted measure of bales held over will probably level or increase (noticeable mainly in the smaller centres).

Hypothesis C :

The total number of sales will progressively decrease with single sales becoming more predominant.

Because of more wool being sold per sale, less total sales will result. The lower sale size restriction for double sales will become too high for double sales to be held in many centres.

Hypothesis D :

The average evaluation period (closing to sale date period) will decrease as sale size limits increase.

Sale size limits will tend to dominate the between sale within centre restrictions, and sales will be held as soon as enough bales are available. This will lower the average evaluation period.

4.2.1 Means of Varying Sales Size Limits

Under the present wool auction system, sale size limits are directly related to the rate of sale of lots, and, the average lot size offered at auction. As indicated in Section 3.3.1 the relationship, after some adjustment, yields sale size limits, of:

20,000 bales minimum for single sales

28,000 bales maximum for single sales

40,000 bales minimum for double sales

50,000 bales maximum for double sales

Assuming that neither an extension of the auction day, nor an increase in the hourly rate of sale of lots are possible then two means of increasing the sale size limits are available. These means involve changing the average lot size of wool offered. Changing the average lot size could be effected by:

i. an across the board increase in lot sizes, i.e. a shift in the distribution of lot sizes to a higher level.

ii. raising the minimum lot size permitted, everything else remaining equal.

The disadvantage in raising the minimum lot size permitted is that some producers will not be able to retain the identity of their wool. This should not, however, be greatly to their disadvantage unless they have a very distinct wool type which they produce in small quantities. Raising the minimum lot size permitted has advantages to brokers in greater ease of processing, setting up, and categorising wool for auction. These same advantages would accrue to the wool brokers with an across the board increase in lot sizes, but to a lesser extent.

A study by Peirse and Beggs (7) showed that a high proportion of auctioning time is taken up in selling small lots. Almost 50% of the auctioning time is taken to sell about 20% of the bales offered; these are the bales in the 1 - 6 lot size category. Some simple calculations based on the findings of Peirse and Beggs show that restricting lot sizes to a low minimum value has a considerable effect on the average lot size.

TABLE 4.1 MINIMUM LOT SIZES AND SALE SIZE LIMITS

Minimum Lot Size (bales)	Average Lot Size (bales)	Percentage Increase in Sale Size Limits
1*	≃10	0
6*	11.35	13.5
7*	12.07	20.7
8	12.8	28
9	13.6	36
10*	14.45	44.5
11	15.4	54
12	16.2	62
15*	18.73	87.3

* calculated from Table 1.2.

The calculated (asterisk) values in Table 4.1 above indicated a linear relationship between minimum lot sizes and percentage increases in the average lot size. Interpolation was used to estimate the corresponding average lot size values for minimum lot sizes of 8, 9, 11 and 12 bales. The percentage increase in sale size limits values are assumed to be the same as the corresponding percentage increases in average lots sizes, for varying minimum lot sizes.

In order for the above argument, and estimations in Table 4.1, to be realistic two assumptions must be made:

i. that the 1964/65 data of Peirse and Beggs (Table 1.2 is applicable today,

ii. that imposing the various minimum lot sizes does not alter the distribution of lot sizes above the minimum value.

The first assumption is probably a realistic one as wool brokers still aim to average ten bale lot size offerings. The second assumption is not so realistic. If minimum sizes of lots were enforced it is likely that the distribution of lot sizes would shift back to some extent. Consequently the average lot size might be lower than that estimated. This could be overcome by enforcing some minimum lot size value and asking brokers to work for some average lot size corresponding to the estimates given in Table 4.1.

Assuming the producer is not harmfully effected by imposing a minimum lot size restriction on wool sold at auction, and the broker benefits, then the buyer must be considered. Is the buyer for, against, or indifferent, as to the average and distribution of lot sizes at auction? Buyers would only be against imposing a minimum lot size if they bought small quantities in total or small quantities of a wide range of wool types. Buyers that operate in either of these two ways could purchase by private treaty from wool stores, or producers.

The implementation of a minimum lot size scheme would appear to find most opposition from those growers who reap, or believe they reap, benefit from wool price fluctuations at auction. On a national basis, however, the study by Peirse and Beggs indicated that revenue from wool sold at auction would probably increase if the very small and very large lots were removed. Peirse and Beggs state:

> "It has been shown that small lots and some very large lots show a perceptible discount when sold at auction. Any measures that can be taken to reduce the proportion of lots sold in these categories should be helpful to growers and would tend to meet buyers current requests."[1]

From the conclusions of Peirse and Beggs it appears that imposing a minimum lot size would be advantageous.

4.2.2 Varying Sale Size Limits : Results and Conclusions

Rosters were obtained for sale size limit increases of 0%, 10%, 20%. 30%, 40%. 50%, and 60% on the limits used in Chapter III (given in previous section[2]). Table 4.1 indicates values for minimum lot sizes which would give these increases in the sale size limits (approximately). No changes in any other restrictions were made. The results obtained for programme rosters are given in Table 4.2 below.

TABLE 4.2 PARAMETRIC VARIATION OF SALE SIZE LIMITS

Performance Parameter	PERCENTAGE INCREASE IN SALE SIZE LIMITS						
	0	10	20	30	40	50	60
Pre-Sale Storage ('000 bale-days)							
All Centres	54,066	49,040	47,730	48,290	47,987	47,577	49,523
Napier	11,533	9,633	9,170	9,658	8,393	8,478	7,754
Timaru	2,806	3,948	3,900	4,877	4,731	4,821	4,792
Bales Held Over ('000 bale-days)							
All Centres	20,289	14,678	12,942	14,132	10,867	11,420	9,931
Napier	6,309	4,762	4,032	5,915	3,108	2,976	2,126
Timaru	543	688	670	360	296	340	219
Single:Double							
All Centres	23:16	23:14	25:11	32:5	28:6	30:4	27:4
Napier	1:4	1:4	2:3	5:1	3:2	3:2	2:2
Timaru	4:0	3:0	3:0	2:0	2:0	2:0	2:0
Average Evaluation Period (days)							
All Centres	10.58	9.21	9.41	9.10	8.41	8.29	8.19
Napier	13.60	10.40	12.20	12.16	10.00	9.20	7.50
Timaru	8.50	9.66	10.00	10.00	9.00	8.00	9.00

1. Source: Peirse and Beggs (7), p.12.
2. Sale size limits are increased by the percentage indicated and corrected to the nearest thousand bales.

The results summarised in Table 4.2 above support, in most instances, the hypotheses put forward in Section 4.2.

Hypothesis A was that pre-sale wool storage will decrease initially and then increase, as the sale size limits increase. The results obtained support this hypothesis; storage appears to be lowest when sale sizes are increased by 20 - 50%. Larger centres (e.g. Napier) benefit from larger sale size limits (in terms of storage) whereas smaller centres (e.g. Timaru) are adversely effected.

Hypothesis B, that bales held over would initially decrease and then level or increase, as sale size limits are increased, is partially supported by the results. The results indicate that bales held over decreased significantly for small increases in sale size limits, and continued to decrease but at a less rapid rate as sale size limits increased further. If a levelling phase exists it requires somewhat above 60% increases in sale size limits to reach it. Furthermore both large and small centres benefitted in terms of this performance parameter. It appears that it is the number of bales held over, rather than the period they are held over, that is the more important determinant of this performance measure. This observation is important as it makes this measure of the performance parameter of more relevance to wool brokers (see Section 3.4.2).

The results support Hypothesis C in that the single : double sales ratio increases, while the total number of auction days decreases (taking one double sale as being equivalent to two auction days), as the sale size limits are raised. For large centres the effects are more pronounced than for smaller centres where double sales are infrequently held anyway.

Hypothesis D is not disproved; the results show a fairly consistant decline in the average evaluation period when sale size limits are raised. The effect is more pronounced in larger centres due to the upper sale size limits becoming less restrictive (actively) when raised. When the sale size rostered is less than the relevant upper size limit, the decision process described in Section 3.5.1 will force the closing to sale date (evaluation) period to its minimum value. Consequently, the average evaluation period decreases as the sale size limits increase.

In conclusion it appears that sale size limits are very important in determining the performance of the roster. Small changes in these limits have significant effects on the performance parameters of the model. Furthermore, significant changes in sale size limits could be achieved without seriously effecting the system by means of a minimum lot size constraint. Table 4.1 indicates that the value of this minimum lot size constraint does not have to be large to produce significant increases in the sale size limits.

4.3 Alteration of Wool Handling Rates in Wool Stores

The effects on the roster of increased or decreased handling rates in wool stores can be studied by varying the between sale within centre time constraints. Most interest lies in an increased handling rate; this could result from sale by sample and dense baling, or, reductions in the proportions of wool binned and reclassed. Lower handling rates would result if overtime work in wool stores was abolished.

One reason the between sale within centre restrictions are increased is to indicate the expected performance of the system when sale size limits are increased. Raising sale size limits means that more wool must be processed for each sale, and processing times (between sale within centre restrictions) will increase. This relationship between these constraints is studied in Section 4.4.

Hypotheses on the performance of the system for varying between sale within centre restriction values (other restrictions remaining at the levels given in Chapter III) are:

Hypothesis A:

Pre-sale wool storage will increase as the between sale within centre restrictions increase. This effect will be more noticeable in larger centres.

Hypothesis B:

Bales held over will increase as the between sale within centre restrictions increase. Larger centres will show this trend more distinctly.

Hypothesis C:

Sale numbers will decrease with double sales becoming more predominant as the between sale within centre restrictions increase.

Hypothesis D:

The average evaluation period will increase as the between sale within centre restrictions increase.

4.3.1 Means of Varying Handling Rates

Simulated changes in handling rates were achieved by making percentage changes to the between sale within centre restrictions (hereinafter referred to as the time limits). The changes made were decreases of 10% and 20%, no change, and increases of 10% and 20%, on the values given for these constraints in Section 3.3.2.[3]

Results for decreases in the time limits are useful as an indication of how the roster may perform if sale by sample and dense baling was introduced, or, less binning and reclassing occurred. Percentage decreases were made to maintain consistency.

Increases in the time limits are of relevance to Section 4.4 where experimentation involving changes in both sale size limits and time limits is presented. Percentage increases in the time limits were made as the sale size limits were increased on a percentage basis.

4.3.2 Varying Handling Rates : Results and Conclusions

Rosters were obtained for time limit variations of -20%, -10%, 0%, +10%, +20% of their present values (see Section 3.3.2); other restrictions remained unchanged. The results of these runs are summarised in Table 4.3 below.

3. The restriction values are lowered, or raised, by the percentage indicated and corrected to the nearest day.

TABLE 4.3 PARAMETRIC VARIATION OF BETWEEN SALE WITHIN CENTRE RESTRICTIONS

Performance Parameter	PERCENTAGE CHANGE IN TIME LIMITS				
	-20	-10	0	+10	+20
Pre-Sale Storage ('000 bale-days)					
All centres	43,104	53,836	54,066	59,300	68,479
Napier	10,358	12,188	11,583	14,552	17,267
Timaru	2,914	4,214	2,806	4,049	4,937
Bales Held Over ('000 bale-days)					
All Centres	15,095	17,694	20,289	26,171	28,915
Napier	6,221	7,440	6,309	9,674	11,009
Timaru	559	304	543	256	159
Single:Double Sales					
All Centres	32:13	23:16	23:16	25:15	14:20
Napier	3:3	2:4	1:4	2:4	1:4
Timaru	4:0	3:0	4:0	3:0	1:1
Average Evaluation Period (days)					
All Centres	9.48	10.51	10.58	10.72	10.35
Napier	12.50	12.33	13.60	13.00	13.60
Timaru	9.00	10.33	8.50	10.33	9.00

Table 4.3 above indicates that the results obtained support the hypotheses made in Section 4.3. Pre-sale storage and bales held over increase as the time limits increase. The reason for this is that wool (new arrivals and bales held over) must await sale for longer periods. Percentage increases in the time limits represent exponential absolute increases. So it may be expected that storage and bales held over would increase in a exponential fashion. The reason this does not occur lies in a changing pattern of rosters; this change being from a low to a high proportion of double sales rostered. Some compensation for higher time limits is provided by rostering more double sales.

Hypothesis C stated that the number of sales will decrease, with double sales becoming more predominant as the time limits increase. The results support this hypothesis; the explanation as to why this trend occurs is given above. Less sales in total result but the number of auction days is fairly consistent (a double sale involves two auction days). Consequently the trend is a direct result of increasing the proportion of double sales.

The results show the average evaluation period increases as the time limits increase (Hypothesis D). The reason for this is that the relevant upper sale size limit is often reached well before a sale can be held due to the time restrictions between sales.

In conclusion it appears that the roster is very sensitive to changes in the between sale within centre constraints. In evaluating policies which effect these constraints, the sensitivity of the roster's performance parameters to these constraints must be borne in mind.

4.4 Simultaneous Variation of Both Sale Size Limits and Handling Rates

The aim of this experimentation was to indicate trends in the performance parameters of the roster when both the sale size restrictions and the between sale within centre restrictions were varied together from their present values (see Sections 3.3.1 and 3.3.2). Earlier in this Chapter the point was made that restrictions are not independent; changes to one restriction are likely to cause changes to another. It is important to know how, and to what extent, these simultaneous changes may effect the performance of the roster before introducing such a change to the auction system.

Experimentation involved obtaining rosters for increases in the sale size limits when the between sale within centre restrictions were lower and higher than their present values. In proposing hypotheses on the trends in performance parameters for the experiments, the results for the previous two sections are useful. Table 4.4 below summarises the trends in performance parameters obtained in previous experimentation.

TABLE 4.4 TRENDS IN PERFORMANCE PARAMETER VALUES

Performance Parameter	Changes in Restrictions from Present Values (2)		
	Increasing Sale Size Limits	Decreasing Time Limits (1)	Increasing Time Limits (1)
Pre-Sale Storage	Decrease then Increase	Decrease	Increase
Bales Held Over	Decrease	Decrease	Increase
Single:Double Sales	Increase	Increase	Decrease
Average Evaluation Period	Decrease	Decrease	Increase

(1) time limits refer to the between sale within centre restrictions
(2) present values refers to those values given in Chapter III (Sections 3.3.1 and 3.3.2).

Table 4.4 above shows that combining increases in sale size limits with increases, or decreases in the between sale within centre restrictions may have unpredictable effects on performance parameters in some instances. An example of this is when both restrictions are increased. Until sale size limits become high (60% increases), changing the limits will have opposed effects on all performance parameters. At high sale size limits pre-sale storage should increase.

Combining increased sale size limits with decreased between sale within centre restriction levels should decrease bales held over, and the average evaluation period, and increase the single:double sales ratio. Pre-sale storage should decrease for small increases in the sale size restrictions but may level or increase at higher levels of these limits.

4.4.1 Means of Varying the Selling and Handling Rates Simultaneously

Achievement of the changes in the restrictions being varied individually has been discussed in Section 4.2 and 4.3. The between sale within centre restrictions are dependent on the sale size limits. Increasing the sale size limits, by raising the average lot size, would be accompanied by increases in the between sale within centre restrictions probably. It would be possible to increase the sale size limits, and decrease the between sale within centre restrictions, by introducing policies which raised the average lot size and decreased handling times. For example, the policies could be to introduce a minimum lot size policy, in conjunction with sale by sample and dense baling (at significant levels).

In Section 4.1 it was pointed out that the experimentation conducted is not intended to give quantitative measures of changes in performance that may occur when different policies were implemented. In this section an experimental block technique is used which may prove useful for initial investigations into the consequences of introducing new policies. However, the results obtained are indicative of likely trends only and should not be used for quantitative evaluations.

4.4.2 Varying Sale Size Limits and Handling Rates : Results and Conclusions

The experimental block was a matrix of rosters for all combinations of 0%, 10%, 20%, 30%, 40%, 50%, and 60% increases in the sale size limits from their present values (see Section 3.3.1) with -20%, -10%, 0%, +10%, +20% changes in the between sale within centre constraints (for present values see Section 3.3.2).

The results obtained for the runs are summarised in Table 4.5 below.

TABLE 4.5 PARAMETRIC VARIATION OF TWO RESTRICTIONS

Percentage Increase in Sale Size Limits (1)	PERCENTAGE CHANGE IN BETWEEN SALE WITHIN CENTRE CONSTRAINTS (2)				
	-20	-10	0	+10	+20
0%					
Pre-Sale Storage (3)	43,104	53,836	54,066	59,300	68,479
Bales Held Over (3)	15,095	17,694	20,289	26,171	28,915
Single:Double Sales	32:13	23:16	23:16	25:15	14:20
Average Evaluation Period (4)	9.48	10.51	10.58	10.72	10.35
10%					
Pre-Sale Storage	45,122	46,822	49,040	61,027	58,410
Bales Held Over	11,726	13,607	14,678	22,894	22,116
Single:Double Sales	28:12	31:10	23:14	17:18	20:16
Average Evaluation Period	8.92	9.31	9.21	10.31	10.13
20%					
Pre-Sale Storage	43,680	43,989	47,730	54,215	58,021
Bales Held Over	10,720	10,779	12,942	16,891	19,735
Single:Double Sales	34:6	29:9	25:11	21:13	20:13
Average Evaluation Period	8.62	8.39	9.41	10.02	10.03
30%					
Pre-Sale Storage	44,734	45,983	48,290	51,427	54,859
Bales Held Over	11,150	10,973	14,132	12,451	14,765
Single:Double Sales	34:4	31:6	32:5	25:8	22:9
Average Evaluation Period	8.44	8.81	9.10	8.63	8.67
40%					
Pre-Sale Storage	44,671	45,857	47,987	50,239	53,494
Bales Held Over	10,356	9,331	10,867	11,167	13,596
Single:Double Sales	31:5	28:6	28:6	27:6	22:9
Average Evaluation Period	8.19	8.05	8.41	8.48	8.45
50%					
Pre-Sale Storage	46,660	46,734	47,577	52,535	52,568
Bales Held Over	9,818	9,816	11,420	12,603	14,197
Single:Double Sales	30:4	30:4	30:4	25:6	26:5
Average Evaluation Period	8.08	8.08	8.29	8.32	8.87
60%					
Pre-Sale Storage	49,857	48,245	49,523	49,273	52,210
Bales Held Over	9,523	9,954	9,931	10,923	11,577
Single:Double Sales	28:3	29:3	27:4	28:3	24:6
Average Evaluation Period	7.90	7.81	8.19	8.03	8.40

(1) Increased from limits given in Section 3.3.1

(2) Increased from values given in Section 3.3.2

(3) units - thousand bale-days

(4) units - days

The results in Table 4.5 above indicate that pre-sale storage tends to increase, for any set of sale size limits, as the between sale within centre restrictions increase. The rate of increase in pre-sale storage decreases for higher sale size limits. The reason for this is that at high sale size limits, these limits play a greater part in restricting the rate of sale of wool, (on say a monthly basis), than do the between sale within centre restrictions. So altering the between sale within centre restrictions has little effect on the performance of the roster, in terms of pre-sale storage. Looking down the table it is seen that pre-sale storage increases for low values of the between sale within centre restrictions and decreases at higher values of these constraints. For smaller changes in the between sale within centre restrictions, (-10%, 0% and +10%), pre-sale storage goes through a decreasing then increasing phase as the sale size limits are raised. This effect is due to restriction of the rate of sale of wool by the lower sale size limits when the between sale within centre restrictions are low, and restriction by the upper sale size limits when the between sale within centre restrictions are high. Relaxation of the restrictions caused by sale size limits results in better performance with regard to pre-sale wool storage.

Table 4.5 shows trends in the bales held over performance parameter. For any set of sale size limits, bales held over tend to increase as the between sale within centre limits increase. The rate of this increase is much less for higher sale size limits. This is because at low sale size limits, the upper size limits effectively restrict the number of bales that can be sold, especially when the between sale within centre restrictions are high. Consequently, large quantities of wool are carried over. At higher sale size limits the upper limits on sale sizes are not nearly so restrictive, so little wool is carried over despite increases in the between sale within centre restrictions. Looking down Table 4.5 it is seen that the extent of bales held over decreases as the sale size limits are raised. The extent of this decrease is greatest for high between sale within centre restrictions. Again the reason lies in restriction by the upper sale size limits. This restriction is felt most when the between sale within centre restrictions are high. Consequently, the rate of decline in bales held over, when sale size limits increase, is greater when the between sale within centre restrictions are set at higher levels.

Looking across Table 4.5, the single:double sales ratio decreases as the between sale within centre restrictions increase. The reason for this is that the larger the restriction the more likely it is that enough wool will be available for a double sale. Naturally this tendency weakens when the sale size limits become very high. Going down Table 4.5 it appears that the single: double sale ratio rises as the sale size limits increase for any set of between sale within centre restrictions. This is expected as the same wool arrivals data is being used for each run. Sale size limits are rising so the total number of auction days will decrease with single sales becoming more predominant. This effect is more apparent for low levels of the between sale within centre restrictions.

The average evaluation period increases across, and decreases down, Table 4.5. The crosswise increase is due to the upper sale size limits being reached before the between sale within centre restrictions are fulfilled, whereas the downward decrease is due to increasing upper sale size limits.

Study of the diagonals in Table 4.5 shows the performance parameter changes correspond with predictions embodied in Table 4.4 (Section 4.4). Downward, left to right, diagonals in Table 4.5 combine increasing sale size limits with increasing between sale within centre restrictions.[4] Downward, right to left, diagonals give results for increasing sale size limits and decreasing between sale within centre restrictions. The downward, left to

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4. These diagonals indicate likely shifts in performance parameter values if a minimum lot size scheme was introduced. The most relevant of these diagonals (in this context) is the one starting at 0% change in the between sale within centre restrictions.

right, diagonals indicate that the sale size restrictions tend to dominate the between sale within centre restrictions in their effects on the performance parameters for the experiments carried out. The dominance is not complete but appears significant nevertheless. The downward, right to left diagonals show that the complementary effects expected (see Table 4.4), hold for this experimentation. The opposing effects of the restrictions on pre-sale storage at high increases in the sale size limits indicate that the sale size limits are again dominating the trend in this performance parameter.

In conclusion, the complementary effects hypothesised for changing levels of the restrictions (in their effects on performance parameters) are supported by the experimental results. Where the effects of the two restrictions are opposed, the sale size limit restrictions tend to dominate the between sale within centre restrictions.

4.5 Increasing Only the Upper Sale Size Limits

Increasing the upper sale size limits on a percentage basis, yet leaving the lower limits at 20,000 bales for single sales and 40,000 bales for double sales, broadens the range of sale sizes possible to a greater extent than if the increases apply over all limits.

The effect of increasing the upper sale size limits should be favourable to all centres, with regard to pre-sale wool storage and bales held over. Lesser centres, such as Timaru and Wanganui, should not be disfavoured as they were when lower sale size limits were also increased. The number of auction days will probably decrease with single sales becoming more predominant. The average evaluation period should decrease as upper sale size limits are raised.

4.5.1 Achievement of the Limit Changes

Raising the upper sale size limits could be achieved by two means:

i. raising the average lot size offered at auction but accepting that some sales will not involve a full days auctioning,

ii. raising the average lot size offered only for those sales in which it is necessary to enable wool to be sold in one auctioning day.

Wool brokers would probably favour means i. more than ii. whereas the preferences of wool buyers would probably be in the reverse order. Achievement of the limit changes seems unlikely in view of the preferences which have led to the present auction procedure. However, it is worthwhile experimenting with expanded sale size limits to see what effect the expansion is likely to have on the performance parameters of the model.

4.5.2 Results for the Expansion of Sale Size Limits

The results for increases in the upper sale size limits of 10%, 20%, 30%. and 40% of their present values[5] are summarised in Table 4.6. Table 4.1 indicates minimum lot sizes which could achieve these sale size limit increases.

TABLE 4.6 PARAMETRIC INCREASES IN THE UPPER SALE SIZE LIMITS ONLY

Performance Parameter	PERCENTAGE INCREASE IN UPPER SALE SIZE LIMITS				
	0	10	20	30	40
Pre-Sale Storage ('000 bale-days)	54,066	48,514	46,207	42,193	40,838
Bales Held Over ('000 bale-days)	20,289	13,959	12,193	10,746	10,080
Single:Double Sales	23:16	23:15	24:14	31:9	33:8
Average Evaluation Period (days)	10.58	9.15	8.44	8.45	8.04

Table 4.6 shows that both pre-sale wool storage and bales held over

5. Present values are given in Section 4.2.1. The upper limits are corrected to the nearest thousand bales after percentage increases are made.

decreased with parametric increases in the upper sale size limits. The rate of this decrease, decreased itself, and would probably have approached zero at about 60% increases in the upper limits. However, a 60% increase in the upper limit of single sales takes this limit beyond the lower limit of double sales. At 40% increases the difference between the upper single and lower double sale size limits is only 1,000 bales.

Experimental results in Table 4.6 show that the extent of the reduction in pre-sale storage for a 10% increase in upper sale size limits is very significant, (about 5,000,000 bale-days), compared to pre-sale storage requirements at present sale size limits. About the same saving could be made in bales held over. Results show that the ratio of single to double sales is likely to increase when the upper sale size limits are raised; the reason for this being that the upper single sale limit approaches the lower double sale limit in the experimentation. The average evaluation period decreased in experimentation; the reason being that as the upper sale size limits increase these limits are less often reached, and many sales are rostered with minimal evaluation periods.

In conclusion it appears that any expansion in the feasible range of sale sizes is likely to be beneficial in terms of pre-sale storage and bales held over. This opinion was supported by the finding that the sale size limits tend to be dominant constraints on the system (see Section 4.4.2).

4.6 'Monday' Sales

The two teams of wool buyers are based mainly in Wellington and Christchurch. 'Monday' sales, (first feasible day of week sales), in centres other than Wellington and Christchurch, usually mean that buyers must spend part, or all, of weekends or holidays before the sale, away from home. Consequently, they disfavour such sales. In Chapter III the rosters were adjusted to reduce the incidence of 'Monday' sales wherever possible. This means of adjustment was used, rather than making 'Monday' sales infeasible days in the programme, due to the results obtained in this section.

4.6.1 Results of Runs

Three estimates of performance parameters were made for three programme runs. These runs comprised:

1. all 'Mondays' infeasible,
2. all 'Mondays' other than in Wellington and Christchurch infeasible,
3. hand correction of the run with all 'Mondays' feasible.

The results obtained are summarised below in Table 4.7.

TABLE 4.7 THE RESULTS OF RUNS WITH VARYING RESTIRCTIONS ON 'MONDAY' SALES

Run Number	'Monday' Sales			Pre-Sale Wool Storage +	Bales Held Over +	Single: Double Sales	Av. Evaluation Period (days)
	Wellington	Christchurch	Total Other Centres				
1	0	0	0	64,422	25,388	15:20	11.48
2	3	5	0	62,591	24,465	22:16	11.36
3(a)	3	4	20	54,066	20,289	23:16	10.58
(b)	0	0	6	52,934	22,183	23:16 ǂ	11.08 ǂ

3(a) above is for the programme roster

3(b) above is for adjustments to 3(a) to decrease 'Monday' sales and to roster unsold bales for sale (see Section 3.6.2).

+ '000 bale-days

ǂ corrected only for 'Monday' sale day changes.

From the results in Table 4.7 above it can be seen that prohibiting 'Monday' sales has serious repercussions on the roster. This is due to the fact that in a four day week only two single or one double sale may be rostered, compared to two single, or, a double and a single, when the week comprises five feasible days. Consequently, a lower sale frequency occurs at that period of the year when wool arrivals are greatest. This causes the observed changes in performance parameter values.

4.7 Reducing the Number of Auction Centres

There has been some consideration given to phasing out various centres and having their wool transported to, and sold at, other centres. A run was performed in which it was assumed that the Wanganui wool was sold at Wellington, and the Timaru wool at Christchurch; Wanganui and Timaru being the least important centres insofar as total seasonal wool arrivals are concerned. The main argument for phasing out smaller centres lies in the long term economics of providing storage and processing facilities at wool stores.

4.7.1 Results of the Run for Less Centres

Table 4.8 below gives the results of the run. Wanganui and Timaru phased out, (run 2) as compared to the normal run for the experimental year data (run 1).

TABLE 4.8 PERFORMANCE WITH LESS CENTRES

PERFORMANCE PARAMETER	RUN 1	RUN 2
Pre-Sale Wool Storage ('000 bale-days)	54,066	66,498
Bales Held Over ('000 bale-days)	20,289	37,180
Single : Double Sales	23:16	15:20
Average Evaluation Period (days)	10.48	12.31
Storage Christchurch ('000 bale-days)	7,880	14,146
Storage Timaru ('000 bale-days)	2,806	0
Storage Wellington ('000 bale-days)	5,624	16,670
Storage Wanganui ('000 bale-days)	6,071	0

From Table 4.8 it can be seen that reducing the number of centres lowers the single to double sales ratio, and increases pre-sale wool storage and bales held over to a considerable extent. The reason for these results appears to be due to exponential increases in storage and bales held over, with increasing arrivals, in a centre. A 40% increase in arrivals at Christchurch practically doubled storage of wool there; a 79% increase in arrivals at Wellington tripled storage in that centre.

In terms of the performance parameters of the model it appears undesirable to reduce the number of selling centres. Before such a policy could be implemented, the short term economic implications of the model's performance parameters would have to be weighed against the long term economies involved in reducing the number of centres.

The results obtained assume unchanging restrictions on the system. If the combination of centres could be achieved with reductions in the between sale within centre restrictions, then the situation could be somewhat different. This new situation would only result if enlarged centres showed great time economies in terms of wool handling.

4.8 An Even Rate of Sale of Wool

In considering the demand for wool at auction, an even rate of sale of wool (per week, per month or per quarter) appears conceptually advantageous. The extent of this advantage depends on the price elasticity of demand for wool at auction; the lower the elasticity the greater the advantage. In Section 2.1.4 it was proposed that the demand for wool could not be included as a factor effecting the roster format. The reasons for this exclusion were the inability to estimate the price elasticity of demand for wool at auction, and, the observation that this elasticity is probably high; therefore, the demand aspect at auction is not so important (as if the elasticity were low).

To estimate the effects of rostering for a more even rate of sale on the performance parameters of the model, a run was carried out in which single sales only were rostered.[6] In so doing, it was expected that wool sales would be rostered in each centre in a cyclical pattern. This cyclical pattern would probably result in a fairly even selling density (say on a monthly basis) for wool.

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6. This was achieved by turning sense switch 2 off for the run (see Section 3.5.4).

The results of rostering all single sales were expected to show increases in pre-sale storage and bales held over (especially), and a higher average evaluation period. Only single sales would be rostered but probably less auction days would be involved, as most of the sales would be of 28,000 bales.[7]

4.8.1 Results for a Run Rostering All Single Sales

Table 4.9 below gives the performance parameter values for the run with all single sales, and the normal run (single and double sales).

TABLE 4.9 RESULTS FOR A MORE EVEN MONTHLY SALE RATE.

Performance Parameter	All Single Sales	Single & Double Sales
Pre-Sale Storage ('000 bale-days)	61,014	54,066
Bales Held Over ('000 bale-days)	34,742	20,289
Single:Double Sales Ratio	51:0	23:16
Total Auction Days	51	55
Average Evaluation Period (days)	11.58	10.58

In Table 4.9 above it is seen that the pre-sale storage and bales held over performance parameters are adversely effected by rostering all single sales. The reason for this is that wool builds up rapidly in the larger centres from December to March, and when single sales only are rostered large amounts of wool must be carried over from sale to sale in these centres. This involves more storage and a far higher amount of held over wool. The average evaluation period is shown to be higher in Table 4.9 for when the programme rosters

7. The maximum number of bales that can be sold on one auction day of a double sale is assumed to be 25,000 bales. i.e. half of the 50,000 bale upper double sale size limit.

all single sales. This is due to the upper single sale size limit being reached before the between sale time constraints are fulfilled.

Less auction days were involved in the all single sales roster (see Table 4.9). The average sale size for the single sales roster was 26,160 bales whereas the normal roster sold an average of 24,420 bales per auction day.

The degree to which an even rate of sale was achieved by rostering all single sales is indicated in Figure 4.1 below.

FIGURE 4.1 ROSTERING FOR AN EVEN RATE OF SALE

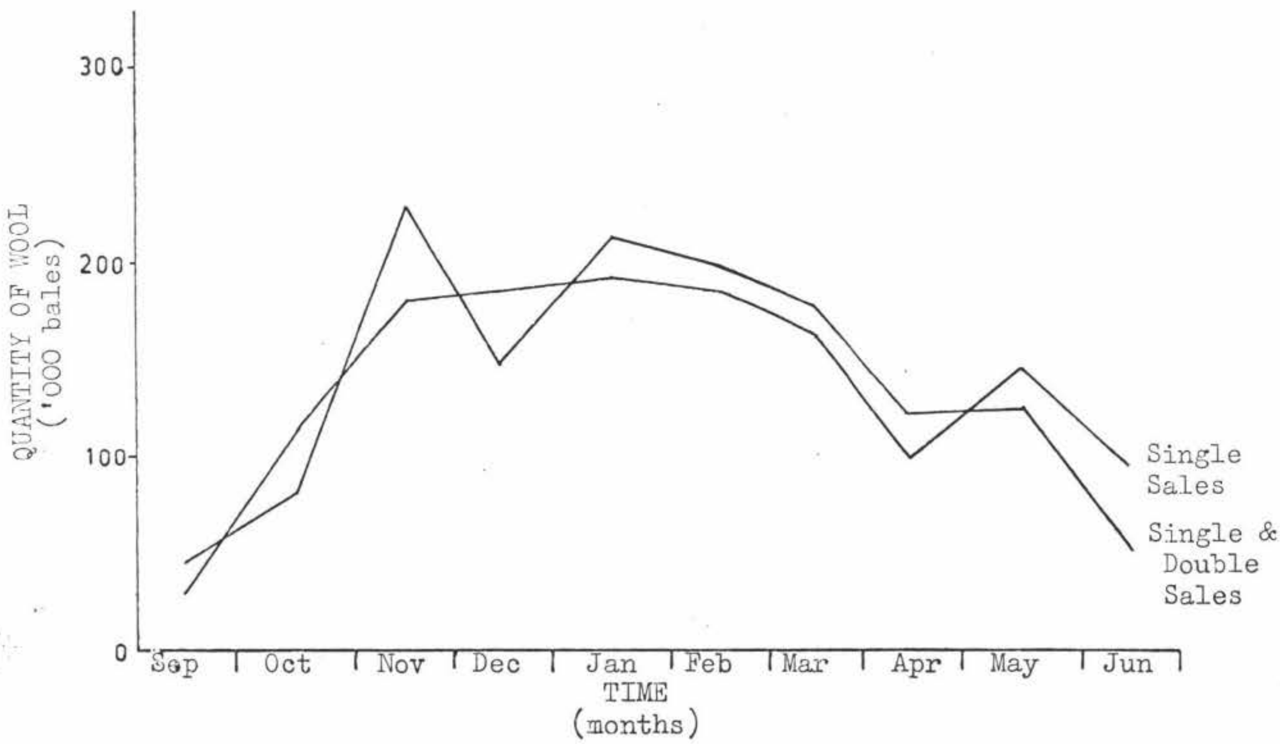

Figure 4.1 above indicates the monthly selling density for the two rosters being compared. It shows that the roster with all single sales approximated an even rate of sale much more closely than the other roster. Approximately twenty eight day cycles of single sales were rostered in the major centres when all single sales were rostered. Considerable quantities of wool had to be carried over in these centres during the first quarter of the second year of the season.

In conclusion it appears that the roster format would need to effect wool prices significantly before the format was changed to give a more even rate of sale of wool. Considerably more wool is held over when attempts are made to roster for an even selling density due the pattern of seasonal wool arrivals.

4.9 Experimentation with Different In-To-Store Arrivals Estimates

Due to changing levels of wool being available for auction in different seasons, it was felt necessary to experiment with different wool arrivals estimates in order to establish whether or not the trends found in performance parameter values remained consistent. The amount of wool for auction varies seasonally due to both seasonal fluctuations and trends. At present the trend in total arrivals for auction is a downward one due to a levelling in production and increased private selling. Consequently, the data used for this experimentation was the "Weighted Average" data set (see Section 3.2.1) for wool arrivals; this data being the lowest estimate of wool arrivals made. The infeasible day constraints used were the same as for other experimentation done in this Chapter.

The number of runs that could be carried out were limited by computer costs. It was decided that experimentation would involve one run across, and one run down, the experimental matrix given in Section 4.4.

4.9.1 Results for Experimentation Using Lower In-To-Store Arrivals Data

Table 4.10 below gives the results for comparable runs made for two different wool arrivals estimates. The results for run 1 in the Table are based on expected arrivals of 1,415,000 bales; run 2 involves 1,327,000 bales. This constitutes a difference of 6.2% between the two estimates.

TABLE 4.10 RESULTS FOR DIFFERENT WOOL ARRIVALS ESTIMATES

Normal Sale Size Limits and Varying Between Sale Within Centre Constraints

Performance Parameter		Percentage Change in Between Sale Within Centre Constraints				
		-20	-10	0	+10	+20
Pre-Sale Storage	1	43,104	53,836	54,066	59,300	68,479
('000 bale-days)	2	41,131	49,665	52,082	53,418	62,233
Bales Held Over	1	15,095	17,694	20,289	26,171	28,915
('000 bale-days)	2	12,701	15,742	18,233	20,967	26,281
Single:Double Sales	1	32:13	23:16	23:16	25:15	14:20
	2	34:10	25:14	26:13	26:13	18:17
Average Evaluation	1	9.48	10.51	10.58	10.72	10.35
Period (days)	2	9.70	9.94	10.76	10.89	10.82

Normal Between Sale Within Centre Restrictions and Varying Sale Size Limits

Performance Parameter		Percentage Increase in Sale Size Limits						
		0	10	20	30	40	50	60
Pre-Sale Storage	1	54,066	49,040	47,730	48,290	47,987	47,577	49,523
('000 bale-days)	2	52,082	43,857	43,432	45,768	48,217	46,034	48,936
Bales Held Over	1	20,289	14,678	12,942	14,132	10,867	11,420	9,931
('000 bale-days)	2	18,233	13,136	11,344	11,984	9,679	8,502	7,643
Single:Double Sales	1	23:16	23:14	25:11	32:5	28:6	30:4	27:4
	2	26:13	28:11	32:6	32:4	25:6	26:5	26:3
Average Evaluation	1	10.58	9.21	9.41	9.10	8.41	8.29	8.19
Period (days)	2	10.76	9.20	9.34	9.69	9.00	8.58	8.68

1. :- Experimental Data

2. :- "Weighted Average" Data

Table 4.10 shows fairly consistent trends in storage for parametric changes in sale size and between sale within centre restrictions. The difference in trends between the two sets of data appears to be insignificant. It would be expected that minimum storage using the "Weighted Average" data, would occur at lesser sale size limit levels, than for the experimental data; this expectation being based on the hypothesis that at lower levels of wool arrivals, upper sale size limits should be less restrictive. This hypothesis is supported by the results obtained. Consequently, policy suggestions when wool for auction is likely to decrease, would involve lowering the suggested extent to which sale size limits should be raised (to lower pre-sale wool storage). At normal between sale within centre restriction values the relevant policy suggestion would be to increase sale size limits by 20% to 30%, (if expected arrivals approximated the "Weighted Average" estimates), rather than by 30% to 40% as based on the experimental data results.

The trends in bales held over, resulting from parametric changes in sale size and between sale within centre restrictions, are consistent in Table 4.10 for the two sets of data. The absolute value of the performance parameter, in comparable rosters, is lower for the "Weighted Average" data than for the experimental year data. This is expected due to the lesser quantity of wool involved.

The single to double sale ratio is higher (in Table 4.10) for comparable rosters made on lower wool arrivals estimates. Trends in the ratio remain consistent with those established using the experimental year data. (See Section 4.4).

Table 4.10 shows little disparity between the average evaluation periods resulting from using different wool arrivals data estimates. On the whole the average period shows a tendency to be inversely related to the quantity of wool auctioned (over the season). This inverse relationship probably results from the comparatively greater number of single sales rostered when wool arrivals are lowered. When more sales are rostered the between sale within centre restrictions become more effective. As explained in Section 4.8.1 this could raise the average evaluation period. However, this inverse relationship is probably insignificant.

In conclusion it appears that altering the total bales rostered for each sale has little effect on the performance parameters of the model. Trends would appear to remain consistent. Because of this consistency in trends for the runs studied, and because of computer time restrictions runs over other parts of the experimental matrix were not considered necessary.

Experimentation in this section is significant with regard to policy recommendations made on the basis of previous experimentation with the model. The trends in performance parameter values established earlier appear insensitive to decreases (6.2%) in wool arrivals for auction. Policy recommendations would appear to hold over a range of in-to-store arrivals estimates.

4.10 Experimentation with the NETT : 100 Decision Rule

The experimentation done previously in this Chapter was for the NETT : 0 decision rule (see Section 3.5.4).[8] In Chapter III (Section 3.6.1) it was shown that experimentation with varying values for the NETT decision variable give different roster formats. To check the consistency of performance parameter trends under varying values for the NETT decision variable further runs across and down the experimental matrix were carried out. The runs carried out used the experimental year data with a NETT : 100 decision rule. The areas of the matrix looked at were the same as in Section 4.9.

It was expected that the trends in performance parameter values established in Sections 4.2 and 4.3 would remain consistent for experimentation

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8. Raising the value of the single/double decision rule (from NETT : 0, NETT : 100,...) has the effect of phasing out double sales which were marginal with respect to this decision procedure.

with the NETT : 100 decision rule. For increases in the sale size limits these trends were:

- i. pre-sale storage decreases initially then increases,
- ii. bales held over decreases,
- iii. the single : double sales ratio increases,
- iv. the average evaluation period decreases.

The trends in performance parameter values when the between sale within centre restrictions were raised (from -20% of their values) were:

- i. pre-sale storage increases,
- ii. bales held over increases,
- iii. the single : double sales ratio decreases,
- iv. the average evaluation period increases.

Hypotheses based on experimentation in Section 3.6.1 can be proposed for the NETT : 100 rosters, compared to their NETT : 0 counterparts. The hypotheses are that lower pre-sale storage, bales held over, and average evaluation periods, with higher single : double sales ratios, would be found in the NETT : 100 rosters. However, these hypotheses are based on results obtained at present levels of restrictions; the hypotheses may not hold when restrictions are varied.

4.10.1 Results for NETT : 100 and NETT : 0 Runs

Table 4.11 below gives the results for experiments with NETT : 100 and NETT : 0 runs over part of the experimental matrix.

TABLE 4.11 EXPERIMENTAL RESULTS FOR NETT:0 AND NETT:100 DECISION RULES

Normal Sale Size Limits and Varying Between Sale Within Centre Restrictions

Performance Parameter		Percentage Change in Within Centre Restrictions				
		-20	-10	0	+10	+20
Pre-Sale Storage	NETT:0	43,104	53,836	54,066	59,300	68,479
('000 bale-days)	NETT:100	43,104	50,264	49,976	58,780	67,206
Bales Held Over	NETT:0	15,095	17,694	20,289	26,171	28,915
('000 bale-days)	NETT:100	15,095	17,287	19,766	26,377	31,362
Single:Double	NETT:0	32:13	23:16	23:16	25:15	14:20
Sales	NETT:100	32:13	25:15	32:12	27:14	22:16
Average Eval-	NETT:0	9.48	10.51	10.58	10.72	10.35
uation Period (days)	NETT:100	9.48	9.80	9.84	10.87	11.28

Normal Between Sale Within Centre Restrictions and Varying Sale Size Limits

Performance Parameter		Percentage Increase in Sale Size Limits						
		0	10	20	30	40	50	60
Pre-Sale Storage	NETT:0	54,066	49,040	47,730	48,290	47,987	47,577	49,523
('000 bale-days)	NETT:100	49,976	47,981	50,441	48,290	48,055	47,577	50,355
Bales Held Over	NETT:0	20,289	14,678	12,942	14,132	10,867	11,420	9,931
('000 bale-days)	NETT:100	19,766	16,530	15,487	14,132	11,127	11,420	10,521
Single:Double	NETT:0	23:16	23:14	25:11	32:5	28:6	30:4	27:4
Sales	NETT:100	32:12	31:10	30:7	32:5	29:5	30:4	29:2
Average Eval-	NETT:0	10.58	9.21	9.41	9.10	8.41	8.29	8.19
uation Period (days)	NETT:100	9.84	9.48	9.54	9.10	8.73	8.29	8.16

Table 4.11 indicates that the trends in performance parameter values are consistent for both decision rules. The reasons for these trends are explained in Section 4.2 and 4.3, where corresponding results for the NETT : 0 decision rule are presented and explained.

The hypotheses made in the previous section, which were based on experimentation carried out in Section 3.6.1, are not all supported by the results in Table 4.11. The hypothesis that the NETT : 100 rosters would have higher single : double sales ratios (than their NETT : 0 counterparts) is supported by the results. Bales held over is greater in many of the NETT : 100 runs than expected, as is pre-sale storage and the average evaluation period: these results are opposite to what was stated in the hypotheses. Table 4.11 shows that these hypotheses appear to be incorrect at higher levels of the sale size and between sale within centre restrictions. Reasons why the hypotheses are incorrect are given in the following paragraphs.

At higher levels of the between sale within centre restrictions, wool which is held over must await sale longer. When a higher proportion of single sales are rostered more bales of wool are likely to be held over. Consequently, the bales held over performance parameter measure increases, at higher levels of the between sale within centre restrictions, for the NETT : 100 decision rule (which rosters a higher proportion of single sales than the NETT : 0 decision rule). Pre-sale storage increases also as it comprises, in part, bales held over. The average evaluation period increases as upper single sale size limits are more often reached, and it takes longer for the between sale within centre restrictions to be fulfilled.

When the sale size limits are raised double sales dispose of large proportions of wool arrivals at individual sales. Reducing the number of double sales (raising the single : double sales ratio) lowers the rate of wool disposal. Consequently, pre-sale storage increases. Single Sales are usually associated with more bales of wool being held over; this tends to increase the extent of bales held over. The average evaluation period is likely to increase when a higher proportion of single sales are held as the upper single sale size limit is likely to be reached before the between sale within centre constraints are fulfilled. The differences in performance parameter values become less at higher levels of the sale size limits (30%....60% increases) as the upper single sale size limit becomes less restrictive.

Divergence of these results from what was expected (based on hypotheses postulated from results obtained in Section 3.6.1) is unimportant insofar as policy recommendations (based on experimentation with the model) are concerned as trends in performance parameter values remained consistent. The results in this section merely support previous statements which argued that a number of rosters should be derived, using different decision rules, for each set of data and restrictions operative for a particular auction season, to provide the roster makers with a range of rosters for the season concerned, (see Section 1.5 and 1.6).

4.11 Non-Conforming Rosters

Throughout the experimentation odd rosters show performance parameter values which are inconsistent with the trends indicated. The reason for inconsistent results lies in complex interactions between the sale size and time constraints, coupled with large proportions of wool being sold at each auction sale. If similar runs were conducted using a range of wool arrivals estimates these inconsistencies would probably average out to give reasonably smooth trends.

The experimentation conducted in Sections 4.9 and 4.10 was aimed at establishing whether the trends hypothesised were supported by results obtained from a different wool arrivals estimate, and a different decision rule. The hypotheses on performance parameter trends were supported by this experimentation. Consequently, it was felt that non-conforming rosters were merely fluctuations about the trends, and were unimportant insofar as policy recommendations (made on the basis of experimentation with the model), were concerned. The fact that these fluctuations do occur indicate that a range of rosters should be produced about any point on the experimental matrix. Furthermore, a range of rosters should be prepared if the model is used to prepare roster bases for the Wool Auction Sales Committee.

4.12 Summary

The results and observations made in this Chapter are based on a small sample of rosters. The objective was to find trends, or directional changes in performance parameters, when the rostering constraints underwent changes. The trends established by the model are summarised below.[9] Unless stated otherwise (see 2. below) the trends summarised assume comparisons with the roster based on present levels of all restrictions (Section 4.2).

1. Increasing Sale Size Limits (Section 4.2):

   Pre-sale storage decreases (for 10%,....40% increases in the limits), then increases (40% upwards increases in the limits).

   Bales held over decreases

   Average evaluation period decreases

   Single : double sales ratio increases

2. Increasing Between Sale Within Centre Restrictions (Section 4.3): (from -20% to +20% of present values).

   Pre-sale storage increases

   Bales held over increases

   Average evaluation period increases

   Single : double sales ratio decreases

3. Increasing the Upper Sale Size Limits (Section 4.5):

   Pre-sale storage decreases

   Bales held over decreases

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9. The results obtained in Section 4.4 are not summarised due to the complexity of doing so.

Average evaluation period decreases

Single : double sales ratio increases

4. Prohibiting 'Monday' Sales (Section 4.6):

Pre-sale storage increases

Bales held over increases

Average evaluation period increases

Single : double sales ratio decreases (slightly)

5. Reducing the Number of Auction Centres (Section 4.7):

Pre - sale storage increases

Bales held over increases

Average evaluation period increases

Single : double sales ratio decreases

6. Rostering for an Even Rate of Sale (Section 4.8):

Pre-sale storage increases

Bales held over increases

Average evaluation period increases

Single : double sales ratio increases

The trends summarised show relationships between the performance parameters of the model. The pre-sale storage, bales held over, and average evaluation period parameters are generally complementary to one another; they are usually competitive with regard to the single : double sales ratio performance parameter (assuming a lower single : double sales ratio is desirable as it involves less sales generally). Explanations throughout this Chapter indicate that the factors contributing to these relationships between performance parameters vary in importance according to the conditions operating for each run.

CHAPTER V

CONCLUSIONS

5.1 Approximations and Model Validation

Model validation in terms of the wool rostering problem, has two facets. These involve validation in terms of the feasibility of rosters with regard to real world constraints, and validation in terms of the performance or desirability of model generated rosters for practical use.

5.1.1 Approximations in the Model

The most important approximations in the model are concerned with:

i. weekly increments for in-to-store arrivals estimates,

ii. non-work days partially fulfilling the time constraints,

iii. approximation to the nearest thousand bales.

It has been argued that the approximation of weekly increments for in-to-store wool arrivals was made as interpolation within weeks to obtain daily increments added little in terms of accuracy. The distribution of arrivals over the week is probably random (except for Sundays, where a zero arrivals situation is generally the rule). Using a process which provided within week randomness for arrivals could give shifts in the timing of sales. The question is whether randomisation of within week arrivals would give better rosters in terms of the real world situation. If the within week arrivals are random fractions of the total arrivals for that week then the answer is no; randomisation of within week arrivals would add nothing in terms of accuracy of rosters. If, however, the within week arrivals follow some sort of definable distribution then appropriate data could, and should, be inputted on a daily basis to increase the accuracy of rosters.

The approximation of weekly increments for in-to-store arrivals estimates is not important due to present difficulties in estimating seasonal wool arrivals for auction. If variability in these estimates could be removed then this approximation should be removed from the model.

The time constraints between sales are in part fulfilled by infeasible sale days. Some of these days are also infeasible work days at wool stores. The fact that distinction between feasible and infeasible work days was not made in the model is not too serious as there is flexibility in labour use in wool stores (i.e. through overtime). Statutory holidays should be prohibited from fulfilling the time constraints for greater model realism. However, the rosters produced provide some flexibility in the timing of sales. Consequently a correction for those few cases where it is felt sales are too close together could be carried out to overcome this problem.

The model approximates wool arrivals (and sales) to the nearest thousand bales; i.e. wool inputs are in thousand bale increments. This approximation was made due to the inability to estimate wool arrivals more accurately. Little loss of realism of the model results from this approximation. If more accurate means of estimating seasonal wool arrivals become available then conversion of the model to include this greater accuracy would be desirable. This conversion of the programme would be simple as it would involve mainly format changes.

5.1.2 Model Validation with Regard to Restrictions

The realism of the model, in terms of rostering restrictions, is of a high degree. The restrictions included in the model are virtually exhaustive; they are strictly enforced (compared to enforcement by the Wool Auction Sales Committee). As indicated in Chapter III the restrictions used were given by the New Zealand Wool Board; they are regarded (by the Wool Auction Sales Committee) as desirable rather than mandatory. When constraints are transgressed then undesirable features such as peak handling periods, overtime, and small sale sizes are likely to result.

Some of the restrictions included in the model may be regarded as unnecessary, especially those regarding the infeasible sale days (including

Anniversaries, public holidays etc.). Most of the trivial constraints included added little to model complexity but contributed to the realism of the model.

5.1.3 Performance of Model Generated Rosters

In Chapter III it was shown that the programme could generate rosters as well as, or better than, the Wool Auction Sales Committee's roster in terms of pre-sale wool storage and bales held over, two of the most important performance parameters of the system. Furthermore the time constraints are not violated by the models rosters; therefore this source of peak handling periods in wool stores is likely to be suppressed more than in the case of the actual roster.

Throughout this Thesis little has been said about the wool demand aspect. The reason for this is that conclusive econometric findings on wool demand are scarce. Because of the paucity and inadequacy of information on the demand for raw wool at auction, performance parameters and decision processes including the demand aspect were excluded from the model. This exclusion is unimportant if the price elasticity of demand for raw wool at auction is very elastic (as wool prices would be neglibibly effected by the quantity of wool offered for auction at individual sales). The model attempts to roster so as to maximize the rate of sale of wool possible over the season, i.e. to sell wool as soon as possible. If it is felt that this objective is detrimental with regard to wool prices, and the New Zealand wool industry, then the usefulness of the model depends on whether either:

i. model generated rosters with a higher single : double sales ratio would be satisfactory.[1]

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1. Lowering the rate of sale of wool (e.g. on a monthly basis) could be achieved by rostering many single sales (using the NETT criterion) and letting the between sale within centre restrictions spread out sales and thus stabilise the selling density. Raising the between sale within centre restrictions and lowering the sale size limits could further this process (when applied with a high NETT value or with sense switch 2 off).

or ii. the decision processes in the model can be altered to be heuristic with regard to performance parameters determined by demand while retaining the basic framework of the model.

Unless a very accurate procedure for measuring expected demand schedules for wool sold at auction was developed then method ii. above would not be worthwhile implementing. Manipulation of the programme, via the NETT criterion and restriction values, would probably suffice to provide the Wool Auction Sales Committee with bases to aid rostering.

5.2 Real World Applicability of Model Generated Rosters

In Chapter III rosters for the 1971/72 season are generated and compared with the actual roster for this season. The roster derived from the "Corrected Average" data shows a pattern of sales similar to that of the actual roster, indicating that the decision processes of the roster makers and the model are not dissimilar.

The major difference between model generated rosters and the actual roster are in the numbers of single and double sales rostered. In attempting to decrease pre-sale wool storage and bales held over the model sells as much wool as possible as soon as possible. When it appears beneficial (for pre-sale storage) to wait until a double sale can be held then the model rosters accordingly; this situation presents itself more often to the model than it does to the roster makers. Presumably factors other than pre-sale wool storage cause this difference in roster formats.

By manipulation of the model it would be possible to generate a roster more closely approximating the actual roster. For example, the actual roster for 1971/72 has no double sales with more than 48,000 bales rosters. The double sale size upper limit could be decreased to this amount.[2] Double Sales

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2. Doing so would decrease the NETT value for double sales rostering over 48,000 bales and may result in a single rather than double sale being rostered.

could be decreased in number by raising the lower sale size limit for double sales or by raising the NETT criterion value. Best use of the programme would be made if a number of runs were carried out for various manipulations of parameter values and decision processes in the model. This would provide the roster makers with a number of bases on which to decide the final roster.

Apart from the flexibility aspects of the model, giving it the capability of producing a range of rosters, there is its performance parameter measurement property. By studying the performance parameter and roster print-out (see example in Appendix C2) opinions on likely demands on wool brokers stores, and the selling density for wool, may be formed. The model prints out total cumulative arrivals, bales in store, and sale size rostered (if applicable) at weekly intervals (and for each sale day) for each centre. By studying these weekly figures brokers would be able to obtain a good idea of their organisational requirements over the season. For example, the nature of arrivals between sales, and the sizes of sales, indicate when peak handling periods are likely to occur in brokers stores. Brokers would receive an idea of how many bales they may have to carry over, of how long they may have between the closing and sale dates for a sale. The selling density (per week, month or quarter etc.,) can be obtained by adding the sale sizes over each period. However, the value of the roster print-out depends on estimates of seasonal wool arrivals being accurate.

The implications of rosters can be studied in basis providing, and, final rosters. From the most favourable basis rosters, (with regard to performance parameters and format implications), final rosters could be prepared for final consideration by the Wool Auction Sales Committee.

With regard to the implications and performance of rosters it is important to realise that the rosters are only useful if the data they are based on is realistic. At present some degree of overrostering occurs, i.e. wool rosters formulated by the Wool Auction Sales Committee appear to roster more wool for sale than is likely to be available. The main reason behind overrostering is that it provides wool brokers some flexibility in organising wool for sale. Overrostering allows brokers to include extra bales in sales when actual arrivals outnumber expected arrivals. Furthermore, overrostering provides the Wool Commission more flexibility to offer stockpile wool at sales.

Retaining overrostering in the model could be achieved by two means. Firstly, the expected wool arrivals data could be inflated (by the means used in Chapter III for the "Corrected Average" roster). Secondly, the sale size limits could be lowered (proportionately) for the run, and then inflated for the final roster. Which of these methods is desirable depends on which is acceptable to the roster makers. If overrostering is to continue, and the model is to be used, then one (or both) of the methods must be adopted.

5.3 Experimentation With the Model

In terms of the performance parameters measured by the model experimentation has produced some important results. The importance of the results is indicated by the extent of shifts in performance measures for different experimental runs. As indicated earlier the experimental results obtained are not quantitatively accurate. Further experimentation around defined areas of restriction and input values would be required before accurate quantitative changes in performance could be proposed with a high degree of accuracy.

5.3.1 Results

Proportionate across the board increases in sale size limits are likely to decrease total pre-sale wool storage and the extent of bales held over, provided (for storage) the increases are not too great. Increases of the order 20% - 40% on present limits would be desirable with regard to these two performance parameters. Increases in sale size limits could be achieved by introducing a minimum lot size scheme whereby the minimum lot size was made six or more bales. Introduction of such a scheme should meet with little resistance from any sector of the wool industry.

The between sale within centre time restrictions are severe restrictions on the system. Pre-sale wool storage and bales held over would decrease significantly with decreases in these constraints. To achieve such decreases in the constraints some new technology or practice, such as sale by sample and dense baling, would need to be introduced (unless wool stores could economically increase their efficiency as measured by the rate of throughput of wool). Increases in the between sale within centre restrictions are detrimental with regard to pre-sale wool storage and bales held over.

For simultaneous changes in both the sale size limits and between sale within centre restrictions, the effect on performance parameter values depends on the extent and direction of these changes. If the between sale within centre restrictions could be decreased then little advantage would result if the sale size limits were increased (in terms of wool storage). If the between sale within centre restrictions were to increase then serious thought could be given to increasing the sale size limits as this would tend to minimize resulting storage increases. Reversing the argument, if sale size limits were raised then there would be little advantage in attempting to decrease the between sale within centre restrictions. If, however, sale size limits were reduced then lower between sale within centre restrictions would be very desirable with regard to pre-sale wool storage and bales held over. When consideration is given to changing one of these two restrictions, the effect of that change on the other restriction must be considered; the joint effects of these changes will determine the performance of the system.

Increasing only the upper sale size limits has beneficial effects on pre-sale wool storage and bales held over parameters. This would be expected for any changes which widened the feasible sale size range without increasing the lower, or decreasing the upper, limits. Unless changes in the auction procedure were to be introduced then the probability of implementing such changes in sale size restrictions is low.

Reducing the number of auction centres has undesirable repercussions in terms of the performance parameters of the model. Unless either the long term economies of decreasing the number of auction centres are very favourable, or the decrease can be accompanied by compensatory changes in the levels of restrictions, then reducing the number of auction centres would be undesirable.

Rostering to even out the rate of sale of wool (on a monthly or quarterly basis) has heavy costs in terms of increased storage and bales held over. Before attempting to reduce or stabilise the monthly selling density for wool, more should be known about the demand for raw wool at auction. If more accurate information on raw wool demand was available then the economic balance could be found between the costs of holding wool and the return from holding wool (due to increases in wool prices).

Increasing the rostered period may be desirable in the light of better knowledge of the demand for raw wool at auction (if this knowledge suggested that extending the rostered period could be economically beneficial). In terms of the main performance parameters of the model an increase in the rostered period would be of no advantage.

The conclusions drawn from experimentation with the model appeared to hold for different wool arrivals estimates and decision rules for the single/double decision procedure. Consequently policy recommendations made on the basis of findings in the study should hold over a range of conditions within the industry.

5.4 Value of the Study

The value of the study depends on whether the auction system is retained in its present form. In Chapter I it was indicated that the future of the auction system (and roster) depends very much on the policies followed by the New Zealand Wool Marketing Corporation.

At present the major difficulty in rostering wool sales is in obtaining accurate estimates of seasonal wool arrivals for auction. Forecasting arrivals is very difficult at present due to fluctuations caused by private sales. Unless forecasting techniques can be improved the potential of the model as an aid to rostering is very restricted.

If the roster is retained in its present form, and the forecasting of wool arrivals improves, then the value of the study hinges on demand aspects for wool sold at auction. In the light of future knowledge demand may become important in determining roster formats. However, present knowledge does not point to demand as being important in the roster; the exclusion of demand aspects from this model of the roster system should not detract from the value of the study.

In conclusion the immediate threat to the value of the study lies in the problem of forecasting wool arrivals for auction. If the forecasting problem can be resolved then the policies decided by the Wool Marketing Corporation will determine the future value of the study.

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APPENDIX A

THE COMPUTER PROGRAMME

The programme was written in FORTRAN II to be run on an IBM 1620 computer with disk storage.

Wool inputs and outputs are approximated to the nearest 1000 bales. The pre-sale storage and bales held over performance parameters have '000 bale-day units of measurement.

APPENDIX A1 ALPHABETIC LISTING OF VARIABLES

AVAR(J)	floating point conversion for total possible storage.
BVAR(J)	floating point conversion for bales held over.
CFACT(J)	multiplication factors to alter data input estimates for wool arrivals.
CNB(J)	floating point conversion for cumulative wool arrivals.
DBH(J)	bales held over as a percentage of total possible storage.
DNAC(J)	floating point conversion for sums of evaluation periods.
DNOC	floating point conversion for total sum of evaluation periods.
DNOM(J)	floating point conversion for sale numbers.
DNUM	floating point conversion for total number of sales.
DOY(M)	days of week (alphameric).
DVAR(J)	floating point conversion for storage removed due to sales.
EVAR(J)	floating point conversion for net storage.
FMTS	total storage removed due to sales.
FNBL	sum of bales not rostered for sale.
FNTB	total number of bales that arrived over the season.
FVAR(J)	floating point conversion for unrostered bales.
GVAR(J)	floating point conversion for total bale arrivals.
I	day identification
IELD	day identification used to estimate the evaluation period.
IHOLD(J)	future day identification used to enforce the between sale within centre restrictions.
IL	first day of week (I value). Used to input data.
ILOW	day identification used to enforce between sale within centre restrictions.
IMAX	length of the selling season in days.
IOLD	variable to hold present I value when I is to be varied within a stage (day).
IU	last day of week (I value). Used to input data.

IUPR	day identification used to enforce between sale within centre restrictions.
J	wool auction centre identification.
JHOLD	holding value for J when other J values are being used.
JLOWN	within Island centre identification used for between sale between centre restrictions.
JLOWS	within Island centre identification used for between sale between centre restrictions.
JMON(J)	stores the number of 'Monday' sales in each centre.
JOLD	centre identification used mainly for sense switch 3 option.
JUPRN, JUPRS	within Island centre identifications used for between sale between centre restrictions.
K	season identification.
KDATE	date of month.
KL	the minimum closing to sale date period.
L	used to enforce between sale between centre restrictions.
LAD	minimum period between sales between centres in the same Island when sale rostered is a double one.
LAS	as for LAD but for a single sale.
LMAX	a value of LAD or LAS depending on sale type rostered.
LS	minimum period until a single sale can be rostered (in some centre). Used in between sale within centre restriotions.
LSD(J)	path control variable. Control returns to different parts of the programme depending on the value of LSD(J).
M	week day identification.
MC(J)	feasible day identification within centres.
MFACT	multiplication factor used to estimate bales held over and storage.
MNTH	month.
MOND	identification variable used to give the value of M.
MRS(J)	net storage in centre J.

MSR(J)	storage removed due to sales in centre J.
MSTR	storage removed due to a sale.
MSUM	sum of 'Monday' sales.
MUN(I)	feasibility (general) identification for days.
N(K)	disk track identification.
NAC(J)	sum of evaluation periods in centre J.
NAH	bale numbers; used to establish centre priorities for a sale.
NB(J)	cumulative wool arrivals in centres.
NBA(J)	number of bales previously rostered for sale in centre J at that stage of the programme.
NBALES	number of bales; used to establish the number of days until a double sale can be rostered in some centre.
NBH(J)	number of bales held over (weighted) in centre J.
NBHO	weighted bales held over from last sale until this one.
NBO(J)	unrostered bales in centre J (unsold bales).
NBR	additional days involved in the between sale within centre restrictions when the sale considered is a double one.
NBS(J)	the number of bales sold in the previous sale in centre J.
NCLOSE	the evaluation period of the sale just rostered.
NDC(J)	as above within centres.
NDD(J)	the double - double between sale within centre restrictions.
NDIFF	the difference between the upper sale size limits for single and double sales.
NDL	the lower sale size limit for double sales.
NDS(J)	the double - single between sale within centre restriction.
NDU	the upper sale size limit for double sales.
NETT	net storage saved if a double sale in the future is rostered rather than a single sale now.
NGAIN	gain in storage from rostering a double sale in the future.
NH(J)	the number of bales held over from a sale.

NI(J)	holding value for I when a sale is rostered so as weighted bales held over can be calculated in the future.
NK	disk track identification.
NLOSS	loss in storage from rostering a double sale in the future.
NOC	sum of evaluation periods.
NOM(J)	total sales in centres.
NOMD(J)	total double sales in centres.
NOMS(J)	total single sales in centres.
NOVER	bales that cannot be sold now but could be sold in a double sale in the near future.
NSD(J)	the single-double between sale within centre restrictions.
NSELL	number of bales sold in a sale.
NSL	lower sale size limit for single sales.
NSOLD(J)	number sold in a sale just rostered.
NSS(J)	the single - single between sale within centre restrictions.
NST(J)	bales that can be sold in a centre, and/or the number rostered for sale. Bales in store (output).
NSU	upper sale size limit for single sales.
NTS(J)	total possible storage in centres (assuming no wool was sold over the season).
NUM	total sales.
NUMD	total double sales.
NUMS	total single sales.
NWAIT	period before a double sale can be held when a single sale can be held now.
NYRF	first year of season being rostered.
NYRS	second year of season being rostered.
PAT	percentage of total storage removed by sales.
PHB	bales held over as a percentage of total storage.
PMOS	total net storage.

PNHO	total bales held over (weighted).
PNOS	total possible storage.
PST(J)	storage removed as a percent of total storage.
SOLD	total bales rostered for sale.

APPENDIX A2 DISKIM

This is the input programme for cumulative weekly wool arrivals and general feasible and infeasible days of the season for each centre.

Season length input is of 297 days from the 5th September to the 27th June or 28th June; the former if the second year rostered is a leap year.

Inputs (to disk) day of week identification number, date and month for each day of the season.

With sense switch 3 on DISKIM prints a listing of all data inputs to disk storage.

Data card order:

k = 2 for when second year of season is a leap year, otherwise
k = 1....5, k $\neq$ 2 (depending on disk capacity).

CFACT(J)...correction factors for arrivals data if corrections are desired.

MUN(I), NB(J)...cards for each week giving feasible and infeasible days and cumulative wool arrivals.

N.B. The CFACT(J) section (if not at unit values) will give truncated estimates for cumulative wool arrivals. e.g. a value of 28.888 would be truncated to 28.

DISKIM

```
      DIMENSION N(5),MC(8),NB(8),MUN(300),DOY(10),NDC(8),CNB(8),CFACT(8)
      DEFINE DISK (8,4500)
      COMMON M,N,K,NK,I,MC,NB,NDC,MUN,DOY,KDATE,MNTH
       READ 100,K
      READ 40,(CFACT(J),J=1,8)
      MOND=0
      IL=1
      IU=7
      KDATE=4
      MNTH=9
      NK=900*(K-1)
      GO TO 14
   12 IL=IU+1
      IU=IU+7
      IF (K-2) 27,28,27
   28 IF (IL-296) 14,15,25
   27 IF (IL-295) 14,15,25
   15 IU=297
   14 M=MOND
      READ 100,(MUN(I),I=IL,IU),(NB(J),J=1,8)
   17 DO 41 J=1,8
      CNB(J)=NB(J)
   41 NB(J)=CNB(J)*CFACT(J)
      DO 1 I=IL,IU
      N(K)=NK+I+300
      RECORD (N(K)) (NB(J),J=1,8)
      M=M+1
      KDATE=KDATE+1
      N(K)=NK+I+600
      RECORD (N(K)) M,KDATE,MNTH
      IF (MUN(I)) 2,3,3
    2 DO 4 J=1,8
    4 MC(J)=0
      GO TO 6
    3 DO 30 J=1,8
      MC(J)=I
   30 CONTINUE
    6 N(K)=NK+I
      RECORD (N(K)) (MC(J),J=1,8)
      IF (SENSE SWITCH 3) 20,21
   20 CALL FINDMM
      CALL FINDNM
      CALL FINDAM
      PRINT 102,I,IL,IU,MUN(I),KDATE,MNTH,(NB(J),J=1,8),(MC(J),J=1,8),N(
     1K),M
   21 GO TO (7,8,7,9,7,9,7,7,9,7,9,7),MNTH
    7 IF (KDATE-31) 1,13,13
    9 IF (KDATE-30) 1,13,13
    8 IF (K-2) 11,10,11
   11 IF (KDATE-28) 1,13,13
   10 IF (KDATE-26) 1,16,19
   16 IL=IU+1
      IU=IU+8
      READ 100,(MUN(I),I=IL,IU),(NB(J),J=1,8)
      M=0
```

```
      MOND=1
      GO TO 17
   19 IF (KDATE-29) 1,13,13
   13 MNTH=MNTH+1
      KDATE=0
      IF (MNTH-12) 1,1,18
   18 MNTH=1
    1 CONTINUE
      GO TO 12
   25 CALL LINK (BEGINM)
   40 FORMAT (8F6.2)
  100 FORMAT (16I4)
  102 FORMAT (4I4,18I5,I8,I4)
  101 FORMAT (8A4)
      END
```

APPENDIX A3 DISKMM

As for DISKIM but only inputs feasible and infeasible days data. Cumulative wool arrivals data must have been put on to disk by DISKIM in a previous run. This programme does not handle the leap year situation.

DISKMM was devised to speed up the input process for experimentation conducted in Chapter IV.

DISKMM

```
      DIMENSION N(5),MC(8),NB(8),MUN(300),DOY(10),NDC(8)
      DEFINE DISK (8,4500)
      COMMON M,N,K,NK,I,MC,NB,NDC,MUN,DOY,KDATE,MNTH
       READ 100,K
      NK=900*(K-1)
      IL=1
      IU=7
   55 READ 100,(MUN(I),I=IL,IU)
      DO 1 I=IL,IU
      IF (MUN(I)) 2,3,3
    2 DO 4 J=1,8
    4 MC(J)=0
      GO TO 6
    3 DO 30 J=1,8
   30 MC(J)=I
    6 IF (SENSE SWITCH 2) 60,62
   60 IF (MUN(I)-1) 62,63,62
   63 MUN(I)=-1
      GO TO 2
   62 N(K)=NK+I
      RECORD (N(K)) (MC(J),J=1,8)
      IF (SENSE SWITCH 3) 20,1
   20 CALL FINDMM
      CALL FINDNM
      CALL FINDAM
      PRINT 102,I,IL,IU,MUN(I),KDATE,MNTH,(NB(J),J=1,8),(MC(J),J=1,8),N(
     1K),M
    1 CONTINUE
      IL=IU+1
      IU=IU+7
      IF (IL-297) 5,25,25
    5 IF (IU-297) 55,55,56
   56 IU=297
      GO TO 55
   25 CALL LINK (BEGINM)
  100 FORMAT (16I4)
  102 FORMAT (4I4,18I5,I8,I4)
      END
```

APPENDIX A4 RECORD AND RETRIEVE SUBROUTINES

FINDMM retrieves data from disk indicating feasibility of the day retrieved for sales in individual centres.

FINDNM retrieves cumulative wool arrivals data from disk for individual centres for the day concerned.

RECMCM records on disk, feasible days data for individual centres.

FINDAM retrieves general day feasibility data, day of week identification data, and month identification data from disk storage.

```
SUBROUTINE FINDMM

DIMENSION MC(8),N(5)
COMMON M,N,K,NK,I,MC
N(K)=NK+I
FETCH (N(K)) (MC(J),J=1,8)
RETURN
END


SUBROUTINE FINDNM

DIMENSION NB(8),N(5),MC(8)
COMMON M,N,K,NK,I,MC,NB
N(K)=NK+I+300
FETCH (N(K)) (NB(J),J=1,8)
RETURN
END


SUBROUTINE RECMCM

DIMENSION MC(8),N(5)
COMMON M,N,K,NK,I,MC
N(K)=NK+I
RECORD (N(K)) (MC(J),J=1,8)
RETURN
END


SUBROUTINE FINDAM

DIMENSION N(5),MUN(300),DOY(10),MC(8),NB(8),NDC(8)
COMMON M,N,K,NK,I,MC,NB,NDC,MUN,DOY,KDATE,MNTH
N(K)=NK+I+600
FETCH (N(K)) M,KDATE,MNTH
RETURN
END
```

APPENDIX A5 BEGINM

BEGINM prints the roster heading. The programme calls in initiating subroutines and initiates the value for the NETT variable of the single/double decision process. Initiation of the NETT value is done via card input.

```
      BEGINM


      DEFINE DISK (8,4500)
      DIMENSION N(5),MC(8),NB(8),NDC(8),MUN(300),DOY(10),NBS(8),NSOLD(8)
     1,NBH(8),IHOLD(8),NOMS(8),NOMD(8),MSR(8),NTS(8),NH(8),NI(8),JMON(8)
     2,NAC(8),NSS(8),NSD(8),NDS(8),NDD(8),NBA(8),NST(8),LSD(8)
      COMMON M,N,K,NK,I,MC,NB,NDC,MUN,DOY,KDATE,MNTH,NBS,NSOLD,NBH,IHOLD
     1,NOMS,NOMD,MSR,NTS,NH,NI,JMON,NAC,IMAX,NSL,NSU,NDL,NDU,KL,LAS,LAD,
     2FMTS,FNTB,PNOS,NUMS,NUMD,PNHO,NOC,NSS,NSD,NDS,NDD,NBA,LSD
      NK=900*(K-1)
      CALL STARTM
      CALL INITNM
      READ 120,MUN(299)
      CALL INDMCM
      GO TO (60,65,66,69,77),K
   60 PRINT 115
      GO TO 7
   65 NYRS=1971
      NYRF=1972
      PRINT 103,NYRS,NYRF
      GO TO 7
   66 NYRS=1968
      NYRF=1969
      GO TO 78
   69 NYRS=1969
      NYRF=1970
      GO TO 78
   77 NYRS=1970
      NYRF=1971
   78 PRINT 100,NYRS,NYRF
    7 PRINT 101
      PRINT 102
      I=1
      CALL FINDNM
      CALL FINDAM
      DO 1 J=1,8
    1 NBS(J)=0
      PRINT 110,I,MUN(I),KDATE,MNTH,(NB(J),NB(J),NBS(J),J=1,8)
      CALL LINK (SELLEM)
  100 FORMAT (63X,18HWOOL  SALE  ROSTER,//67X,I4,2X,I4)
  101 FORMAT (//2X,2HI ,5H MAN ,3X,4HDATE,4X,12H  AUCKLAND   ,1X,12H  WAN
     1GANUI   ,1X,10H  NAPIER  ,1X,14H   WELLINGTON ,1X,12HCHRISTCHURCH,1
     2X,12H   TIMARU    ,1X,12H  DUNEDIN    ,1X,12HINVERCARGILL)
  102 FORMAT (20X,8(12H NB NST SALE,1X),2X,5H NDC ,5H PER ,7H   NETT)
  103 FORMAT (63X,18HWOOL  SALE  ROSTER,//61X,I4,2X,I4,2X,10HCORR  AVGE)
  110 FORMAT (/I4,I3,1X,4H DAY,2I3,1X,8(3I4,1X),/)
  115 FORMAT (63X,18HWOOL  SALE  ROSTER,//63X,18HEXPERIMENTAL  YEAR)
  120 FORMAT (I4)
      END
```

APPENDIX A6 INITNM

INITNM initiates mainly the unsubscripted variables at their starting levels. Variables initiated via card input (in order) are:

the between sale within centre restrictions,

the order of days for the week,

LSD(J) values (these were used initially when the programme was capable of rostering all wool arrivals for sale (see Appendix A11). It is now used as a path control variable with zero values initiated.

the sale size limits.

```
      SUBROUTINE INITNM

      DIMENSION N(5),MC(8),NB(8),NDC(8),MUN(300),DOY(10),NBS(8),NSOLD(8)
     1,NBH(8),IHOLD(8),NOMS(8),NOMD(8),MSR(8),NTS(8),NH(8),NI(8),JMON(8)
     2,NAC(8),NSS(8),NSD(8),NDS(8),NDD(8),NBA(8),NST(8),LSD(8)
      COMMON M,N,K,NK,I,MC,NB,NDC,MUN,DOY,KDATE,MNTH,NBS,NSOLD,NBH,IHOLD
     1,NOMS,NOMD,MSR,NTS,NH,NI,JMON,NAC,IMAX,NSL,NSU,NDL,NDU,KL,LAS,LAD,
     2FMTS,FNTB,PNOS,NUMS,NUMD,PNHO,NOC,NSS,NSD,NDS,NDD,NBA,LSD
      IMAX=297
      KL=7
      LAS=4
      LAD=6
      FMTS=0.
      FNTB=0.
      PNOS=0.
      NUMS=0
      NUMD=0
      PNHO=0.
      NOC=0
      READ 100,(NSS(J),J=1,8)
      READ 100,(NSD(J),J=1,8)
      READ 100,(NDS(J),J=1,8)
      READ 100,(NDD(J),J=1,8)
      READ 101,(DOY(M),M=1,8)
      READ 102,(LSD(J),J=1,8)
      READ 102,NSL,NSU,NDL,NDU
  100 FORMAT (6X,I2,7(I4))
  101 FORMAT (8A4)
  102 FORMAT (8I4)
      RETURN
      END
```

APPENDIX A7 STARTM

STARTM initiates variables at zero levels. It calculates pre-sale wool storage for the first week of the season (first KL days).

```
      SUBROUTINE STARTM

      DIMENSION N(5),MC(8),NB(8),NDC(8),MUN(300),DOY(10),NBS(8),NSOLD(8)
     1,NBH(8),IHOLD(8),NOMS(8),NOMD(8),MSR(8),NTS(8),NH(8),NI(8),JMON(8)
     2,NAC(8),NSS(8),NSD(8),NDS(8),NDD(8),NBA(8),NST(8)
      COMMON M,N,K,NK,I,MC,NB,NDC,MUN,DOY,KDATE,MNTH,NBS,NSOLD,NBH,IHOLD
     1,NOMS,NOMD,MSR,NTS,NH,NI,JMON,NAC,IMAX,NSL,NSU,NDL,NDU,KL,LAS,LAD,
     2FMTS,FNTB,PNOS,NUMS,NUMD,PNHO,NOC,NSS,NSD,NDS,NDD,NBA
      DO 85 J=1,8
      NBS(J)=0
      NSOLD(J)=0
      NBA(J)=0
      IHOLD(J)=0
      NOMS(J)=0
      NOMD(J)=0
      MSR(J)=0
      NBH(J)=0
      NH(J)=0
      NI(J)=0
      JMON(J)=0
      NDC(J)=0
   85 NAC(J)=0
      I=1
      CALL FINDNM
      DO 20 J=1,8
   20 NTS(J)=NB(J)*297
      RETURN
      END
```

APPENDIX A8 INDMCM

INDMCM records (on disk) specific centre day infeasibility. e.g. anniversaries.

```
      SUBROUTINE INDMCM

      DIMENSION N(5),MC(8),NB(8),NDC(8),MUN(300)
      COMMON M,N,K,NK,I,MC NB,NDC,MUN
      DO 191 JOLD=1,8
      GO TO (190,195,192,195,193,193,194,194),JOLD
190   I=149
      GO TO 196
195   I=142
      GO TO 196
192   I=58
      GO TO 196
193   I=100
      GO TO 196
194   I=198
196   CALL FINDMM
      J=JOLD
      MC(J)=0
      CALL RECMCM
191   CONTINUE
      RETURN
      END
```

APPENDIX A9 SELLEM

This is the main programme. Its functions include rostering wool sales subject to the model constraints, and measuring performance parameters.

SELLEM is broken up into thirteen sections for ease of reference from the model development section in Chapter III.

SELLEM

```
      DIMENSION N(5),MC(8),NB(8),NDC(8),MUN(300),DOY(10),NBS(8),NSOLD(8)
     1,NBH(8),IHOLD(8),NOMS(8),NOMD(8),MSR(8),NTS(8),NH(8),NI(8),JMON(8)
     2,NAC(8),NSS(8),NSD(8),NDS(8),NDD(8),NBA(8),NST(8),LSD(8)
      DEFINE DISK (8,4500)
      COMMON M,N,K,NK,I,MC,NB,NDC,MUN,DOY,KDATE,MNTH,NBS,NSOLD,NBH,IHOLD
     1,NOMS,NOMD,MSR,NTS,NH,NI,JMON,NAC,IMAX,NSL,NSU,NDL,NDU,KL,LAS,LAD,
     2FMTS,FNTB,PNOS,NUMS,NUMD,PNHO,NOC,NSS,NSD,NDS,NDD,NBA,LSD

      DO 710 J=1,8                                                    I
  710 NST(J)=0
      IF (SENSE SWITCH 3) 700,701
  700 READ 100,IOLD,JHOLD,NSELL,NSL,NSU,NDL,NDU
      NWAIT=0
      NETT=0
  701 DO 88 I=8,297
      IF (SENSE SWITCH 3) 702,703
  702 NCLOSE=0
      IF (I-IOLD) 6,705,706
  705 J=JHOLD
      NST(J)=NSELL
      GO TO 132
  706 IF (NDU-100) 707,6,6
  707 READ 100,IOLD,JHOLD,NSELL,NSL,NSU,NDL,NDU
      GO TO 702

  703 IOLD=I                                                          II
   24 NWAIT=0
      NDIFF=NDU-NSU
      NETT=0
      NCLOSE=0
      NBALES=0
      NBR=0
      IF (MUN(I)) 98,90,90
   98 GO TO 6
   90 CALL FINDMM
      DO 3 J=1,8
      IF (I-MC(J)) 3,5,3
    3 CONTINUE
      GO TO 6
    5 I=I-KL
      CALL FINDNM
      I=IOLD
      NST(J)=NB(J)-NBA(J)
    9 IF (J-8) 7,10,10
    7 J=J+1
      IF (I-MC(J)) 9,5,9
   10 NAH=NST(1)
      JHOLD=1
      DO 4 J=2,8
      IF (NAH-NST(J)) 11,4,4
   11 NAH=NST(J)
      JHOLD=J
    4 CONTINUE
      J=JHOLD
```

III

```
      IF (NST(J)-NSL) 97,37,37
  97  GO TO 6
  37  IF (IHOLD(J)) 16,16,417
 417  IF (NBS(J)-NDL) 14,15,15
  14  IF (NST(J)-NSU) 16,16,17
  17  IF (NST(J)-NDL) 16,18,18
  18  NBR=NSD(J)-NSS(J)
      GO TO 21
  15  IF (NST(J)-NSU) 16,16,19
  19  IF (NST(J)-NDL) 16,20,20
```

IV

```
  20  NBR=NDD(J)-NDS(J)
      GO TO 21
  16  NBR=0
  21  IHOLD(J)=IHOLD(J)+NBR
      IF (IHOLD(J)-NBR) 23,23,91
  91  IF (I-IHOLD(J)) 22,23,23
  22  I=I-KL
      CALL FINDNM
      I=I+KL
      NOVER=NB(J)-NBA(J)-NSU
      IF (NDIFF-NOVER) 453,454,454
 453  NOVER=NDIFF
 454  I=IHOLD(J)
      IF (I-297) 124,124,125
 124  CALL FINDMM
      IF (MC(J)-I) 122,123,122
 122  I=I+1
      IF (I-297) 124,124,125
 123  I=I+2
      IF (I-297) 400,400,338
 400  CALL FINDMM
      IF (MC(J)-I) 402,403,402
 402  I=I-1
 419  CALL FINDMM
      IF (MC(J)-I) 404,123,404
 404  I=I+1
      IF (I-297) 419,419,125
 403  I=I-2
      NWAIT=I-IOLD
      IF (LSD(J)) 603,603,604
 603  I=I-KL
      CALL FINDNM
      I=I+KL
      NOVER=NB(J)-NBA(J)-NSU
      IF (NOVER-NDIFF) 654,654,655
 655  NOVER=NDIFF
 654  NLOSS=NSU*NWAIT
      NGAIN=NOVER*(NSS(J)-NWAIT)
      NETT=NGAIN-NLOSS
      IF (SENSE SWITCH 2) 130,125
 130  IF (NETT-MUN(299)) 125,125,195
 125  NST(J)=NSU
      GO TO 129
 195  IF (NWAIT) 500,500,611
 611  NST(J)=0
 129  IHOLD(J)=IHOLD(J)-NBR
      I=IOLD
```

```
      NWAIT=0
      GO TO 10
  338 NWAIT=0
      NETT=0
      GO TO 132

   23 IF (NST(J)-NDL) 131,123,123
  131 NBR=NDS(J)-NSS(J)
      IHOLD(J)=IHOLD(J)+NBR
      IF (IOLD-IHOLD(J)) 600,601,601
  600 I=IHOLD(J)
      GO TO 602
  601 I=IOLD
  602 IF (I-297) 160,160,338
  160 I=I-KL
      CALL FINDNM
      NBALES=NB(J)-NBA(J)
      IF (NBALES-NDL) 59,51,51
   59 I=I+KL+1
      GO TO 602
   51 I=I+KL
      LSD(J)=100
      GO TO 124
  604 LSD(J)=0
      I=I-KL
      CALL FINDNM
      IF (NST(J)-NSU) 451,451,450
  450 NST(J)=NSU
  451 NOVER=NB(J)-NBA(J)-NST(J)
      IF (NOVER-NDIFF) 503,503,650
  650 NOVER=NDIFF
  503 NLOSS=NST(J)*NWAIT
      NGAIN=NOVER*(NSS(J)-NWAIT)
      NETT=NGAIN-NLOSS
      IF (SENSE SWITCH 2) 137,500
  137 IF (NETT-MUN(299)) 500,500,195
  500 IHOLD(J)=IHOLD(J)-NBR
  132 IF (NST(J)-NSU) 820,810,820
  810 DO 800 J=1,8
      IF (NST(J)-NSU) 800,802,802
  802 I=IOLD
      I=I-KL
      CALL FINDNM
      I=I+KL
      NST(J)=NB(J)-NBA(J)
  800 CONTINUE
      NAH=NST(1)
      JHOLD=1
      DO 804 J=2,8
      IF (NST(J)-NAH) 804,804,803
  803 NAH=NST(J)
      JHOLD=J
  804 CONTINUE
      J=JHOLD
      NST(J)=NSU
  820 I=IOLD

      IF (NST(J)-NSU) 25,25,26
```

V

VI

```
 26 IF (NST(J)-NDL) 27,28,28
 28 IF (NST(J)-NDU) 29,30,30
 25 NOMS(J)=NOMS(J)+1
    LS=NSS(J)
    NSS(J)=NSS(J)
 31 NBA(J)=NBA(J)+NST(J)
    NBS(J)=NST(J)
    GO TO 32
 27 NST(J)=NSU
    GO TO 25
 29 NOMD(J)=NOMD(J)+1
    LS=NDS(J)
    GO TO 31
 30 NST(J)=NDU
    GO TO 29

 32 IHOLD(J)=I+LS                                   VII
    I=IOLD
    MFACT=IMAX-I
    MSTR=NBS(J)*MFACT
    MSR(J)=MSR(J)+MSTR
    MFACT=I-NI(J)
    NBHO=NH(J)*MFACT
    NBH(J)=NBH(J)+NBHO
    CALL FINDNM
    NH(J)=NB(J)-NBA(J)
    NI(J)=I

    IF (MUN(I)-1) 33,34,33                          VIII
 34 JMON(J)=JMON(J)+1

 33 I=I-15                                          IX
    IF (I) 61,61,62
 61 I=1
 62 DO 39 I=I,IOLD
    CALL FINDNM
    IF (NBA(J)-NB(J)) 38,38,39
 39 CONTINUE
 38 IELD=I
    I=IOLD
    NDC(J)=I-IELD
    IF (SENSE SWITCH 3) 708,709

709 IF (LS-NSS(J)) 40,40,41                         X
 40 LMAX=LAS
    GO TO 42
 41 LMAX=LAD
 42 IF (J-4) 43,43,44
 43 JLOWS=1
    JUPRS=4
    JLOWN=5
    JUPRN=8
    GO TO 50
 44 JLOWS=5
    JUPRS=8
    JLOWN=1
    JUPRN=4
 50 DO 45 L=1,LMAX
```

```
      I=IOLD+L
      IF (I-297) 94,94,92
   94 CALL FINDMM
      DO 63 J=JLOWS,JUPRS
   63 MC(J)=0
   45 CALL RECMCM
   92 IF (LMAX-4) 46,46,47
   46 I=IOLD+1
      IF (I-297) 93,93,460
   93 CALL FINDMM
      DO 48 J=JLOWN,JUPRN
   48 MC(J)=0
      CALL RECMCM
      GO TO 460
   47 DO 49 L=1,3
      I=IOLD+L
      IF (I-297) 104,104,460
  104 CALL FINDMM
      DO 57 J=JLOWN,JUPRN
   57 MC(J)=0
   49 CALL RECMCM

  460 ILOW=IOLD+1                                         XI
      IUPR=IOLD+LS
      IF (IUPR-297) 95,95,96
   96 IUPR=297
   95 J=JHOLD
      DO 55 I=IOLD,IUPR
      CALL FINDMM
      MC(J)=0
   55 CALL RECMCM

  708 I=IOLD                                              XII
      NSOLD(J)=NST(J)
    6 MFACT=IMAX-I
      I=I-1
      CALL FINDNM
      DO 64 J=1,8
   64 NTS(J)=NTS(J)-(NB(J)*MFACT)
      I=I+1
      CALL FINDNM
      DO 58 J=1,8
      NAC(J)=NAC(J)+NDC(J)
      IF (NDC(J)) 58,58,79
   79 NCLOSE=NDC(J)
   58 NTS(J)=NTS(J)+(NB(J)*MFACT)

      CALL FINDAM                                         XIII
      DO 170 J=1,8
      NST(J)=NB(J)-NBA(J)
      IF (NSOLD(J)-0) 170,170,172
  172 NST(J)=NST(J)+NSOLD(J)
      PUNCH 100,I,J,NSOLD(J),NSL,NSU,NDL,NDU
  170 CONTINUE
   99 IF (NCLOSE) 67,67,83
   67 IF (M-1) 80,80,76
   76 IF (M-8) 2,80,2
   83 MUN(I+1)=-1
```

```
 80 PRINT 103,I,MUN(I),DOY(M),KDATE,MNTH,(NB(J),NST(J),NSOLD(J),J=1,8)
   1,NCLOSE,NWAIT,NETT
  2 DO 89 J=1,8
    NDC(J)=0
    NST(J)=0
 89 NSOLD(J)=0
 88 CONTINUE
    CALL LINK (PARAM)
103 FORMAT (I4,I3,1X,A4,2I3,1X,8(3I4,1X),3X,I4,2X,I3,2X,I6,/)
100 FORMAT (7I4)
    END
```

APPENDIX A10 PARAM

PARAM evaluates and summarises performance parameter (and other) values. These values are printed in the performance parameter section of output (see example roster in Appendix C2).

PARAM

```
      DIMENSION N(5),MC(8),NB(8),NDC(8),MUN(300),DOY(10),NBS(8),NSOLD(8)
     1,NBH(8),IHOLD(8),NOMS(8),NOMD(8),MSR(8),NTS(8),NH(8),NI(8),JMON(8)
     2,NAC(8),NSS(8),NSD(8),NDS(8),NDD(8),NBA(8),NST(8),PST(8),DBH(8),DN
     3AC(8),DNOM(8),NBO(8),FNBO(8),FNB(8),NOM(8),MRS(8),AVAR(8),BVAR(8),
     4GVAR(8),DVAR(8),EVAR(8),FVAR(8)
      DEFINE DISK (8,4500)
      COMMON M,N,K,NK,I,MC,NB,NDC,MUN,DOY,KDATE,MNTH,NBS,NSOLD,NBH,IHOLD
     1,NOMS,NOMD,MSR,NTS,NH,NI,JMON,NAC,IMAX,NSL,NSU,NDL,NDU,KL,LAS,LAD,
     2FMTS,FNTB,PNOS,NUMS,NUMD,PNHO,NOC,NSS,NSD,NDS,NDD,NBA
      MSUM=0
      FNBL=0
      DO 1 J=1,8
      AVAR(J)=NTS(J)
      BVAR(J)=NBH(J)
    1 DVAR(J)=MSR(J)
      DO 65 J=1,7,2
      FMTS=FMTS+DVAR(J)+DVAR(J+1)
      PNOS=PNOS+AVAR(J)+AVAR(J+1)
      PNHO=PNHO+BVAR(J)+BVAR(J+1)
      NUMS=NUMS+NOMS(J)+NOMS(J+1)
      NUMD=NUMD+NOMD(J)+NOMD(J+1)
   65 NOC=NOC+NAC(J)+NAC(J+1)
      DO 60 J=1,8
      MSUM=MSUM+JMON(J)
      NOM(J)=NOMS(J)+NOMD(J)
      MRS(J)=NTS(J)-MSR(J)
      EVAR(J)=MRS(J)
      PST(J)=DVAR(J)/AVAR(J)*100.
      DBH(J)=BVAR(J)/AVAR(J)*100.
      DNAC(J)=NAC(J)
      DNOM(J)=NOM(J)
      DNAC(J)=DNAC(J)/DNOM(J)
      I=297
      CALL FINDNM
      NBO(J)=NB(J)-NBA(J)
      FVAR(J)=NBO(J)
      FNBL=FNBL+FVAR(J)
      GVAR(J)=NB(J)
   60 FNTB=FNTB+GVAR(J)
      SOLD=FNTB-FNBL
      PMOS=PNOS-FMTS
      NUM=NUMS+NUMD
      DNOC=NOC
      DNUM=NUM
      DNOC=DNOC/DNUM
      PAT=FMTS/PNOS*100.
      PHB=PNHO/PMOS*100.
      PRINT 103
      PRINT 107
      PRINT 108,(NTS(J),J=1,8),(MSR(J),J=1,8),(MRS(J),J=1,8),(PST(J),J=1
     1,8),PNOS,FMTS,PMOS,PAT
      PRINT 109,(NBH(J),J=1,8),(DBH(J),J=1,8),PNHO,PHB
      PRINT 110,(NB(J),J=1,8),(NBA(J),J=1,8),(NBO(J),J=1,8),FNTB,SOLD,FN
     1BL
      PRINT 111,(NOMS(J),J=1,8),(NOMD(J),J=1,8),(NOM(J),J=1,8),NUMS,NUMD
```

```
   1,NUM
    PRINT 112,(NAC(J),J=1,8),(NOM(J),J=1,8),(DNAC(J),J=1,8),NOC,NUM,DN
   1OC
    PRINT 113,(JMON(J),J=1,8)
    PRINT 114,MSUM
103 FORMAT (55X,18HSUMMARY  OF  SALES,//62X,3HAND,//52X,23HPERFORMANCE
   1  PARAMETERS)
107 FORMAT (//28X,12H  AUCKLAND  ,12H  WANGANUI  ,10H  NAPIER  ,14H WE
   1LLINGTON   ,12HCHRISTCHURCH,12H   TIMARU   ,12H  DUNEDIN   ,12HINV
   2ERCARGILL,//)
108 FORMAT (24H    TOTAL STORAGE      = ,8(4X,I8),/24H    STORAGE REMOV
   1ED   = ,8(4X,I8),/24H    NET STORAGE        = ,8(4X,I8),/24H    REM
   2OVED PERCENT   = ,8(4X,F8.2),//44X,24H    GRAND TOT STORAGE = ,F10
   3.0,/44X,24H    GRAND TOT REMOVED = ,F10.0,/44X,24H    GRAND TOT RE
   4MAIN  = ,F10.0,/44X,24H    OVERALL PERCENT   = ,3X,F6.2)
109 FORMAT (//24H    BALES HELD OVER    = ,8(4X,I8),/24H    PERCENT OF
   1TOTAL   = ,8(4X,F8.2),//44X,24H    TOTAL HELD OVER    = ,F10.0,/44X,
   224H    PERCENT OF TOTAL  = ,3X,F6.2)
110 FORMAT (//24H    TOTAL ARRIVALS     = ,8(4X,I8),/24H    TOTAL BALES
   1 SOLD   = ,8(4X,I8),/24H    REMAINDER UNSOLD  = ,8(4X,I8),//44X,24H
   2     G TOTAL ARRIVALS  = ,I10,/44X,24H    GRAND TOTAL SOLD  = ,I10,
   3/44X,24H    G TOTAL REMAINING = ,I10)
111 FORMAT (/24H    SINGLE SALES       = ,8(6X,I6),/24H    DOUBLE SALES
   1       = ,8(6X,I6),/24H    TOTAL SALES        = ,8(6X,I6),//44X,24H
   2   TOTAL SINGLE        = ,4X,I6,/44X,24H    TOTAL DOUBLE       = ,4X,
   3I6,/44X,24H    GRAND TOTAL SALES = ,4X,I6)
112 FORMAT (//4X,20HEVALUATION DAYS    = ,8(I12),/3X,21H NUMBER OF SALE
   1S    = ,8(I12),/3X,21H AVGE LENGTH EVAL  = ,8(6X,F6.2),//44X,24H
   2 TOTAL EVALUATION  = ,I12,/44X,24H    TOTAL SALES        = ,I12,/44
   3X,24H    AVGE TOTAL EVALN  = ,6X,F6.2)
113 FORMAT (//24H    MONDAY SALES       = ,8(6X,I6))
114 FORMAT (//44X,24H    TOTAL MON SALES    = ,I12)
    END
```

APPENDIX A11 ADDITIONAL PROGRAMMING

The programming presented in this section was incorporated in SELLEM to produce rosters with little or no wool remaining unsold at the end of the season. This property of the programme was removed due to variability in wool arrivals estimates towards the end of the season. The programming was included in Section VII of SELLEM.

```
 32 IHOLD(J) = I + LS
    I = LSD(J)
    CALL FINDNM
    NB(J) = NB(J) - NBA(J)
    IF (IHOLD(J) - 297) 402,402,403
403 NB(J) = NB(J) + NBS(J)
    IF (NB(J) - NDL) 400,401,401
400 NDIFF = NSU
    GO TO 410
401 NDIFF = NDU
410 IUPR = LSD(J)
    DO 404 I = IOLD, IUPR
    I = I - KL
    CALL FINDNM
    NB(J) = NB(J) - NBA(J) + NBS(J)
    IF (NB(J) - NDIFF) 405,406,406
405 I = I + KL
    CALL FINDMM
    MC(J) = 0
404 CALL RECMCM
406 I = I + KL
    IF (I - IOLD) 465,465,409
```

```
465 NST(J) = NDIFF
    GO TO 65
409 IF (MUN(J) - 400) 490,65,65
490 NST(J) = 0
    MUN(J) = 400
480 IF (NBS(J) = NBL) 411,412,412
411 NOMS(J) = NOMS(J) - 1
    GO TO 413
412 NOMD(J) = NOMD(J) - 1
413 NBA(J) = NBA(J) - NBS(J)
    NBS(J) = NGAIN
    IHOLD(J) = IHOLD(J) - LS
    GO TO 129
```

APPENDIX B

DATA USED

The data presented in this appendix is:

Appendix	B1	"Unweighted Average" wool arrivals data,
	B2	"Weighted Average" wool arrivals data,
	B3	correction factors for "Corrected Average" data,
	B4	infeasible sale days for the 1971/72 season.
	B5	regional anniversaries 1971/72,
	B6	wool arrivals data used in experimentation conducted in Chapter IV.

APPENDIX B1 "UNWEIGHTED AVERAGE" CUMULATIVE WOOL ARRIVALS DATA

(In Thousand Bales)

Date	Auckland	Wanganui	Napier	Welling-ton	Christ-church	Timaru	Dunedin	Inver-cargill
Sep								
5	3	2	4	3	12	5	44	7
12	3	2	5	3	16	7	52	8
19	4	2	6	3	19	10	59	9
26	6	2	9	4	23	11	65	11
Oct								
3	9	3	15	5	24	14	69	12
10	13	5	23	9	28	19	73	15
17	17	8	32	14	34	21	76	18
24	24	12	46	17	43	22	80	20
31	32	16	61	21	48	25	84	23
Nov								
7	40	20	76	28	55	27	90	30
14	49	28	90	39	63	31	94	38
21	60	38	107	49	74	36	99	43
28	72	43	122	56	83	41	104	48
Dec								
5	83	49	137	66	93	43	110	56
12	93	57	152	74	103	47	115	61
19	106	65	165	82	114	50	121	66
26	112	70	172	88	122	52	124	70
Jan								
2	117	74	178	95	127	54	127	74
9	127	80	187	102	136	57	131	83
16	135	85	194	108	143	60	136	93
23	143	89	199	113	148	65	140	104
30	148	91	203	116	153	68	145	112
Feb								
6	153	93	205	119	158	70	148	119
13	156	94	207	121	161	71	152	126
20	159	95	209	122	164	73	155	134
27	162	96	211	124	166	74	158	141
Mar								
6	166	97	215	126	168	75	161	150

Date	Auckland	Wanganui	Napier	Wellington	Christchurch	Timaru	Dunedin	Invercargill
Mar								
13	169	99	218	128	171	77	163	154
20	173	102	221	130	173	80	166	162
27	176	105	224	132	174	81	167	165
Apr								
3	180	107	227	134	175	82	169	168
10	185	108	229	136	177	83	170	172
17	188	109	232	138	178	83	173	175
24	193	110	233	139	180	83	176	177
May								
1	198	111	235	140	182	83	178	178
8	206	112	236	141	184	83	180	179
15	211	113	238	143	185	83	180	180
22	215	114	239	143	185	83	180	182
29	220	115	241	143	185	83	180	183
Jun								
5	224	115	242	143	185	83	180	183
12	225	115	242	143	185	83	180	183
19	225	115	242	143	185	83	180	183
26	225	115	242	143	185	83	180	183

Estimates are unweighted averages of the weekly arrivals for the 1968/69, 1969/70, 1970/71 seasons. Primary data was obtained from the New Zealand Wool Brokers' Association Schedule of Weekly Receipts Into Store 1968-69 - 1969-70 - 1970-71 Seasons.

APPENDIX B2 "WEIGHTED AVERAGE" CUMULATIVE WOOL ARRIVALS DATA

(In Thousand Bales)

Date	Auckland	Wanganui	Napier	Welling-ton	Christ-church	Timaru	Dunedin	Inver-cargill
Sep								
5	3	2	5	3	11	6	42	6
12	4	2	6	3	15	7	50	7
19	5	2	7	3	18	10	56	8
26	6	2	10	4	22	11	63	10
Oct								
3	9	3	15	5	24	14	67	11
10	12	5	23	8	28	18	71	14
17	16	7	32	13	33	21	74	18
24	24	12	43	16	41	22	78	21
31	31	16	61	21	46	24	82	23
Nov								
7	38	19	73	27	53	27	87	29
14	46	27	88	37	61	30	91	38
21	57	37	105	47	71	35	96	42
28	68	43	121	54	80	39	103	47
Dec								
5	79	49	137	63	90	42	108	55
12	90	59	152	73	101	44	113	60
19	101	65	166	81	114	48	118	65
26	107	70	172	87	121	50	120	68
Jan.								
2	113	73	178	92	126	51	124	73
9	120	78	187	99	135	54	128	80
16	127	82	192	103	141	57	133	91
23	135	86	197	109	146	62	136	103
30	140	88	202	111	150	66	141	109
Feb								
6	144	90	204	113	156	68	144	117
13	147	91	206	115	159	70	148	124
20	150	92	209	116	162	71	151	133
27	152	93	212	118	164	73	154	139
Mar								
6	156	94	215	120	166	74	156	151
13	159	95	218	122	169	76	158	154

Date	Auckland	Wanganui	Napier	Wellington	Christchurch	Timaru	Dunedin	Invercargill
Mar								
20	163	98	221	124	170	79	161	159
27	166	101	225	126	172	81	163	163
Apr								
3	169	103	227	128	173	81	164	166
10	174	104	230	130	175	81	166	170
17	178	104	232	132	176	81	169	174
24	182	105	234	133	178	81	173	176
May								
1	187	106	236	134	180	81	175	177
8	193	107	237	135	183	81	176	177
15	199	109	239	137	183	81	177	178
22	203	109	240	137	183	81	177	179
29	208	111	241	138	183	81	177	180
Jun								
5	212	111	243	138	183	81	177	180
12	214	111	243	138	183	81	177	180
19	214	111	243	138	183	81	177	180
26	214	111	243	138	183	81	177	180

Estimates are weighted averages for three seasons data. The data is extracted by taking:

10% of the figure for the 1968/69 season,

30% of the figure for the 1969/70 season,

60% of the figure for the 1970/71 season.

Primary data was obtained from the New Zealand Wool Brokers' Association Schedule of Weekly Receipts Into Store 1968-69 - 1969-70 - 1970-71 Seasons.

APPENDIX B3 CORRECTION FACTORS FOR "CORRECTED AVERAGE" DATA

The product of "Unweighted Average" weekly arrivals data with the appropriate correction factor yields corresponding "Corrected Average" data (weekly estimates of cumulative wool arrivals in centres).

	Correction Factor
Auckland	1.054
Wanganui	1.079
Napier	1.108
Wellington	1.105
Christchurch	1.028
Timaru	1.085
Dunedin	1.034
Invercargill	1.082

Correction factors are derived by the equation:

$$\text{Correction Factor} = \frac{\text{total bales rostered for sale}^{1}}{\text{"Unweighted Average" estimate of total arrivals}} \text{(per centre)}$$

1. Obtained from the roster for the 1971-72 season, see "New Zealand Wool Sales - Season - 1971-72", New Zealand Wool Commission.

APPENDIX B4 INFEASIBLE SALE DAYS - 1971/72 : ALL CENTRES

1971	Monday 25th October	- Labour Day
	Thursday 23rd December to	- Christmas Break
1972	Monday 10th January	
	Friday 31st March	- Good Friday
	Monday 3rd April	- Easter Monday
	Tuesday 25th April	- Anzac Day
	Monday 5th June	- Queen's Birthday

APPENDIX B5 REGIONAL ANNIVERSARIES - 1971/72

Auckland	31st January
Wanganui	24th January
Napier	1st November
Wellington	24th January
Christchurch	13th December
Timaru	13th December
Dunedin	20th March
Invercargill	20th March

Source: New Zealand Official Year Book, 1971-72.

APPENDIX B6 CUMULATIVE WOOL ARRIVALS DATA USED FOR EXPERIMENTATION

(In thousand bales)

Date	Auckland	Wanganui	Napier	Wellington	Christchurch	Timaru	Dunedin	Invercargill
Sep								
5	3	1	4	3	12	5	44	6
12	3	2	5	3	16	6	50	7
19	4	2	6	3	19	9	57	8
26	6	2	9	4	23	11	63	11
Oct								
3	10	3	15	6	25	14	67	13
10	15	5	22	10	28	19	71	16
17	20	9	34	16	35	21	75	18
24	28	15	49	20	44	23	79	21
31	36	18	61	25	50	25	83	24
Nov								
7	47	24	78	33	57	28	89	31
14	57	32	94	45	66	32	93	39
21	67	39	109	53	75	37	99	44
28	78	44	123	60	83	41	103	49
Dec								
5	89	50	137	70	93	44	109	58
12	100	55	153	77	103	47	114	62
19	114	67	166	87	113	52	121	68
26	120	72	175	93	122	55	124	73
Jan								
2	126	75	182	101	128	56	127	77
9	138	83	192	108	138	59	132	88
16	148	91	200	116	144	64	138	98
23	157	96	205	122	150	68	143	109
30	163	98	208	126	156	70	148	118
Feb								
6	169	100	209	129	161	72	151	126
13	175	101	211	131	164	73	156	134
20	178	102	213	132	166	75	159	142
27	183	104	215	134	169	76	162	150
Mar								
6	187	105	219	136	171	78	165	156
13	190	107	222	138	174	79	167	160
20	194	110	226	141	176	81	169	168

Date	Auckland	Wanganui	Napier	Welling-ton	Christ-church	Timaru	Dunedin	Inver-cargill
27	197	113	228	143	177	83	171	172
Apr								
3	202	116	230	146	178	84	173	175
10	206	117	232	149	179	85	175	178
17	210	117	234	150	181	85	176	180
24	215	118	236	151	183	85	178	182
May								
1	220	119	237	152	184	85	180	183
8	228	121	238	153	186	85	182	184
15	234	122	240	154	186	85	182	186
22	238	123	242	155	186	85	182	188
29	242	123	244	156	186	85	182	188
Jun								
5	246	123	245	156	186	85	182	188
12	249	123	245	156	186	85	182	188
19	250	123	245	156	186	885	182	188
26	250	123	245	156	186	85	182	188

This data was extracted by taking unweighted averages of weekly arrivals for the seasons 1967/68, 1968/69, 1969/70.[1]

---

1. Primary data was obtained from the New Zealand Wool Brokers' Association Schedule of Weekly Receipts Into Store 1967-68 - 1968-69 - 1969-70 Seasons.

APPENDIX C

ROSTERS

The rosters contained in Appendix C1 are adjusted rosters for the three sets of data obtained under the NETT : 100 operating rule for the single/double decision process. The Committee roster was the roster formulated by the Wool Auction Sales Committee for the 1971/72 season.

Abbreviations used for centre identification are:

AK	Auckland
WG	Wanganui
NP	Napier
WN	Wellington
CH	Christchurch
TM	Timaru
DN	Dunedin
IN	Invercargill

In Appendix C2 an example of a programme roster is given. The roster is for the NETT : 100 "Corrected Average" run and is printed in computer output form.

APPENDIX C1   ADJUSTED ROSTERS FOR THE 1971/72 SEASON

Date	Wool Sale Roster 1971/72 (In thousand bales)							
	"Unweighted Average"		"Weighted Average"		"Corrected Average"		Committee	
	Centre	Sale Size	Centre	Sale Size	Centre	Sale Size	Centre	Sale Size
Sep								
Wed 15th	DN	44	DN	42	DN	45		
Wed 25th							DN	40
Oct								
Wed 6th	CH	23	CH	22	CH	23	CH	22
Fri 15th							TM	20
Wed 20th	DN	28	DN	28	DN	28	IN	20
Fri 22nd	NP	23	NP	23	NP	25	NP	25
Wed 27th							AK	20
Thu 28th	TM	21	TM	21	TM	22		
Nov								
Wed 3rd	AK	24	AK	24	AK	25	WN	22
Fri 5th	CH	20	IN	21	CH	21	CH	22
Mon 8th							WG	22
Wed 10th	IN	23	CH	24	IN	24		
Fri 12th	WN	21	WN	21	WN	23	DN	25
Wed 17th	WG	20			WG	21	IN	20
Fri 19th					DN	20		
Mon 22nd							NP	42
Wed 24th	DN	22	WG	27				
Fri 26th			DN	21				
Mon 29th	NP	50	NP	50	NP	50	AK	45
Dec								
Fri 3rd	CH	28	IN	21	CH	28	CH	24
Mon 6th	AK	48			AK	50		
Wed 8th			AK	44			TM	24
Fri 10th	IN	25			In	27	WG	26
Mon 13th							DN	25
Wed 15th	WG	28	TM	20	WG	28	WN	28
Fri 17th	TM	22			TM	24	IN	23
Mon 20th			CH	50			NP	28
Wed 22nd	WN	50			WN	50		

Jan								
Mon 10th	NP	50	NP	50	NP	50	AK	28
Fri 14th	DN	26	DN	26	IN	28	WG	26
Mon 17th	WG	27	WN	50	WG	28	CH	44
Wed 19th	CH	50			CH	50		
Fri 21st							WN	28
Mon 24th							DN	26
Wed 26th	AK	50	AK	50	AK	50	NP	48
Feb								
Wed 2nd	IN	50	IN	50	DN	50	IN	46
Mon 7th	WN	45	WG	44	WN	45		
Wed 9th							TM	26
Fri 11th	TM	20	TM	20	TM	24		
Mon 14th							AK	45
Wed 16th	DN	20	CH	47	WG	23		
Fri 18th					IN	28		
Mon 21st	NP	50	NP	50	NP	50	WN	26
Fri 25th	CH	24	DN	20	CH	28	CH	28
Mar								
Wed 1st	AK	23	AK	28	AK	28		
Fri 3rd							WG	26
Wed 8th	WG	20	WN	47	DN	20	NP	48
Wed 15th	IN	45	IN	48			DN	26
Mon 29th							IN	44
Fri 24th	CH	20	CH	20	CH	20	AK	24
Tue 28th			WG	20				
Wed 29th	AK	20			AK	28	WN	24
Thu 30th			TM	20				
Apr								
Wed 5th	NP	49	NP	50	NP	50		
Mon 10th					IN	50		
Wed 12th	DN	20	AK	23			CH	26
Fri 14th					WN	20	NP	26
Mon 17th							DN	24
Wed 19th	IN	20	IN	20	TM	20	AK	22
Wed 26th	TM	20	DN	20			TM	20
Fri 28th							WG WN	12 15
May								
Mon 1st							IN	25

Wed 3rd	AK	20						
Wed 10th					NP	23		
Wed 17th	DN	20	AK	24	AK	28		
Fri 19th			CH	20	IN	21	CH	24
Mon 22nd							NP	25
Wed 24th	WN	27	DN	20	DN	23	DN	20
Fri 26th	CH	20			WN	20	AK	25
Mon 29th							IN	20
Wed 31st	AK	20	WN	20	CH	20	WG WN	12 15
Jun								
Fri 2nd			IN	20				
Wed 7th	WG	20	WG	20	WG	24		
Fri 9th	IN	20						
Wed 14th	NP	20	NP	20				
Fri 16th					IN	20	NP	26
Tue 20th							AK	28
Wed 21st			AK	21	NP	20		
Tue 27th	AK	20			AK	28		
Totals	47[1]	1,356	44[1]	1,327	48[1]	1,451	54[1]	1,451

1. Total number of sales rostered.

APPENDIX C2 EXAMPLE PROGRAMME ROSTER

The roster presented in this appendix is the programme (unadjusted) roster for "Corrected Average" data using the NETT : 100 rule for the single/ double decision process.

Output variables in the roster are defined below (refer to Appendix A1):

MAN equivalent to MUN(I) (no units)

NB,NST correspond to NB(J) and NST(J) respectively (in thousand bales)

SALE the sale size rostered (in thousand bales)

NDC corresponds to NCLOSE - the closing to sale date period (in days)

PER corresponds to NWAIT - the period that must elapse before a double sale may be rostered (in days)

NETT as in Appendix A1 (in thousand bale-days)

In the roster summary, storage (pre-sale) and bales held over have units of thousand bale-days. Evaluation (closing to sale date period) parameters are in units of days.

$$\text{Removed Percent (storage)} = \frac{\text{Storage Removed}}{\text{Total Storage}} \times \frac{100}{1}$$

$$\text{Percent of Total (bales held over)} = \frac{\text{Bales Held Over}}{\text{Total Storage}} \times \frac{100}{1}$$

WOOL SALE ROSTER

1971 1972 CORR AVGE

I	MAN	DATE	AUCKLAND			WANGANUI			NAPIER			WELLINGTON			CHRISTCHURCH			TIMARU			DUNEDIN			INVERCARGILL			NDC	PER	NETT
			NB	NST	SALE	NB	NST	SALE	NB	NST	SALE	NB	NST	SALE	NB	NST	SALE	NB	NST	SALE	NB	NST	SALE	NB	NST	SALE			
1	-1	DAY 5 9	3	3	0	2	2	0	4	4	0	3	3	0	12	12	0	5	5	0	45	45	0	7	7	0			
8	-1	SUN 12 9	3	3	0	2	2	0	5	5	0	3	3	0	16	16	0	7	7	0	53	53	0	8	8	0	0	0	0
9	1	MON 13 9	3	3	0	2	2	0	5	5	0	3	3	0	16	16	0	7	7	0	53	53	45	8	8	0	8	0	459
15	-1	SUN 19 9	4	4	0	2	2	0	6	6	0	3	3	0	19	19	0	10	10	0	61	16	0	9	9	0	0	0	0
22	-1	SUN 26 9	6	6	0	2	2	0	9	9	0	4	4	0	23	23	0	11	11	0	67	22	0	11	11	0	0	0	0
29	-1	SUN 3 10	9	9	0	3	3	0	16	16	0	5	5	0	24	24	0	15	15	0	71	26	0	12	12	0	0	0	0
30	1	MON 4 10	9	9	0	3	3	0	16	16	0	5	5	0	24	24	23	15	15	0	71	26	0	12	12	0	8	28	-665
36	-1	SUN 10 10	13	13	0	5	5	0	25	25	0	9	9	0	28	5	0	20	20	0	75	30	0	16	16	0	0	0	0
43	-1	SUN 17 10	17	17	0	8	8	0	35	35	0	15	15	0	34	11	0	22	22	0	78	33	0	19	19	0	0	0	0
44	1	MON 18 10	17	17	0	8	8	0	35	35	0	15	15	0	34	11	0	22	22	0	78	33	28	19	19	0	8	21	-510
46	0	WED 20 10	17	17	0	8	8	0	35	35	25	15	15	0	34	11	0	22	22	0	78	5	0	19	19	0	10	12	30
50	-1	SUN 24 10	25	25	0	12	12	0	50	25	0	18	18	0	44	21	0	23	23	0	82	9	0	21	21	0	0	0	0
52	1	TUE 26 10	25	25	0	12	12	0	50	25	0	18	18	0	44	21	0	23	23	22	82	9	0	21	21	0	9	41	-1056
57	-1	SUN 31 10	33	33	0	17	17	0	67	42	0	23	23	0	49	26	0	27	5	0	86	13	0	24	24	0	0	0	0
58	1	MON 1 11	33	33	25	17	17	0	67	42	0	23	23	0	49	26	0	27	5	0	86	13	0	24	24	0	8	14	-129
60	0	WED 3 11	33	8	0	17	17	0	67	42	0	23	23	0	49	26	21	27	5	0	86	13	0	24	24	0	10	19	-239
64	-1	SUN 7 11	42	17	0	21	21	0	84	59	0	30	30	0	56	12	0	29	7	0	93	20	0	32	32	0	0	0	0
65	1	MON 8 11	42	17	0	21	21	0	84	59	0	30	30	0	56	12	0	29	7	0	93	20	0	32	32	24	8	14	-115
67	0	WED 10 11	42	17	0	21	21	0	84	59	0	30	30	23	56	12	0	29	7	0	93	20	0	32	8	0	10	12	24
71	-1	SUN 14 11	51	26	0	30	30	0	99	74	0	43	20	0	64	20	0	33	11	0	97	24	0	41	17	0	0	0	0
72	1	MON 15 11	51	26	0	30	30	21	99	74	0	43	20	0	64	20	0	33	11	0	97	24	0	41	17	0	8	14	-34
74	0	WED 17 11	51	26	0	30	9	0	99	74	0	43	20	0	64	20	0	33	11	0	97	24	20	41	17	0	10	26	-500
78	-1	SUN 21 11	63	38	0	41	2	0	118	93	0	54	31	0	76	32	0	39	17	0	102	9	0	46	22	0	0	0	0
85	-1	SUN 28 11	75	50	0	46	25	0	135	110	0	61	38	0	85	41	0	44	22	0	107	14	0	51	27	0	0	0	0

86	1	MON	29	11	75	50	0	46	25	0	135	110	50	61	38	0	85	41	0	44	22	0	107	14	0	51	27	0	15	0	594
90	0	FRI	3	12	75	50	0	46	25	0	135	60	0	61	38	0	85	41	28	44	22	0	107	14	0	51	27	0	12	10	94
92	-1	SUN	5	12	87	62	0	52	31	0	151	76	0	72	49	0	95	23	0	46	24	0	113	20	0	60	36	0	0	0	0
93	1	MON	6	12	87	62	50	52	31	0	151	76	0	72	49	0	95	23	0	46	24	0	113	20	0	60	36	0	8	0	594
97	0	FRI	10	12	87	12	0	52	31	0	151	76	0	72	49	0	95	23	0	46	24	0	113	20	0	60	36	27	12	10	-15
99	-1	SUN	12	12	98	23	0	61	40	0	168	93	0	81	58	0	105	33	0	50	28	0	118	25	0	66	15	0	0	0	0
100	1	MON	13	12	98	23	0	61	40	28	168	93	0	81	58	0	105	33	0	50	28	0	118	25	0	66	15	0	8	7	44
102	0	WED	15	12	98	23	0	61	12	0	168	93	0	81	58	0	105	33	0	50	28	24	118	25	0	66	15	0	10	40	-1074
106	-1	SUN	19	12	111	36	0	70	21	0	182	107	0	90	67	0	117	45	0	54	8	0	125	32	0	71	20	0	0	0	0
107	1	MON	20	12	111	36	0	70	21	0	182	107	0	90	67	50	117	45	0	54	8	0	125	32	0	71	20	0	8	0	594
113	-1	SUN	26	12	118	43	0	75	26	0	190	115	0	97	24	0	125	53	0	56	10	0	128	35	0	75	24	0	0	0	0
120	-1	SUN	2	1	123	48	0	79	30	0	197	122	0	104	31	0	130	58	0	58	12	0	131	38	0	80	29	0	0	0	0
127	-1	SUN	9	1	133	58	0	86	37	0	207	132	0	112	39	0	139	67	0	61	15	0	135	42	0	89	38	0	0	0	0
128	1	MON	10	1	133	58	0	86	37	0	207	132	50	112	39	0	139	67	0	61	15	0	135	42	0	89	38	0	15	0	594
132	0	FRI	14	1	133	58	0	86	37	0	207	82	0	112	39	0	139	67	0	61	15	0	135	42	0	89	38	28	12	10	77
134	-1	SUN	16	1	142	67	0	91	42	0	214	89	0	119	46	0	147	75	0	65	19	0	140	47	0	100	21	0	0	0	0
135	1	MON	17	1	142	67	0	91	42	28	214	89	0	119	46	0	147	75	0	65	19	0	140	47	0	100	21	0	15	7	84
137	0	WED	19	1	142	67	0	91	14	0	214	89	0	119	46	0	147	75	50	65	19	0	140	47	0	100	21	0	15	0	594
141	-1	SUN	23	1	150	75	0	96	19	0	220	95	0	124	51	0	152	30	0	70	24	0	144	51	0	112	33	0	0	0	0
142	1	MON	24	1	150	75	50	96	19	0	220	95	0	124	51	0	152	30	0	70	24	0	144	51	0	112	33	0	15	0	594
148	-1	SUN	30	1	155	30	0	98	21	0	224	99	0	128	55	0	157	35	0	73	27	0	149	56	0	121	42	0	0	0	0
149	1	MON	31	1	155	30	0	98	21	0	224	99	0	128	55	0	157	35	0	73	27	0	149	56	50	121	42	0	8	0	594
155	-1	SUN	6	2	161	36	0	100	23	0	227	102	0	131	58	0	162	40	0	75	29	0	153	10	0	128	49	0	0	0	0
156	1	MON	7	2	161	36	0	100	23	0	227	102	0	131	58	50	162	40	0	75	29	0	153	10	0	128	49	0	15	0	594
160	0	FRI	11	2	161	36	0	100	23	0	227	102	0	131	3	0	162	40	0	75	29	27	153	10	0	128	49	0	12	45	-1358
162	-1	SUN	13	2	164	39	0	101	24	0	229	104	0	133	10	0	165	43	0	77	4	0	157	14	0	136	57	0	0	0	0
163	1	MON	14	2	164	39	0	101	24	23	229	104	0	133	10	0	165	43	0	77	4	0	157	14	0	136	57	0	8	70	-2341

165	0	WED	16	2	164	39	0	101	1	0	229	104	0	133	10	0	165	43	0	77	4	0	157	14	0	136	57	28	15	0	567
169	-1	SUN	20	2	167	42	0	102	2	0	231	106	0	134	11	0	168	46	0	79	6	0	160	17	0	144	37	0	0	0	0
170	1	MON	21	2	167	42	0	102	2	0	231	106	50	134	11	0	168	46	0	79	6	0	160	17	0	144	37	0	15	0	594
174	0	FRI	25	2	167	42	0	102	2	0	231	56	0	134	11	0	168	46	28	79	6	0	160	17	0	144	37	0	15	10	60
176	-1	SUN	27	2	170	45	0	103	3	0	233	58	0	137	14	0	170	20	0	80	7	0	163	20	0	152	45	0	0	0	0
177	1	MON	28	2	170	45	28	103	3	0	233	58	0	137	14	0	170	20	0	80	7	0	163	20	0	152	45	0	15	0	378
183	-1	SUN	5	3	170	17	0	103	3	0	233	58	0	137	14	0	170	20	0	80	7	0	163	20	0	152	45	0	0	0	0
184	1	MON	6	3	174	21	0	104	4	0	238	63	0	139	16	0	172	22	0	81	8	0	166	23	20	162	55	0	8	63	-2016
190	-1	SUN	12	3	174	21	0	104	4	0	238	63	0	139	16	0	172	22	0	81	8	0	166	3	0	162	55	0	0	0	0
197	-1	SUN	19	3	178	25	0	106	6	0	241	66	0	141	18	0	175	25	0	83	10	0	168	5	0	166	59	0	0	0	0
202	0	FRI	24	3	182	29	0	110	10	0	244	69	0	143	20	0	177	27	25	86	13	0	171	8	0	175	68	0	11	59	-1955
204	-1	SUN	26	3	182	29	0	110	10	0	244	69	0	143	20	0	177	2	0	86	13	0	171	8	0	175	68	0	0	0	0
205	1	MON	27	3	185	32	28	113	13	0	248	73	0	145	22	0	178	3	0	87	14	0	172	9	0	178	71	0	7	21	-510
211	-1	SUN	2	4	185	4	0	113	13	0	248	73	0	145	22	0	178	3	0	87	14	0	172	9	0	178	71	0	0	0	0
213	1	TUE	4	4	189	8	0	115	15	0	251	76	50	148	25	0	179	4	0	88	15	0	174	11	0	181	74	0	15	0	594
218	-1	SUN	9	4	189	8	0	115	15	0	251	26	0	148	25	0	179	4	0	88	15	0	174	11	0	181	74	0	0	0	0
219	1	MON	10	4	194	13	0	116	16	0	253	28	0	150	27	0	181	6	0	90	17	0	175	12	0	186	79	50	15	0	594
223	0	FRI	14	4	194	13	0	116	16	0	253	28	0	150	27	25	181	6	0	90	17	0	175	12	0	186	29	0	11	0	0
225	-1	SUN	16	4	194	13	0	116	16	0	253	28	0	150	2	0	181	6	0	90	17	0	175	12	0	186	29	0	0	0	0
232	-1	SUN	23	4	198	17	0	117	17	0	257	32	0	152	4	0	182	7	0	90	17	0	178	15	0	189	32	0	0	0	0
239	-1	SUN	30	4	203	22	0	118	18	0	258	33	0	153	5	0	185	10	0	90	17	0	181	18	0	191	34	0	0	0	0
240	1	MON	1	5	208	27	22	119	19	0	260	35	0	154	6	0	187	12	0	90	17	0	184	21	0	192	35	0	7	21	-348
246	-1	SUN	7	5	208	5	0	119	19	0	260	35	0	154	6	0	187	12	0	90	17	0	184	21	0	192	35	0	0	0	0
247	1	MON	8	5	217	14	0	120	20	0	261	36	0	155	7	0	189	14	0	90	17	0	186	23	21	193	36	0	7	0	0
249	0	WED	10	5	217	14	0	120	20	0	261	36	28	155	7	0	189	14	0	90	17	0	186	2	0	193	36	0	15	27	-756
253	-1	SUN	14	5	217	14	0	120	20	0	261	8	0	155	7	0	189	14	0	90	17	0	186	2	0	193	36	0	0	0	0
254	1	MON	15	5	222	19	0	121	21	0	263	10	0	158	10	0	190	15	0	90	17	0	186	2	0	194	37	28	15	22	-551
256	0	WED	17	5	222	19	0	121	21	20	263	10	0	158	10	0	190	15	0	90	17	0	186	2	0	194	9	0	9	0	0

260	-1	SUN	21	5	222	19	0	121	1	0	263	10	0	158	10	0	190	15	0	90	17	0	186	2	0	194	9	0	0	0	0
267	-1	SUN	28	5	226	23	0	123	3	0	264	11	0	158	10	0	190	15	0	90	17	0	186	2	0	196	11	0	0	0	0
268	1	MON	29	5	231	28	23	124	4	0	267	14	0	158	10	0	190	15	0	90	17	0	186	2	0	198	13	0	7	0	0
274	-1	SUN	4	6	231	5	0	124	4	0	267	14	0	158	10	0	190	15	0	90	17	0	186	2	0	198	13	0	0	0	0
281	-1	SUN	11	6	236	10	0	124	4	0	268	15	0	158	10	0	190	15	0	90	17	0	186	2	0	198	13	0	0	0	0
288	-1	SUN	18	6	237	11	0	124	4	0	268	15	0	158	10	0	190	15	0	90	17	0	186	2	0	198	13	0	0	0	0
295	-1	SUN	25	6	237	11	0	124	4	0	268	15	0	158	10	0	190	15	0	90	17	0	186	2	0	198	13	0	0	0	0

SUMMARY OF SALES

AND

PERFORMANCE PARAMETERS

		AUCKLAND	WANGANUI	NAPIER	WELLINGTON	CHRISTCHURCH	TIMARU	DUNEDIN	INVERCARGILL
TOTAL STORAGE	=	38490	22510	52550	29425	37521	17983	40322	32739
STORAGE REMOVED	=	31782	18679	37169	23690	30733	13769	35214	24388
NET STORAGE	=	6708	3831	15381	5735	6788	4214	5108	8351
REMOVED PERCENT	=	82.57	82.98	70.73	80.50	81.90	76.56	87.33	74.49

GRAND TOT STORAGE = 271540.
GRAND TOT REMOVED = 215424.
GRAND TOT REMAIN = 56116.
OVERALL PERCENT = 79.33

		AUCKLAND	WANGANUI	NAPIER	WELLINGTON	CHRISTCHURCH	TIMARU	DUNEDIN	INVERCARGILL
BALES HELD OVER	=	2499	1157	9708	1649	2220	282	1129	3482
PERCENT OF TOTAL	=	6.49	5.13	18.47	5.60	5.91	1.56	2.79	10.63

TOTAL HELD OVER = 22126.
PERCENT OF TOTAL = 39.42

		AUCKLAND	WANGANUI	NAPIER	WELLINGTON	CHRISTCHURCH	TIMARU	DUNEDIN	INVERCARGILL
TOTAL ARRIVALS	=	237	124	268	158	190	90	186	198
TOTAL BALES SOLD	=	226	120	253	148	175	73	184	185
REMAINDER UNSOLD	=	11	4	15	10	15	17	2	13

G TOTAL ARRIVALS = 1451
GRAND TOTAL SOLD = 1364
G TOTAL REMAINING = 87

		AUCKLAND	WANGANUI	NAPIER	WELLINGTON	CHRISTCHURCH	TIMARU	DUNEDIN	INVERCARGILL
SINGLE SALES	=	5	5	2	2	5	3	4	5
DOUBLE SALES	=	2	0	4	2	1	0	2	1
TOTAL SALES	=	7	5	6	4	6	3	6	6

TOTAL SINGLE = 31
TOTAL DOUBLE = 12
GRAND TOTAL SALES = 43

		AUCKLAND	WANGANUI	NAPIER	WELLINGTON	CHRISTCHURCH	TIMARU	DUNEDIN	INVERCARGILL
EVALUATION DAYS	=	67	48	85	44	71	31	49	77
NUMBER OF SALES	=	7	5	6	4	6	3	6	6
AVGE LENGTH EVAL	=	9.57	9.60	14.16	11.00	11.83	10.33	8.16	12.83

TOTAL EVALUATION = 472
TOTAL SALES = 43
AVGE TOTAL EVALN = 10.97

		AUCKLAND	WANGANUI	NAPIER	WELLINGTON	CHRISTCHURCH	TIMARU	DUNEDIN	INVERCARGILL
MONDAY SALES	=	7	4	4	2	1	1	5	3

TOTAL MON SALES = 27