STORE CATTLE PRICES, FEEDING STRATEGIES, AND THE OUTLOOK FOR BEEF FEEDLOTS IN NEW ZEALAND.

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ABSTRACT

An investment value model is fitted to data from the market for store cattle and a price expectations model developed for use by a prospective purchaser of steers. The model uses liveweight as the within-sales variable and responds to the major between-sales variables which are found to be ruling beef price, market mood, and climatic considerations.

A computer model of the feeding and growth of a steer is constructed and used in conjunction with least-cost rations derived from a proxy schedule of feedstuff costs and qualities to identify feeding strategies which maximize the present nett discounted value of candidate steers.

The conditions under which a prospective feedlot operator planning to make use of the optimal feeding strategy can expect the market price of candidate steers to fall below their nett present discounted value are found to include a product price advantage for the feedlot.

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CHAPTER ONE

1. INTRODUCTION AND OUTLINE OF STUDY

1.1. The Recent History of the Beef Cattle Industry.

The beef animal on many New Zealand farms has played a major part in pasture development and maintenance. Until recently the production of beef took second place to this function as a motive for grazing beef cattle. The change in emphasis took place slowly in response to changing technology of pasture management and to increasing export trade in beef, these changes being most important in the period from 1950 to the present.

Prior to 1950 a large proportion of steers were slaughtered at more than 3 years of age, the national dairy herd contributed little to the supply of beef for local consumption, and a marked seasonal swing in beef supply was evident. Most beef was consumed locally. In response to the increasing export trade and the steadily rising export prices during the 1950s and 1960s, beef cattle numbers, the proportion of steers slaughtered at 2 years of age, and total annual slaughter of beef cattle all showed increases. Some of the changes are illustrated in Table I.

From an almost complete concentration upon manufacturing quality beef, the export markets in the early 1970s offered opportunities for trade in quality beef. The relationship between export trade and local comsumption changed until export prices became the major determinant of beef price.

During this period of change substantial contributions to beef cattle numbers came from programmes of crossbreeding within the national dairy herd, and widespread interest was shown in breeds other than the traditional New Zealand beef breeds. For these, each introduction with its

Table I

Beef Cattle Population, Export Prices, Beef Production, and Domestic Beef Consumption

1957 - 1973

Year	Beef Cows for breeding. '000 head	Steers and Bulls '000 head	Beef and Veal Production '000 long tons (carcase)	Minimum Export Prices* cts/lb	Domestic Consumption '000 long ton (carcase)
1956/7	860.0	1138.8	266.5		
1957/8	896.5	1126.0	268.3		
1958/9	917.8	1137.7	234.1		
1959/60	968.4	1089	236.2	9.2	
1960/1	1047.4	1278.1	236.5	10.0	
1961/2	1113.2	1257	281.8	10.8	
1962/3	1113.7	1216	293.1	10.8	
1963/4	1141.2	1303	287.0	11.7	
1964/5	1120.0	1416.5	271.4	12.1	129 AV. (1963/4–1965/6)
1965/6	1214.2	1507.8	287.3	12.5	
1966/7	1337.9	1664.0	297.0	13.3	
1967/8	1448.0	1792.4	339.4	13.3	
1968/9	1486.3	1912.3	370.5	15.0	
1969/70	1518.6	2015.0	386.5	15.0	132
1970/1	1577	na	386.0	16.0	
1971/2	1854	na	405.0	17.0	
1972/3	1996	na	442	19.0	

* The minimum point reached by the meat exporters' schedule for quarter beef, ox and heifer, GAQ, 451-700lbs.

Source (3)

attendant publicity brought temporary price advantage to the new breed when its numbers became enough for trade. This was followed by a reversion to the same price levels as traditional breeds when the performance of high potential animals was found to be constrained by the management and feeding techniques of grassland farms.

Beef prices reached a peak in early 1974, and fell steeply. Measures were taken by Government to moderate an accelerating fall in prices, and in June 1974 a guarantee was publicised, to take effect from October 1975. The guarantee was in the form of a floor price for carcase beef and while it was at too low a level to sustain the production of crossbred calves from dairy herds and bobby calf slaughterings increased, an element of certainty was given the store cattle market. Cattle slaughtered before the date of introduction of the guarantee were sold at prices dictated by the further falls in export prices, as were store cattle judged likely to reach slaughter condition and weight before October 1975.

1.2. The Development of Interest in Feedlots in New Zealand.

The recent trends (prior to 1974) of beef price, and the uncertainty of the price outlook in alternative avenues of production, encouraged some specialization in beef activities on grassland farms. Instances where beef cattle wholly displaced sheep or even dairy cattle were not uncommon (3). The oft-quoted economy of labour attributed to beef cattle became a motive for moderating increases in other stock and for using added pasture production through beef cattle.

Improved techniques were devised or developed from those employed for sheep and dairy cattle, so that intensive beef cattle management during summer drought or winter flood would not suffer the problems of interrupted growth or destruction of pasture. Feeding on "pads" in times of stress became popular on grassland farms with high cattle concentrations.

Research work revealed practical ceilings to the physical productivity of the traditional grassland systems, and alternatives were proposed for yet more effective use of land. These alternatives included the concept of "forage farming" (62) to utilize the growth potential of newly developed strains of grass and of fodder crops which were in common use overseas. Intrinsic in these proposals were imported technology and labour-efficient methods of handling fodder. These were seen to involve vertical silos for feed storage, and the terms "forage farming" and "silo farming " became synonymous. Effort was devoted to the critical evaluation of these techniques in respect of their use in beef production (32), (51).

A number of feedlots were established in New Zealand and the choice of feedlot operation as the subject for a symposium of the New Zealand Society of Animal Production in early 1974 demonstrates the interest in feedlots. The papers presented to the symposium show a wide range of involvement in beef cattle feedlotting (e.g. (30), (50), (77).

Following the collapse of beef prices and the cessation of overseas demand for premium beef interest in feedlots became muted.

1.3. Aims, Method, and Scope of the Study.

Feedlot technology is the combination of restricting animal movement within pens, presenting feed to the confined animals, and procuring, processing and storing the feed. A feedlot operation uses this technology to accommodate animals during the period which elapses between purchase and sale.

The purpose of this study is to evaluate the prospects for feedlot operations as complement or alternative to the traditional grassland methods of preparing cattle for slaughter.

Hence it is necessary to develop a means of determining those combinations of beef price, feedstuff cost, and technology which in the New Zealand economic and physical environment offer opportunities for profit to a feedlot operator.

Methodology. An analysis requires to be made of:

(a) The market in store cattle; and

(b) The input-output relationships of a feedlot.

For the first, an investment value theory of store cattle prices is developed, a predicting model devised and fitted to empirical data, the effectiveness of the model validated against a second set of data, and then the model is used to predict market prices for store cattle under a range of beef price assumptions.

For the second, a mathematical model, ("growthmodel"), of the feeding and growth processes of a steer is developed and used in conjunction with least cost rations meeting the same constraints. The output from the growthmodel, in the form of the nett present discounted value of candidate steers, is compared with the market prices for those steers as predicted by the price prediction model. This is done under a wide range of beef price assumptions.

The method therefore depends upon mathematical modelling. Thompson (78) notes "The technique of model building is as yet adolescent and most benefit accrues to the model builder himself." Pollard (71) has summarized some of the considerations bearing upon modelling and simulation techniques relating to grazing management having rather more complex interactions than those in the present study. Grieg (32) developed his feedlot model with the aim of demonstrating the effectiveness of the modelling technique in relation to a system with complicated interactions. While by its nature a model does not duplicate the real system, agreement is growing that experimentation with a model can give important insights into the sensitivity of the real system to changes in its input levels. This is of great value where the system does not exist or cannot be the subject of exhaustive experimentation. Doubt always remains, however, that the assumptions built into the model are faulty even when model output cannot be distinguished from that expected of the real system. This doubt is perhaps no more than a reflection of the scepticism which normally greets any prediction of biological or economic processes.

The non-linear market model is fitted to data by suitable regression techniques and hence is conditioned by the data used. The growthmodel involves the interpretation of the biological processes described in the scientific literature and their approximation by a series of simple mathematical expressions. Quite clearly biological sytems, such as that of a growing steer, are subject to random variation. This suggests that a degree of stochasticity is an essential element of the model. In the interests of simplicity this has been avoided, and the model has been constructed in completely deterministic terms. The major sources of variation - variation in feed quality and variations between animals - are removed by using the subjective expectations of a proxy feedlot operator to set the model parameters and variables which might better be considered as frequency distributions. An obvious later refinement would utilize simulation methods to test output of expected outcome from stochastic input against deterministic output from "expected" input.

The growth model is validated by examination at two levels - against cattle performances recorded in the literature, and against the convictions of the prospective operator, in this case represented by the author. This personalistic approach is not considered to detract from the usefulness of the results, since in animal husbandry it is well recognized that "stockmanship" and other attributes differ between managers and have significant effects upon outcomes. Were feedlots to be found commonly in New Zealand, it would be found that some were better than others. This study aims to consider the best operator, and by identifying the conditions under which he can make profits, set the minimum conditions for a viable feedlot industry. Should those conditions at some stage be met, a second refinement of the model might be of use to examine the probability of any given operator finding himself making profits.

The background and development of both the price predicting model and the growth model are presented in detail and demonstrate the wide diversity of the scientific disciplines which are needed to assist management of sophisticated livestock activities. One of the facets of system modelling which has been emphasised by Wright (84) is the interdisciplinary coordination which is called for. This is easily appreciated in a research environment but is not so clear in applications to commercial farm management, where the range of skills characteristic of managers may be limited and communication with advisors and technical experts may be ill-developed.

Scope. The thesis combines an analysis of the process of price formation in the store cattle market with the choice of optimal feeding strategies for feedlots. Hence the whole range of potential marketing and operational choices is embraced. The isolation of the technical aspects of feedlot management from the cattle marketing aspects maintains the separation of the effects of each aspect of management, and the problem is avoided of prejudging the outcome by making a prior selection of either technology or of store cattle price patterns.

Thus the scope of the study is wide-ranging, and the conclusions are limited in their generality only by the assumptions, most important of which is the assumed schedule of feedstuff costs and qualities.

1.4. Chapter Outline.

Following the introductory matter of this Chapter the processes of price formation and discovery in the market for store cattle are reviewed and summarized in Chapter Two. This includes a description of the beef industry flows and selling channels, an analysis of the auction process in New Zealand livestock markets, the development of a hypothetical price prediction model, and the use of data from the weekly market at Feilding to estimate the parameters and validate the model as a tool for price prediction.

Chapter Three is devoted to the elaboration of a mathematical model of the feeding and growth of a steer. Special attention is paid to consistency with established nutritional relationships. The model is designed to incorporate subjective values for the parameters which influence performance.

Chapter Four includes the derivation of cost and quality schedules for feedstuffs, the formulation of least cost rations meeting the constraints of the growthmodel, and an examination of the characteristics of these least cost rations.

Chapter Five examines the nett present discounted values of candidate steers by use of the least cost ration schedule in conjunction with the growth-model. The optimal feeding strategies which maximize the present value are investigated under alternative assumption sets.

Chapter Six brings together the market and the feedlot by identifying situations in which the market price of steers is exceeded by the computed value to the feedlot operator. The characteristics of these situations are examined and the practical implications pointed out.

Chapter Seven summarizes the conclusions, evaluates the usefulness of the method of study, and discusses factors which may improve the competitive ability of feedlots.

CHAPTER TWO

PREDICTING PRICES FOR STORE CATTLE

2.1. Stratification of the Beef Cattle Industry.

The historical development of New Zealand agriculture led first to localized concentrations of arable farming on level land where cultivation could control regrowth. Dairy farm expansion followed in other fertile and humid areas, and the more remote, less fertile, and steeper country was cleared and used for grazing sheep. Beef remained for a long time a byproduct of the dairy industry and of the widespread and effective use of cattle in the development and maintenance of pasture.

Local demand for beef increased as urban populations expanded, and a beef producing activity was generated. This was carried out on farms located in fertile areas close to the towns and was dependent for its stock not upon its own reproductive activity but upon the herds of cattle maintained on steeper, rougher, and less fertile regions for the purposes of pasture maintenance.

This situation persisted until recent years. The two decades of the 1950s and 1960s reduced the dependence of farmers on the second class land upon cattle as a tool for pasture management. Aerial application of fertilizer, mechanized methods of pasture establishment, intensified sheep stocking rates, and closer control of grazing by subdivision, were the factors playing major parts in this change. During the same period much research and extension effort was devoted to reducing age at slaughter and improving reproductive efficiency.

At the same time as these changes were occurring, local consumption of beef increased and significant export markets for quality beef were established. Though the technical necessity for cattle on less favoured grassland farms had diminished, the output from the beef herd on this class of country now made a significant contribution to farm profit. Thus changes in technology did not result in a reduction of the beef herd on hill country - rather the reverse. The composition of the herd, however, did show changes, with breeding cows and their replacement heifers now predominating and the once common herds of heavy bullocks almost disappearing. The offtake from the hill country farms consequently has changed, with bullocks for slaughter diminishing in number and steers, heifers, and cull cows in store condition making up the greatest proportion. The proportion of cows which survive to slaughter has also increased.

The heightened demand for beef in recent years has encouraged lowland farmers to expand their cattle feeding activities; these became productive and profitable operations instead of low cost means of disposing of surplus grass. The increases in beef price were thus passed on to the hill country farmers whose offtake did not reach slaughter standard.

The beef industry has therefore developed a separation of functions, with reproduction being the primary function of farms on the less fertile hill country, and final growth to slaughter being the primary function of farms located in favoured fertile areas. Both functions are normally subordinate to other farm activities, and the pasture consumed is commonly a surplus resulting from incomplete utilization of the feed by the other preferred grazing animals. It would seem in retrospect that the use of beef cattle to utilize this surplus fodder on the second class country is more an historical accident than "Free market forces work(ing) to reserve the better areas for fattening and enticing the breeder on to the poorer country where he has a comparative advantage." (80) It is reasonable to suppose that less than perfect flock management leads to patchy and seasonal feed surpluses which in past years were unavoidable but which use of better sheep grazing management methods can prevent. A continuation of recent improvements in flock management techniques, coupled with more insistent financial pressures than have been evident in recent decades, may well reduce the use of cattle on hill country farms.

Nevertheless, the stratification of the industry has developed, and with it the marketing channels which facilitate the flows of cattle from farm to farm. Even should the original reasons for the stratification be eroded, sales and purchases of store cattle will continue, and will make use of the methods now established.

2.2. Selling Channels.

2.2.1. Slaughter Prices and Selling Methods.

The rationale for the production and trading of beef cattle is the satisfaction of the demand for beef. About 70% of adult cattle sold for slaughter are sold at schedule rates to the meat export companies (3) and payment for these is immediate on the basis of measured carcase weight and grading standards. A small proportion of export sales are on "own account" or through producer marketing cooperatives. Some animals are bought for slaughter by a buyer's agent in the paddock, and occasionally in saleyards slaughter cattle which do not command a price higher than the ruling export schedule are bought by export buyers.

Sales of cattle for slaughter and local consumption usually take place through commission agents and wholesale operators with price paid on a carcase weight/grade basis. The unit price in these instances can be the subject of negotiation but is normally based on the meat exporters' price schedule. (50). Some cattle are sold to butchers on a per head basis either in the paddock or the saleyard.

Most slaughter cattle are therefore priced by reference to the ruling meat exporters' schedule. The exceptions, occurring at times when stock for local consumption are seasonally scarce, carry a scarcity bonus over that schedule. This situation represents a substantial change from the pricing methods prevalent in earlier years when in general local demand set the price level and purchases for slaughter were commonly made on a per head basis in the paddock or in the saleyard.

2.2.2. Markets for Store Cattle

The demand for store cattle is derived from that for slaughter cattle, and as noted above the prices for all slaughter animals are based on the same export schedule. The transfer of cattle from breeders to finishers and from traders to finishers takes place by diverse methods all of which are carried out under full knowledge of the export schedule. The differences in price paid for comparable store cattle sold by different methods are generally accountable by the specific direct costs of each selling channel. The three main channels of transfer are regular auction markets, irregular auction markets, and private treaty.

Regular auction sales of store cattle are held each week at centres strategically situated in relation to the flows of cattle into and within regions where cattle finishing has become common farm practice (e.g. Frankton in the Waikato, Feilding in the Manawatu, Addington in Canterbury). Of the cattle moving between farms within these areas a large proportion is channelled through these markets.

In regions where breeding cattle predominate and where flows of store cattle are generally seasonal, sales are organized at monthly, seasonal, or yearly intervals (e.g. Dannevirke, Gisborne, Fordell, etc.). Demand at such sales usually originates in other regions, and the inter-relationships of regional weather conditions and feed availability dictate the direction of movement of cattle sold at these markets.

Sales by private treaty are found less commonly than in the past (50). In cases where sales take place at an agreed price per head on the property of the vendor, a continuing relationship is often discernible between vendors and their usual customers. The advantages quoted in such instances include certainty of supply and of quality (on the part of the buyer), and economy of transport costs and confidence in a fair price (on the part of the vendor).

The increasing cattle population, the consequent burgeoning trade in store cattle, and the increased confidence which vendors can hold in finding a buyer at a reasonable price in the open market are contributing to an erosion of the advantages which may have attached to selling by private treaty in earlier days.

The changes in store cattle marketing which are noted have been occurring gradually as responses to the increased scale of cattle trading and the increasing importance of the export trade. Such changes will continue, and one of the problems faced by analysis of prices in the store cattle market is the accompanying structural changes in the mechanisms of price formation and discovery.

2.3. The Prices Discovered at Auction.

With all transfers of store cattle occurring when both buyers and sellers have complete knowledge of the ruling price schedule of the meat exporters, and with the largest proportion of these transfers taking place through livestock auction markets, the prices discovered at auction markets become the reference prices for store cattle sold by whatever means. Knowledge and understanding of the process of price formation and discovery at auction markets is therefore basic to an understanding of the internal economics of the beef cattle industry.

2.3.1. Related Studies.

In a study of cattle auctions in Florida McPherson (57) placed emphasis on an "ideal" market and measured inefficiencies in the operation of local markets by the divergence of their prices from those which would be paid in the "ideal" market.

Johnson (40) describes linear regression equations fitted to sales data from nearly 90,000 animals. The variables include grade, estimated dressing percentage, size of market, and a time variable. While the regression equations accounted for more than 70% of the price variation at the sales his conclusions offer little assistance in determining the pricing mechanism. Another paper by Williamson et al (82) carries this procedure further, but groups the lines into liveweight ranges.

In relation to the present purpose, these American studies have deficiencies one of which is the unexplained constant term in the regression equations.

The explicit acknowledgement that the demand for store cattle is a derived demand appears important to the problem of identifying the mechanisms of formation, and in this respect the paper by Working (83) and that of Taussig (74) to which Working makes reference are of interest in highlighting the importance of price expectations in price formation for commodities and thus of the time factor inherent in the feeding of store cattle.

In New Zealand, Thompson (76) reports regression equations fitted to the price and liveweight data from annual weaner sales. The equations are of the form:

Expected price = Liveweight component + Market Component

The correlation with the data was shown to be extremely high but the equations were not useful as predictors, and the brevity of the data series (from two sales in each of the years 1971, 1972, and 1973) gives little base for understanding the constant term ("market component"). Thompson speculates that it represents a function of demand, and lists four factors which probably affect it - prices for wool and mutton, confidence in the beef market, availability of cash, and availability of feed.

Kingma (44) develops a linear regression equation relating annual beef prices with liveweight and with the ruling meat exporters' schedule in the same manner as Thompson (76). While this gives further support to the use of the meat exporters' schedule as a beef price predictor for buyers of store stock, the linear formulation and the aggregation of data precludes use of Kingma's equations from use in the examination of the mechanisms of price formation except in the most general terms.

Walker (80) has carried out an exhaustive analysis of price formation in the New Zealand store cattle market. His study is limited, as he emphasises, by the aggregated, subjective, and probably biassed nature of his data. The long time series (1957-72) covering a period of drastic change in the beef cattle industry probably includes some trends and structural developments affecting the process of price formation. Walker's results are of a general nature and indicate the direction in which various factors act upon prices. Since the data is aggregated, the mechanisms through which these factors exert their effects is not analysed. This study does make one comment pertinent to the mechanisms of price formation - "... the results did indicate that the behaviour of farmers in New Zealand with respect to the prices paid for store cattle is consistent with investment behaviour, making due allowance for the time which will elapse between purchase and slaughter." Also quoted is the South Auckland Beef Development Committee to the effect that "... store cattle prices fluctuate from year to year but are closely associated with the beef carcase export schedule prices.", and Walker by using the schedule price as a variable in his regression postulates its use by farmers as a naive predictor.

Lattimore (48) states "many other factors may influence the price of store cattle beside the beef schedule price. The supply of store beef cattle is a very complex function of past prices and past trends in breeding cow numbers. This implies that a lagged statistical model is necessary to explain present store cattle price." This conclusion implies that the price of store cattle is a function of supply, and tends to conflict with Walker's cautious conclusion that farmers' behaviour is not inconsistent with investment behaviour. Lattimore also mentions restrictions on killing space at freezing works, grass condition, and grading effects as being important in determining store cattle prices; and cost of rearing as a factor in the decisions of raisers of dairy beef animals.

Some light is thrown on the relationship between the level of expressed demand and price (in the U.S.A.) by Ehrlich (26). Starting from the reasoning of neo-classical firm theory he states "... it is clear that the quantity of cattle placed on feed should be a function of expected fed-cattle prices, feeder cattle prices, and prices of other factors of production." He quotes results consistent with this theory and then, by adding a further three year's data to the series, shows that the statistical results do not hold. A second piece of evidence he puts forward is that over the data period annual marketings of fed cattle did not vary cyclically as did total commercial slaughter of all cattle. Ehrlich makes the point that despite fluctuations in total slaughter and in prices of beef and of fed cattle, the quantity of feeder cattle demanded "has apparently been affected primarily by feedlot capacity and its growth over time."

The paper by Papadopoulos (70) is of restricted interest in the present context, dealing as it does with beef cattle (i.e. slaughter cattle) prices in Australia. The examination involving shifts in supply and demand and their relationships with the price framework is not of relevance to the New Zealand store cattle market.

2.3.2. Bidding Behaviour.

To analyse the store cattle market to predict prices for particular lines of cattle requires some investigation of the behaviour of buyers and sellers. In particular, the negotiating framework and the physical setting need to be understood in relation to that behaviour.

The lines (lots) of cattle offered and sold at auction are each made up of cattle which have broad similarities and are offered by a single vendor. Only very rarely are mixed sex lines offered, but not uncommonly a mixture of ages is combined in one pen. Breeds are usually segregated, but again, pens of mixed breeds are found at most auctions. The size of animals in a single line varies, as does the condition.

Each line of cattle differs in some respects from the others; even the geographical origin is sometimes considered an important attribute. So the cattle offered at any market are far from homogeneous. As well, those characteristics which are thought to affect price can be evaluated by judgement only - no objective measurements are available.

The supply to the sale in the short term may be taken as fixed, although a vendor is able to withdraw his offering prior to the completion of bidding on the line. The quantity demanded, by contrast, becomes fully known after completion of the full auction. The price of each successive line is not known until after the sale of that line.

Under these circumstances the statement by Sosnick (72) "The heart of the bidding problem is that auctions tempt buyers to impose almost perfect discrimination upon themselves" (i.e. that the buyers of earlier lines are those bidders who are prepared to offer higher prices and thus pay more; once their demand is satisfied, the price level falls, and so on throughout the sale), might expect to find confirmation in the sales records. Sosnick offers some reasons why this tendency is not generally revealed, but in practice, since bidders at such auctions are customarily shrewd and experienced, one might expect evidence of strategies aimed at reaping advantage from such a trend, thereby extinguishing it.

If indeed it is the normal condition for a time trend to be absent, the questions might well be asked "how is an equilibrium market-clearing price level to be spontaneously established at the start of the auction, so that lines varying in quality will receive no more than appropriate deviations in price?". "How can the price level which will clear the market be established right at the start, when it will not be known whether in fact the market is cleared until the final line is sold?". "If in fact the demand represented by the bidders is shown to be in excess of the fixed supply of livestock, why does not an upward trend in prices reveal itself?".

These questions all imply that prices at auction are determined by events at that auction. But is that so? Referring to Sosnick again, "... the essence of what might be the shrewd strategy is easy to grasp. The bidder simply regards the present lot as a substitute for a interchangeable waiting lot that he expects to buy if he does not buy the present lot. It pays our bidder to substitute the present lot, provided that he can thereby reduce his expected subsequent outlays by more than he pays at present. The reduction in expected subsequent outlays set his optimum upper limit in bidding for the present lot." The concept of an optimum upper limit is thus introduced, peculiar to each lot in a heterogeneous sale. The "interchangeable waiting lot" need not, of course, be a line of cattle physically present at the sale. It may be no more than an expression of personal conviction about the "going price".

The concept of a bidding limit is common currency in New Zealand livestock markets. Newspaper articles refer to "limits being raised"; disappointed bidders say "the bidding went above my limit".

The inference of individual bidding limits does not satisfy the questions posed. Given the reality of limits, formed in some way by each prospective bidder, how does this enable the general price level to be set in the first few minutes of the auction?

The series of auction experiments performed by Frahm & Schrader (30) "... suggest that the pricing process under less than perfect knowledge is far less determinate than is often acknowledged. ... More perfect knowledge and/or less variation in price determining factors would be expected to reduce variation..." Working (83) earlier pursued the same line of reasoning. From these conclusions the question follows "Are livestock auctions in New Zealand carried on under "perfect knowledge"?". This would imply that the limits established by different bidders are in fact set at the same level.

This discussion has conveniently shelved the heterogeneity of lines offered at a cattle auction, except that reference has been made to "appropriate deviations in price". This point will be further covered in a later section.

The various questions raised can be summarized:

(a) Is there a time trend at New Zealand livestock auctions, and if so, what are the circumstances that promote it?

This question will be re-examined using data from the Feilding market; for the moment it is assumed that there is no time trend.

(b) Is the variability of price (given the heterogeneity of lines presented for sale) consistent with a theory of "perfect knowledge" and of low variation in price determining factors?

This question also will be examined with the help of empirical data; for the moment the assumption is taken that the answer is positive.

(c) Are livestock auctions so operated that bidders invariably (or nearly so) reveal their individual limits?

(d) What are the price determining factors; do bidders have full knowledge of them, and are all bidders subject to the same factors?

2.3.3. <u>The Procedure at Livestock Auctions</u>.

In this section an attempt will be made to answer question (c) above.

In New Zealand, livestock auctions are usually operated using the yards of saleyards companies, the shareholders of which may be either those companies in active business as "stock agents" or consortia of local farmers who are sellers on a regular or a seasonal basis. Whatever the ownership of the physical market facilities, the conduct of the auction is in the hands of the auctioneers and their helpers, all employees of the stock and station agencies ("stock agents", "stock firms"). The immediate recompense to such firms is derived from a commission on sales, deducted from vendors' receipts. Whilst cooperating in the organization of each market, and sharing the work involved, these firms are intensely competitive for market share, i.e. the proportion of vendors channelling their business through one firm. This is of paramount importance in determining the amount of ancillary business directed to them. Both market share in the long run, and immediate return in the short, are maximized by a company when maximum prices are paid for the livestock auctioned under its aegis.

Each auctioneer therefore operates under pressure to ensure that maximum prices are paid for lines of stock under his control. If the concept of buyers' limits is accepted as realistic, this implies that each line will be sold to the bidder who at the time holds the highest limit on that line. The auctioneer must work within the rules, which in New Zealand permit the auctioneer himself to suggest a level for the first bid. In the normal sequence this asking bid is steadily reduced in the fashion of a Dutch auction until a bidder responds. Bidding is competitive thereafter, with the magnitude of the raises set by the auctioneer according to the rate of bidding. The raises are smallest as the auction of each line nears its end.

Each bid as it is made is reported to the auctioneer by his helpers, since bidders do not commonly flaunt their activity. This opens the possibility of false bidding on the part of the auctioneer or his assistants on occasions when bidding flags, and this illegal practice is popularly supposed to be used by auctioneers to encourage timid bidders.

The vendor has the right to one bid, which if he makes it represents the reserve price below which he will withdraw his stock from offer. Commonly, however, the auctioneer asks the vendor at appropriate stages whether the bidding has reached his reserve price. With an affirmative answer the line is open for sale to the highest bidder. If the reserve price has not been reached, the auctioneer continues attempting to elicit higher bids. If the highest bid ultimately forthcoming fails to exceed the reserve price, the line is passed in (not sold to the highest bidder), although it is usual for private negotiations to continue in such cases, with many passed lines finding new owners before the end of the day. In such circumstances the actual sale price is not publicised.

Lines which are not passed in are sold to the highest bidder when no further bids are forthcoming, or, alternatively, when the time limit expires. The organizers take care that bidders cannot foretell the moment of time exhaustion and use it to their own advantage.

Within this framework the auctioneer is permitted to use all reasonable means for extracting higher bids. These means include the description of the line in such terms as he supposes will persuade the reluctant bidder to speak. Notwithstanding this freedom, except on matters of indisputable fact (e.g. number in a line, ownership, sex, etc.) the buyer must rely solely upon his own judgement to evaluate a line.

The auction system is evidently designed to put pressure upon bidders to reveal their highest bids - their limit bids.

Thus one question is answered.

2.3.4. The Derivation of the Upper Limit.

In this section an attempt is made to answer question (d):

"What are the price determining factors ......?"

An investigation of bidders' limits does not start expirical data, although it is conceivable that close questioning of prospective bidders might yield accurate information on the upper limits held by each. The major impediment to such an approach is the unformulated nature of the limit and the inarticulacy characteristic of many saleyeard habitues when facing the need to express an independent concrete opinion. Discussions which attempt to define limits seem always to bog down in irrelevancies. Evidently, only the collective support of all bidders for each other, with the implication that the present bidder if he speaks will not be considered an extravagant fool, encourages each bidder to make his offer.

The nature of the limit appears to be such that bidders do not know what it will be in respect of any one line; they know only what it was, be they successful or unsuccessful. Further, the actual bidding process in the progressive auction seems to assist each bidder in finally defining his limit bid, even though that limit is primarily determined by factors external to the auction. This apparent conflict arises, it is suggested, from the feedback from the other bidders being of assistance to the present bidder in refining his estimation of the various factors contributing to his limit bid.

Thus, for as long as bidding continues, bidders reinforce each other's value estimations. Such reinforcement would be lacking in such a form of sale as the Dutch auction, and use of this system might therefore be expected to result in lower and more variable prices being discovered, since no consensus would then be available to assist the present bidder in forming his judgement.

Were livestock susceptible to objective measurement leading to a formal computation of "real" value, such a value would appear likely to bear a close relationship to the limit bid. If this real value differed significantly between bidders, this would imply that their limit bids also would tend to differ. But since such objectivity is unreal in relation to store cattle it might better be supposed that the limit bid of any bidder on a given line is his estimate of its real value.

The problem of determining the limit bid is then broken down into two simpler problems - that of quantifying this "real" value; and that of relating estimates to it. None of the influences described above - upward pressure on bids by the auctioneer, presence or absence of a downtrend, quick establishment of the price level - are of any help in defining this real value.

Reference has been made to Walker's conclusion that the behaviour of New Zealand farmers in respect of store cattle prices is consistent with investment behaviour. Yver (85) bases his analysis of the Argentine beef industry on the assumption that farmers behave as investors. The investment value would seem to be the best summary of any real value inherent in store cattle, and under the hypothesis that bidding limits are in fact estimates of the investment value, those factors which determine investment value are identical with those that determine bidding limits.

These factors are:

The beef price predictor;
The liveweight, carcase yield and grading at slaughter;
The time period elapsing between purchase and slaughter;
The stream of costs incurred over that time.

The homogeneity of bidders with regard to their use of the ruling meat exporters' schedule as a predictor of future beef prices has been noted. The expected carcase weight and grading at slaughter is likely to be based upon the characteristics of the schedule, rather than upon factors differing between bidders, so these expectations too will be relatively invariable.

The time period before slaughter, and the stream of costs over that time are in fact a function of management. Again, the prevalence of the conventional system of grassland farming is to be noted. The implication is that expectations of rate of liveweight gain, daily costs, and the associated factors will exhibit low variance between bidders. Estimation of the liveweight of the candidate animal, and of the liveweight corresponding to the expected carcase weight at slaughter are the two factors which interact with management considerations to form an expectation of the time period between purchase and slaughter. It is in the estimation of liveweight that the greatest variation between bidders is hypothesized.

To reiterate: the prevalence of the conventional system of grassland farming supports a hypothesis that the various expectations formed by bidders in their estimation of the perceived investment value of a candidate animal will exhibit a low variance; it is in estimation of liveweight and the relationship between liveweight and carcase weight that important between-bidder differences might be expected.

Liveweight Estimation and Carcase Yield. Despite the probability that estimation of liveweight is critical to an evaluation of store cattle on offer, persistent questioning of prospective bidders does not reveal a single individual who habitually makes explicit estimates. Invitations to estimate weights are in fact not welcome, the inference being that each individual holds a low opinion of the accuracy of which he is capable. Personal experience suggests to the writer that this belief would be fully confirmed by trial, although the ability to rank cattle by weight is learnt quickly by stockmen. Nevertheless, sale habitues are most interested to hear and criticize weight estimates made by others, and it is not often that an unsolicited estimate passes unchallenged.

In earlier days, when slaughter cattle were usually bought on a per head basis and the local beef market did not follow the export market so closely, buyers necessarily learnt to estimate the carcase weight of cattle offered (50). Men trained in these circumstances still retain this ability and are inclined to proffer liveweight estimates. Despite the recognition that carcase yield (i.e. carcase weight as a proportion of liveweight) varies according to liveweight and to condition, and might have for individual cattle a value ranging from perhaps

45% to 64%, (34) it is common practice for a value of 50% to be used. (A recent tendency to vary the assumed yield has been noted by McCaw (50)). This method of liveweight estimation thus depends upon estimation the carcase weight and multiplying by the reciprocal of the yield. Clark et al (14) refer to guesswork in this connection, and exhibit the results of a trial which shows that estimates of carcase weight by experienced judges tend to be too low. Barton (4) says "little is known about dressing-out percentages (yields) under New Zealand conditions." In any event this method of arriving at a liveweight estimate is used by only a small proportion of prospective bidders, and not generally by farmers.

For the great majority of bidders, the indication is that liveweight estimation is rarely explicit. The attitudes revealed by discussions in the saleyards suggest that a consensus estimate is arrived at; since general communication between bidders takes place only during the auction itself, this consensus must be reached by consideration of the bids themselves. For this to be so the bids on the early lines offered, presumably made by those who have most confidence in their own judgement, must establish in the bidders mental scales against which later lines are ranked and compared.

The answer proposed to the question which started this section is that the price determining factors are the same as those which determine investment value; that bidders at New Zealand are to a very great extent subject to the same factors (i.e. each factor shows little variance over the population of bidders); that in some of the factors a high degree of knowledge is possessed by every bidder (e.g. the beef price predictor), while in others the fact that bidders share a similar technology enables feedback from the bidding to assist each in moving his estimate closer to a "consensus" value.

2.4. An Investment Value Model.

The hypothesis that prices in the store cattle market approximate investment values, and that this will assist in predicting prices, is investigated by means of a model of the form:

$$\text{Price} = V = aLPe^{-rt} - (1 - e^{-rt})C/r - FW \quad \text{cents/head} \qquad \ldots\ldots\ldots(1)$$

where a is the expected carcase yield at slaughter;
P is the beef price predictor (cents/kg carcase);
r is the daily discount rate;
C is the daily cost of holding (cents/head);
F is the fixed cost of the complete transaction (cents/kg);
W is the present liveweight (kg);
and t is the expected time between purchase and slaughter given by:

$$t = (L - W)/g$$

where L is the liveweight at slaughter (kg);
g is the expected rate of daily liveweight gain.

For simplicity the daily cost is assumed to be independent of age and of liveweight, so the second expression in model (1) is the present value of the stream of daily costs from the day of purchase to slaughter. The first term is the expected value at slaughter discounted over the expected time period. The third term is based on the assumption that costs of the nature of commission or transport are capable of present estimation by buyers whenever the actual payment of them occurs, and hence are deducted in full from the purchase price. These costs will show a close relationship with the size of the animal.

Model (1) can be reformulated so that price per unit liveweight is the dependent variable, and this is the form employed in subsequent sections.

$$V_k = (aLP + C/r)e^{-rt}/W - C/rW - F \quad ....(2)$$

2.4.1. Model Behaviour.

In this section the model (2), on the basis of the unit liveweight, will be analysed, and compared with the actual behaviour of store cattle prices.

Relation of Unit Price with Liveweight. The conclusion of Walker (80) "... Thus store cattle prices per pound will be greater than schedule prices per pound; approaching equality at slaughter weights.", is derived from an analysis of price data and applies to New Zealand conditions. It is no more than a confirmation of common knowledge. This relationship implies that the rate of change of unit price as liveweight increases is negative, i.e. that unit price falls at liveweight increases.

A situation which contrasts with this has been discussed by Ahearn (2) who wrote about the cattle market in the United States in 1956. He states "... The unit price of feeder calves refers to calves weighing about 400 pounds. .....the farmer can pay the same price per pound for a calf that he expects to sell as a beef steer and still make a profit, assuming feed and labour costs are at a reasonable level. Although the feeder prefers to pay less, he may even pay a little higher price for calves than beef steers will sell for, and yet make a profit on feeding. On the other hand yearlings weighing from 600 to 800 pounds .... must be bought for less per pound than beef steers will sell for after feeding is completed. In other words the difference in (unit) price between beef steers and yearlings must be positive."

Evidently, from this description, the market about which Ahearn writes exhibits an increase in unit price with increasing liveweight, except at the lower weights where unit price may remain constant over a range of liveweights, or even show a slight fall as liveweight increases.

Differences between the beef cattle industry of the United States and that of New Zealand as they affect the price of store (feeder) cattle might be found in the beef price and the daily cost of feeding cattle, and in the growth rates attained, since while the feeding of cattle in New Zealand is carried out on grazing, in the U.S.A. this has been traditionally done in feedlots using corn and corn silage as the basic feed. The effect of changes in these values upon the model can be tested by holding the other parameters constant and identifying changes in the relationship of unit price with liveweight.

The following examination of the function and its derivatives permits a classification to be made of the situations facing an investor in cattle.

$$V_k = \frac{C}{rW}((raLP/C + 1)e^{-rt} - 1) - F \ldots.(2.1.)$$

so, $$dV_k/dW = \frac{C}{rW^2}((raLP/C + 1)(rW/g - 1)e^{-rt} + 1)..(2.2.)$$

and when $dV_k/dW = 0$, $raLP/C + 1 = e^{rt}/(1 - rW/g)$

$$\text{and } P/C = \frac{e^{rt} + rW/g - 1}{raL(1 - rW/g)} \ldots\ldots\ldots\ldots\ldots(2.3.)$$

also, $$d^2V_k/dW^2 = \frac{C}{rW^3}((raLP/C + 1)((rW/g - 1)^2 + 1)e^{-rt} - 2)$$
$$\ldots\ldots(2.4.)$$

The value of the second derivative when the first derivative is zero, is found by substituting the value for P/C given by (2.3.) into (2.4.)

$$d^2V_k/dW^2 = \frac{C}{rW^3}(((rW/g - 1)^2 + 1)/(1-rW/g) - 2)$$

$$= \frac{C}{rW^3}\left(\frac{(rW/g)^2}{1 - rW/g}\right) \ldots\ldots\ldots\ldots\ldots (2.5.)$$

The value of (2.5.) is always positive when $0 < W < g/r$ i.e. for all values for W in this range an extremum in the curve $V_k = f(W)$ is a minimum. Under these conditions there is only one minimum and the curve is strictly concave.

The minimum value taken by the R.H.S. of (2.3.) for positive values of W is found as W approaches zero. This value approaches

$$P/C = \frac{e^{rL/g} - 1}{raL} = M$$

Hence, when $0 < W < g/r$, the curve $V_k = f(W)$ is strictly concave if $P/C > M$.

Now, when $W = L$, i.e. at the point of slaughter, $V_k = aP - F$. Hence as W approaches L, V_k may approach $aP - F$ from above or from below. If $V_k = f(W)$ approaches the line $V_k = aP - F$ from above, dV_k/dW will be negative as W approaches L.

Hence, putting $W = L$ in equation (2.2.), when dV_k/dW is negative:

$$\frac{C}{rW^2}\left((raLP/C + 1)(rL/g - 1) + 1\right) < 0$$

i.e. $$P/C > \frac{1}{a(g - rL)} \qquad (= N)$$

The value of N can be shown to exceed that of M, for all positive values of rL/g.

Thus a classification of investment situations is possible, in the circumstances where the maximum value reached by W(ie. L) does not exceed the value of g/r, and F is assumed to be zero:

Class I — when $P/C > N$; V_k always exceeds aP, for values for W between zero and L.

Class II — $N > P/C > M$; at low values for W V_k exceeds aP; as W increases, V_k first falls below aP and then rises to approach aP as W approaches L.

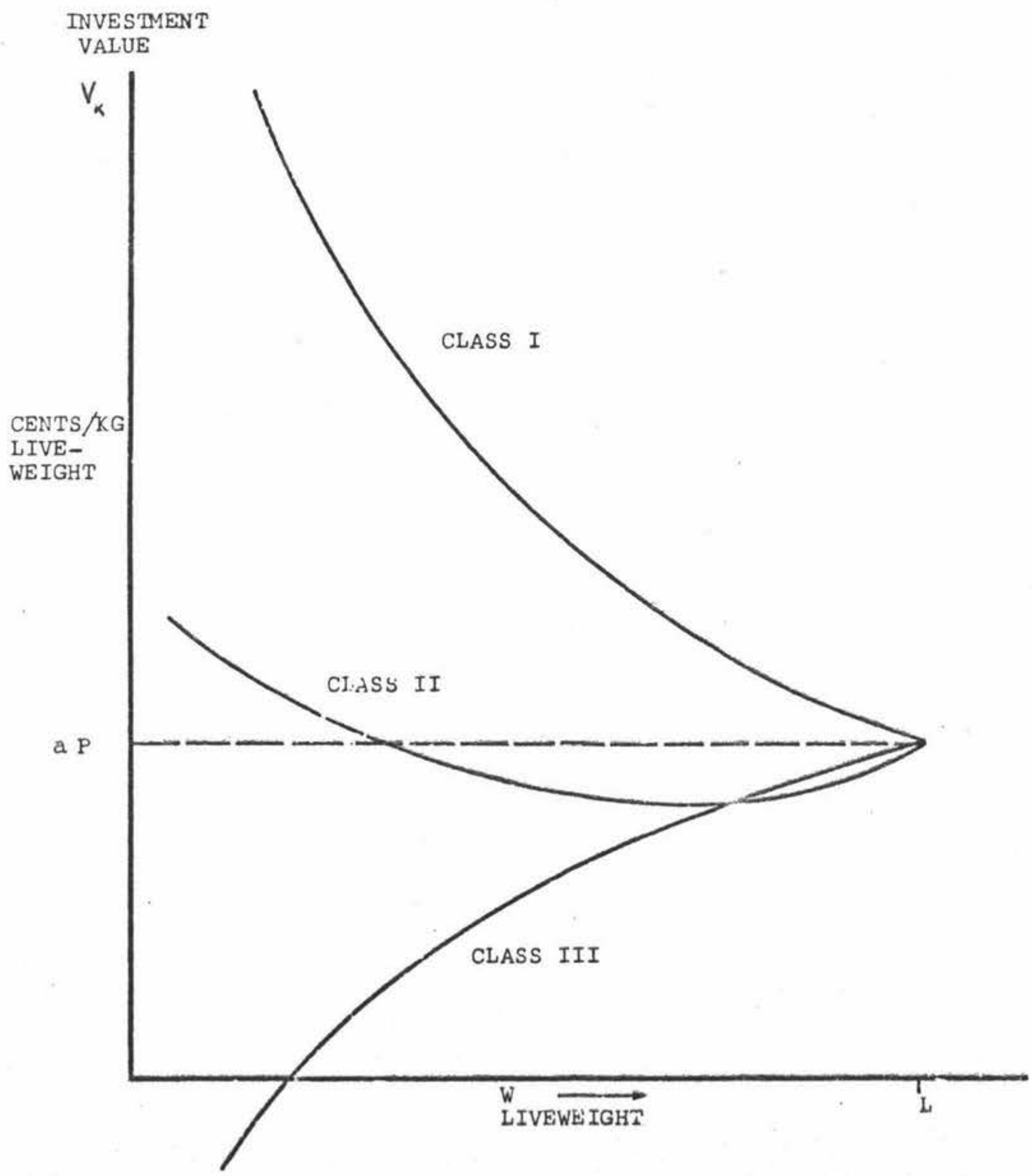
Class III — $M > P/C$; for all values of W less than L the value of V_k is smaller than aP, and as W approaches zero V_k becomes very small. This classification is illustrated in Figure 1.

FIGURE 1.

Three Classes of Investment Situation.

(see text)

Using the model $V_k = \frac{C}{rW}\left((raLP/C + 1)e^{-rt} - 1\right) - F$; with F = 0.



The critical values for the ratio P/C which define the boundaries of the Classes depend upon the four parameters, r, g, L, a, each of which is assumed to be constant with changes in W. To investigate the relevance of the classification to the real world, sets of critical values have been prepared as shown in Table II.

TABLE II

Classification of Investment Models:-
Critical Values for P/C.
(see text)

Assumed: Discount rate - 0.0003288 p.d. (r)
Slaughter weight - 550kgs L.W. (L)
Carcase yield - 0.59 (a)

g kg/day	M*	N**
0.5	4.08	5.31
0.75	2.56	2.98
1.0	1.86	2.07
1.25	1.46	1.59

$$* \quad M = \frac{e^{rL/g} - 1)}{raL}$$

$$** \quad N = \frac{1}{a(g - rL)}$$

Class I: $P/C > N$
Class II: $N > P/C > M$
Class III: $M > P/C$

Table II can be interpreted as follows: In a technological system where the expected rate of live-weight gain equals one of the values in the left hand column, knowledge of the P/C ratio permits the investment to be classified. Where P/C exceeds the given value for N, the investment is a Class I investment with the present value of an animal (per unit liveweight) always exceeding the unit value at slaughter and increasing as the initial liveweight takes smaller values. Where P/C lies between the appropriate values for N and for M, the investment is a Class II investment, with unit present values falling at first with initial liveweights less than the expected liveweight at slaughter but then increasing as smaller values yet are taken for the initial liveweight. Class III investments are identified by situations where P/C is smaller than the relevant value for M. These investments are characterized by present values lower than the unit value at slaughter for animals at all weights below slaughter weight, with the smaller initial liveweights exhibiting the lower present values. These decrease at an accelerating rate as smaller initial liveweights are tested.

The elements of Table II are based upon particular assumptions as to discount rate, carcase yield at slaughter, and liveweight at slaughter. Higher values for M and N would be found where greater discount rates were applicable, where the expected liveweight at slaughter took a greater value, and where the expected carcase yield at slaughter was at a lower level.

Now the model response summarized in Table II can be compared with the price relationships found in the real world a) in the United States in the period of which Ahearn (opp.cit.) writes; and b) in New Zealand in 1974. The unit prices recorded at Chicago in 1954 and 1956 are summarized in Table III. Inspection of these confirms that during that period lighter animals tended to receive lower prices per unit liveweight, with the lightest animals showing a reversal of this trend. These price relationships conform with the trend of values

Table III

Feeder Steer Prices 1954 and 1956 - Chicago

$/100 lbs

Liveweight (lb)	1,001 up	901-1,000	801-900	701-800	500-700
Month		1954 */			
Jan	20.76	19.99	18.94	18.66	18.68
Feb	18.99	20.22	19.69	18.45	18.58
Mar	20.24	20.05	19.33	19.00	19.63
Apr		20.69	20.70	20.13	19.71
May	20.82	21.19	20.49	20.60	20.74
Jun	20.27	20.18	19.62	20.07	19.05
Jul	19.75	19.04	18.30	16.80	16.61
Aug	19.86	18.33	19.65	17.27	18.23
Sep	20.94	20.64	18.79	19.52	19.47
Oct	20.19	18.95	19.20	20.27	20.10
Nov	17.77	18.66	19.69	19.02	19.97
Dec	19.87	20.23	19.00	18.66	18.27
		1956 */*			
Jan	17.53	16.95	16.91	15.65	17.52
Feb	17.44	16.64	16.00	16.80	18.18
Mar	16.87	16.96	16.22	17.00	18.35
Apr	18.75	17.94	17.74	17.94	18.92
May	18.55	18.02	17.66	17.97	17.94
Jun	19.13	18.66	16.34	17.80	17.87
Jul		18.94	18.14	17.43	17.47
Aug	19.19	18.58	18.90	18.20	18.54
Sep	18.30	19.76	18.86	19.30	19.02
Oct	18.76	17.00	17.41	18.39	18.61
Nov	17.89	17.77	17.66	18.56	18.98
Dec	18.22	17.70	17.07	15.75	16.06

*/ Total Number 55,313 head

/ Total Number 55,786 head

Source:- (79)

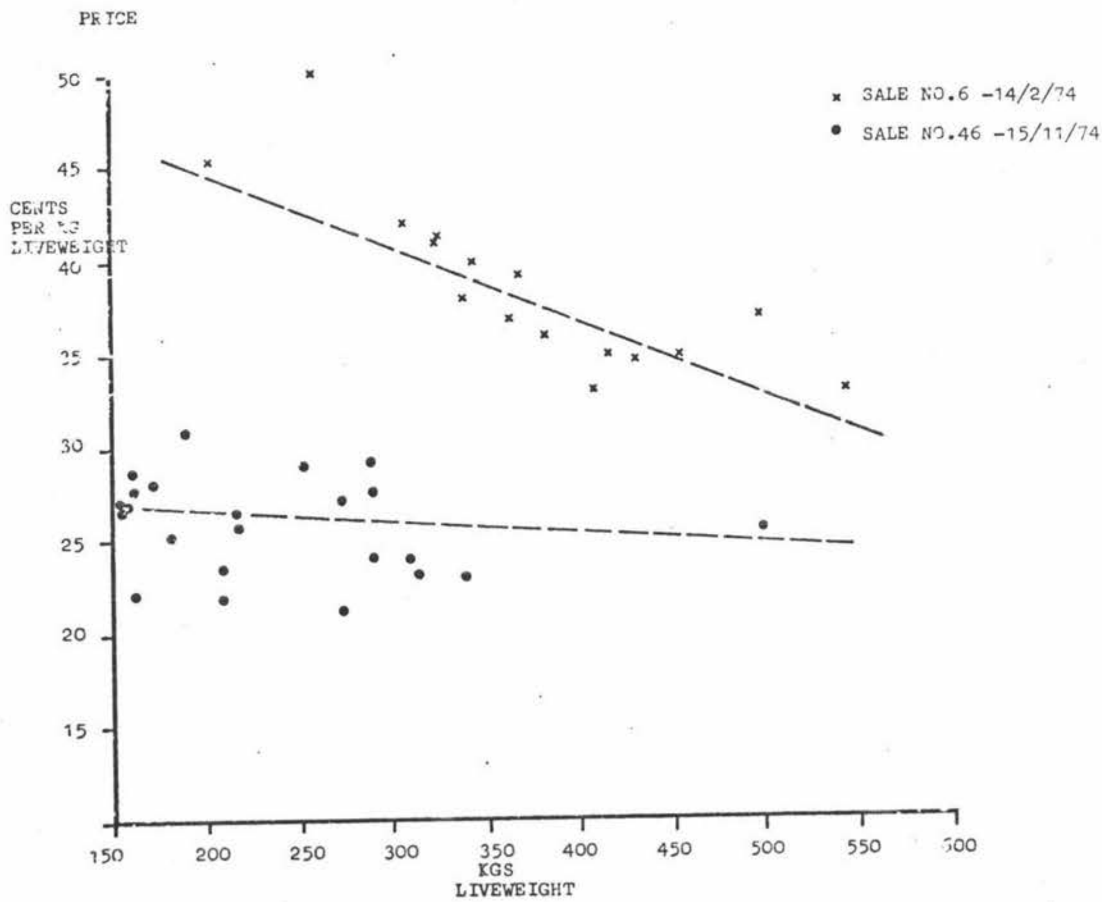
expected from a Class II situation. The price/liveweight relationships revealed at two representative sales at Feilding in 1974 are illustrated in Figure 2. The comments of Walker are fully borne out by the evident tendency for the unit price to approach the slaughter price as slaughter weight is reached. The unit prices at Sale 6 are evidently from a Class I situation, with sale 46 either Class I or II.

The beef price in the United States in 1954 - 6 was of the order of 100 cents/kg carcase (79); at the times of the two Feilding sales depicted the ruling price schedule of the New Zealand meat exporters was at 64 cents and 47 cents per kilogram carcase respectively for a carcase weight and grading which is considered appropriate.

In neither country is the daily cost of holding cattle easily derived. New Zealand grassland farming is considered a "low cost" system, and purchasing cattle for feeding is generally a marginal farm enterprise which utilizes feed surplus to the requirements of the basic farm livestock. An indication of the generally accepted level of costs might be found in the daily fee charged for grazing in the instances where grazing is sold in situ. A representative fee current in the Manawatu during 1974 was 8 cents per head (40). Use of this figure suggests that the P/C ratio prevailing at the dates of the two sales described in Figure 1 was of the order of 8.0 and 5.9 respectively. An alternative daily cost estimate of 12 cents per head would reduce the ratio to 5.3 and 3.9. Reference to Table II shows that these ratios would be associated with a Class I situation under circumstances where the expected rate of gain was about 0.5 kg/day with the lower cost estimate, and about 0.7 kg per day with the higher. This is in fact consistent with the performances of beef cattle in New Zealand as revealed by a comparison of liveweight with age.

FIGURE 2.

The Prices of Steers - Two Sales at Feilding.



To establish an estimate for the daily cost of holding relevant to the feeder market in the United States in 1954-56, the rations described by Culbertson (18) and the costs of feedstuffs recorded in (79) are used to compute an approximation for the unit ration cost. This amounts to 7 cents per kilogram dry matter. With a daily consumption of 5 to 7 kgs dry matter per head, feeders incur a daily cost for feed alone amounting to 35 - 50 cents. The total cost of holding, including the other fixed and variable costs of feedlot operation is thus of the order of 50 - 70 cents per head per day.

The P/C ratio under these circumstances is apparently of the order of 1.4 - 2.0. With expected rates of daily gain in the vicinity of 1.0 kg/day, the evident classification is Class II tending to Class III with the higher level of costs. This confirms the classification found by inspection of the prices in Table III.

Within the limits of accuracy of the cost estimations, and under the assumption that the unadjusted ruling beef price constituted the beef price predictor in use in the two situations, this examination supports the hypothesis that the investment model behaves in a fashion which is consistent with its use as a price predictor.

The interdependence of the three factors of beef price, daily cost, and rate of gain, revealed by the analysis is noteworthy. While an examination of the first partial derivatives of the model with respect to each of the parameters confirms that the response of the model prediction to changes is in each instance intuitively satisfying, this procedure brings forward no further evidence which gives concrete support to the validity of the investment model.

2.4.2. The Model Fitted to Data.

The hypothesis can be examined with the assistance of empirical data, and for this purpose data was collected from the weekly Feilding market over the two-year period 1974-75. The collection of data and the use of the 1974 data to estimate the parameters of the model are described in Appendix A.

The final form of the model which was developed during the process of parameter estimation is:

$$V_k = (aLP(1 - e^{-ks}) + C/r)e^{-rt}/W - C/rW - FP(1+AT) \quad ..(2a)$$

with $t = (L - W)/g + Z_i$

and L is the expected slaughter carcase weight (kg);
a is the expected carcase yield;
P is the beef price predictor (cents/kg carcase);
k is the age variable (weeks);
s is a parameter reflecting the influence of age;
W is the present liveweight (kg);
T is the time variable (days);
r is the discount rate (per day);
C is the expected daily cost of holding (cents/head);
F is the fixed cost of the transaction (a parameter);
A is the daily rate of cost inflation (a parameter);
g is the expected growth rate (kgs/day);
Z_i is a weighting factor for sale i(days).

Each of the Z_i may be interpreted as the number of days of zero growth expected immediately subsequent to sale i.

Of the parameters, several have been given values which were selected with regard to the physical system of store cattle feeding and the prevailing level of interest charges during the data period. These parameters are not varied during the estimation process and are:

$L = 550$ kgs;

$a = 0.59$

$r = 0.0003288$ (ie. 12% p.a.)

The values which are estimated for the other parameters are conditional upon these constants, and also conditional upon the initial set of values taken by the parameters themselves. The parameter values estimated to give the best fit to the 1974 data (minimizing the sum of squares of the deviations of actual from predicted prices) are:

$C = 13.77$ cents/head;

$s = 0.1861$

$F = 0.177$

$A = 0.0091$

These are associated with the set of sale weights, Z_i, which are illustrated graphically in Figure 3; a set of breed-dependent estimates for g (expected daily growth rate); and a set of condition-dependent factors for adjustment to g. These are listed in Table A.II of Appendix A.

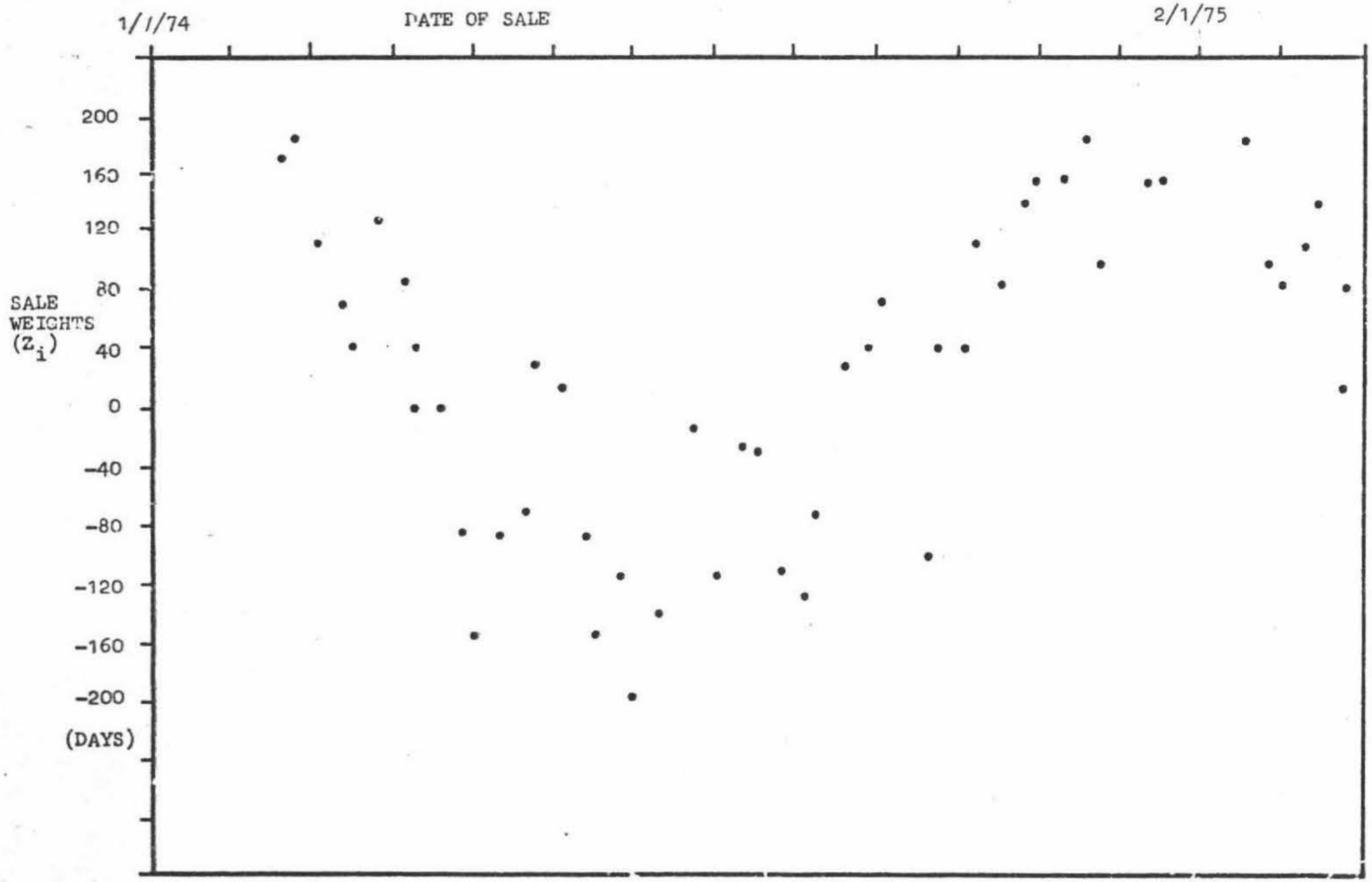
Statistical Analysis.

Having regard to the non-linear structure of the model and the procedures employed for estimation of the parameters, a rigorous statistical analysis of the model performance is not possible. The limited time period to which the data refers renders a statistical examination of little value in the context of the time-dependent variables. However, the fit of the model to the data used in its development is examined with the assistance of the BASIS package on the B6700 computer to confirm that the limited aim of modelling the processes of price formation and discovery during the data period is attained.

In the stage of parameter estimation which preceded the estimation of breed and condition adjustments the number of lots considered totalled 635, spread over 50 sales. The fit of the model can be

FIGURE 3.

The Sale Weights Fitted to 1974 Data.



judged from the statistics in the upper part of Table IV. Subsequent to the inclusion of all the breed and condition groups, and the use of the adjustment factors found appropriate (see Appendix A.2.) the number of lots considered rises to 1122, spread over the same 50 sales. The fit of the amended model is described by the statistics in the lower part of Table IV.

Table IV.

The fit of the model to the data.

Lines selected for breed and condition	Actual Price (Y)	Predicted Price (X)	Deviation (Actual-Predicted)
Mean	32.51	32.40	0.10
Standard Deviation	7.98	8.41	3.05
Correlation	r(X,Y) = 0.93		
Lines of all breeds and conditions			
Mean	33.12	33.12	-0.01
Standard Deviation	8.61	8.29	3.66
Correlation	r(X,Y) = 0.91		

These results permit the model to be described as a reasonable representation of the processes involved in the generation of the 1974 data. Plots of residuals against the variables reveal no evident bias. A separate examination of the lines which were passed in (not sold to the highest bidder) show that the final bid is lower than the predicted price in 73% of the 82 cases, and this is judged to be a reasonable reflection of the motives which lie behind the setting of reserve prices.

Plots of the actual and the predicted prices for two sample sales are shown in Figures 4 and 5.

Special attention needs to be given the sector of the model which reflects the between-sale variation,

FIGURE 4.

Comparison of Actual with Predicted Prices.
(Sale 44; 1/11/74)

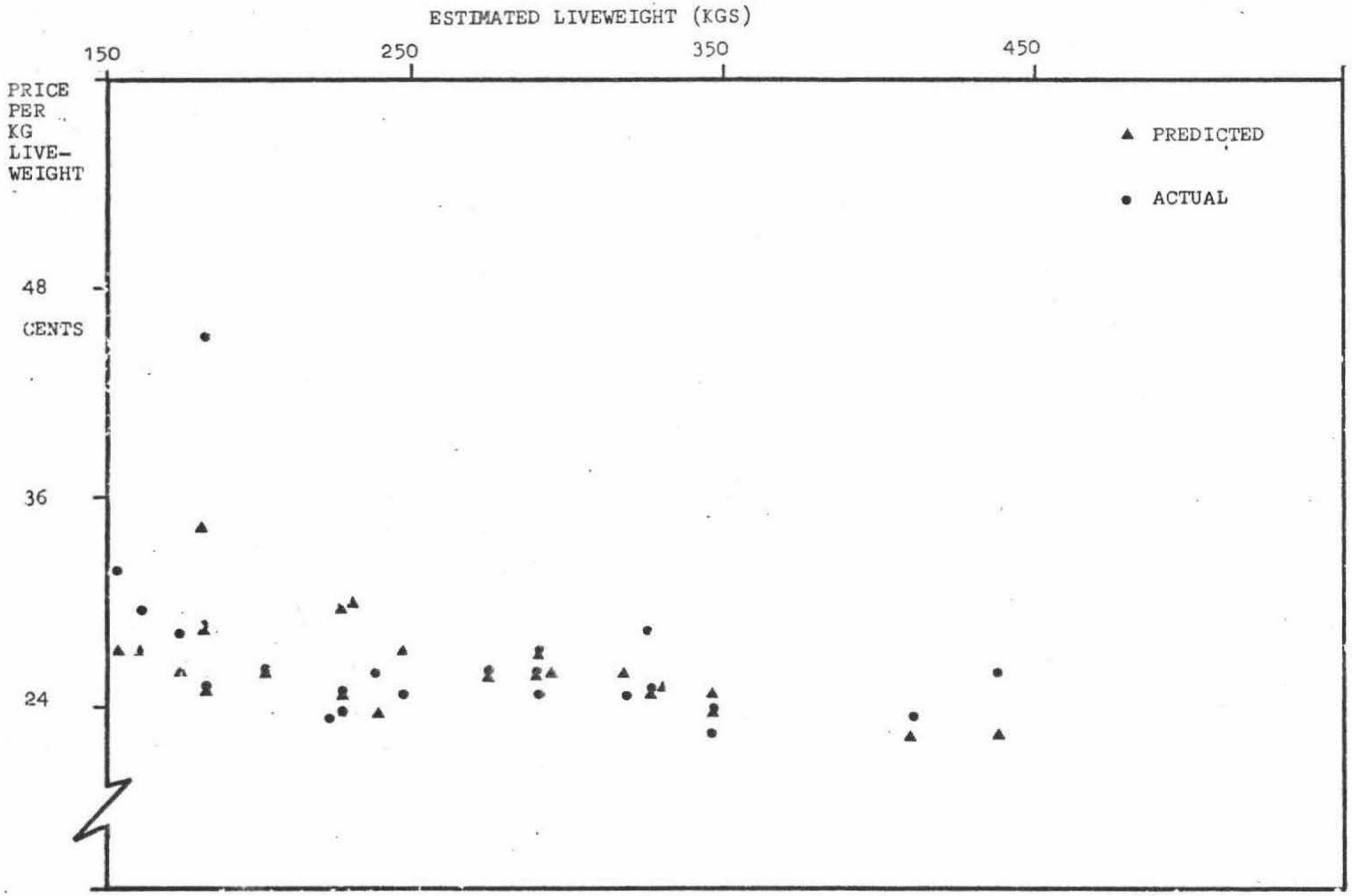
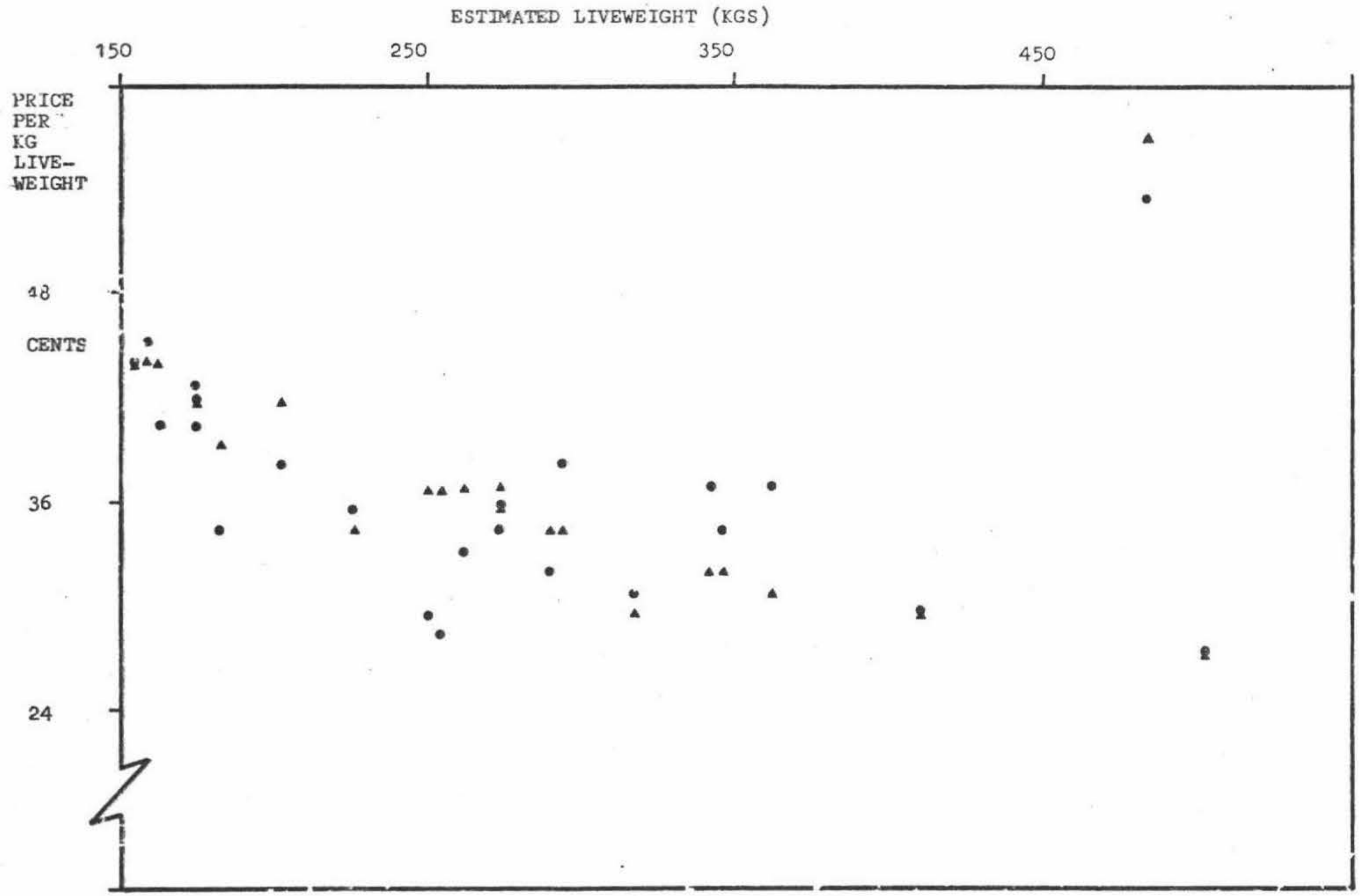


FIGURE 5.

Comparison of Actual Prices with Model Predictions.
(Sale 18; 3/5/74)



and as illustrated in Figure 3, the most striking feature of the sale weights for the 1974 data is the apparent seasonality. Since the data is from one year only, this appearance cannot be taken as proof of a seasonal effect upon prices. However, it is quite consistent with the expectations of farmers who respond to seasonal changes in expected growth rates of cattle in a grassland farming system.

The model formulation is designed to incorporate be means of the sale weights all of the factors which cause variation in between-sales price level, except a possible long term trend. The assumptions underlying this choice of structure carry the corollary that the climatic and economic factors which change from sale to sale and which might be supposed to be the determinants of the growth rate expectations held by bidders would have a definite relationship to the sale weights. Attempts to fit regression equations with the climatic variables, the supply of cattle to the sale, and the sharemarket index (as a proxy for economic outlook), were not successful. Linear regressions involving these variables yielded predictions for the Z_i of 1974 with standard errors in excess of 50. With the range of Z_i values lying between 153 and -175 this level of inaccuracy indicates that other variables influence between-sales variation. Of the regression equations tested few bettered the results given by that with soil temperature as the only independent variable, thus confirming the importance of the purely seasonal effect. Soil temperature is the only variable of those tested which shows a high correlation with the sale weights ($r = 0.77$).

The possiblity exists that some of the factors may act upon the sale weights differently according to the state of other variables. Higher soil moisture deficit may be unfavourable in summer but favourable in winter, with the boundary between the seasons being marked by a critical soil temperature. Rainfall may behave similarly. Using a boundary soil temperature of 13.5°C the correlation of the transformed variables with the sale weights is greatly improved:

Soil moisture deficit	r	= 0.65
Rain in previous week	r	= 0.53
Rain on previous day	r	= 0.36

These correlations are all significant at the 1% level but regression equations employing the transformed variables fail to show an improvement in fit over that of the simplest equation using soil temperature only. Using stepwise regression, the predicting equation giving the best fit is found to be:

$$Z_i = 84.8 - \underset{(0.186)}{0.68St_i} \pm (\underset{(.183)}{0.40Sm_i} - \underset{(.850)}{1.24Rf_i}) + \underset{(2.475)}{10.29T_i}$$

where St_i is the Sharemarket Index on the morning of day i;

Sm_i is the calculated soil moisture deficit on day i;

Rf_i is the daily rain recorded on the morning of day i;

T_i is the soil temperature estimated for day i;

and the bracketed term is positive when the soil temperature exceeds 13.5°C.

The multiple correlation coefficient for this equation is $r = 0.84$, and the standard error of estimate is 51.0.

The model takes no account of the supply of cattle to the sale except insofar as it may act through the sale weights. The regression equations attempting to predict the sale weights were not improved by the inclusion of the supply to the sale as a variable. However it is to be noted that the simple correlation coefficient of the supply to the sale with the sale weights is significant at the 5% level and is negative. The correlation of sale entry with the residual at each step of the stepwise regression described above is also negative, although nearly zero. Thus there is some indication that an increased supply to a sale is associated with a smaller sale weight and thus a higher price level. This effect may be real, or it may be a consequence of the correlation between supply and temperature ($r = -0.23$, not significant at the 5% level). If it is real it may be a reflection of the mood of buyer optimism engendered at large sales. Not enough evidence has been brought forward to enable a conclusion to be reached concerning the effect of the supply of cattle to a sale upon the prices at that sale.

Two questions are raised above (sect. 2.3.2.) to which the results from the process of fitting the model to the 1974 data may permit answers to be attempted:

(a) Is there a time trend at New Zealand livestock auctions, and if so, what are the circumstances that promote it?

(b) Is the variability of prices (given the heterogeneity of lines presented for sale) consistent with a theory of "perfect knowledge" and of low variation in price determining factors?

Since the model structure takes no account of the order of sale, an indication of the possiblity that prices are affected by that factor is found by testing the correlation of the deviations of the actual price from the model predictions against the order of sale. Only with the sales having the largest entry of cattle does this statistic approach significance ($r = 0.2$, when entry exceeds 3,500 head). For smaller sales the correlation coefficient is nearly zero. However, the data collection (see Appendix A), is incomplete in that a proportion of lines from the later stages of some sales are neglected. It is probable that it is the sales with the highest entry of cattle that are affected in this way. Thus, the analysis of the larger sales is inconclusive, but for the smaller sales the probable absence of a trend in prices may be inferred from these results.

Hence some support is given to the hypothesis that prices are formed independently of the auction process.

The standard deviation of the difference between the actual price and the model prediction is found to be 3.66 cents. This is about 10% of the mean price. The variability of prices is thus too high to support a theory of perfect knowledge on the part of bidders, on the assumption that the model incorporates all the variables which influence price. This assumption is very weak; the identity of the vendor, the "breeding", the supplying region, the degree of gut-fill, to mention a few, are other factors which are known to influence, for instance, the expected rate of daily gain from a line of steers.

Even within the variables whose effect is modelled, liveweight has been hypothesized to be estimated inefficiently by bidders. Further, the assumption that the liveweight estimations constituting the data are correct is of doubtful validity, although the estimates were checked when possible against those of other bidders. The availability of objectively measured liveweights would be of use in checking the accuracy of the data, but would not assist in evaluating the accuracy of the bidders' estimates of liveweight.

Hence, while the hypothesis of "perfect knowledge" on the part of bidders is not supported by the evidence, it is possible that the price variation which is revealed is attributable to variation of liveweight estimates between lines of cattle and to the existence of other price determining factors which are not taken account of by the model.

The analysis cannot permit question (b) to be answered unequivocally but at the same time does not invalidate the assumptions upon which the development of the investment value model is based.

2.4.3. Further Development and Validation of the Model.

The final form of the model is developed with the assistance of test data from the 1974 period, with the aim of obtaining a good fit to the full data from 1974. This aim is achieved but it is evident that a wider data base might reveal other sources of between-sale variation. The use of data from a single year to develop the model involves the risk that important variables are neglected.

This possibility is confirmed by a premiminary application of the model to the data from 1975. A consideration of the changed circumstances of 1975 by comparison with 1974 leads to speculation that the mood of bidders is influenced by the outlook for beef prices much more than the model structure permits. The use of the sharemarket index as a proxy for the national economic outlook is evidently not effective in modelling the effects of the beef industry outlook. A need is thus felt for a variable to reflect the optimism or pessimism affecting bidders in the store cattle market.

In turn, the identification of a variable of this nature having effect in the longer term, leads to the possibility that its inclusion in the model might lead to an improved performance with the 1974 data. The aspects of model performance which might benefit include the sale weights (Z_i), the adjustment of the beef price predictor according to age (ie. according to investment time horizon), and the treatment of a long term trend apparent in the data from 1974.

(a) The sale weights (Z_i) which model the between-sales variation are a central feature of the model. The failure of attempts to relate the weights with the sale variables is therefore a serious deficiency. A re-examination of the circumstances which prevailed throughout the 1974 data period makes it clear that within the pervading pessimism resulting from the steep fall in the price schedule of the meat exporters, bidders were subject to intermittent surges of optimism throughout the period. These changes of mood might be attributed to successive public pronouncements by industry which were aimed at bolstering the confidence of producers, and by the apparent success of the guarantee scheme in halting the decline in beef prices.

Incorporation of the variable representing this changing mood might be by means of an "optimism index" and since the mood reflects directly upon beef price expectations, an improved model should employ the index in conjunction with the reference price from the meat exporters' schedule (or the guarantee, when this is applicable). An improved beef price predictor would result, and the between-sales variation modelled through the Z_i sale weights would then reflect strictly technical variations affecting expectations relating to the production process.

(b) In the stage of model development which uses test data from 1974 to improve the model structure it is found that prices for younger steers are predicted more accurately when the beef price predictor is reduced by a function of animal age. When the full 1974 data is used to estimate the parameter values, it becomes evident that this aspect of the model would perform better if the function used varied over time. The use of an improved beef price predictor which includes the optimism index offers prospects of overcoming this problem.

(c) The use of the final model form to estimate the parameter values with the 1974 data revealed that "cost inflation" was affecting the fixed costs of steer purchase at an unrealistic annual rate of 330%. The minor contribution the fixed cost component makes to investment value by comparison with the influence of the daily cost (C), is evidence which supports a reformulation of the method by which the effects of cost inflation are represented in the model. Trends in market mood may complicate the total trend in prices, so that the inclusion of a variable for market mood might be expected to clarify the representation of changing cost expectations.

Time limitations precluded testing these proposals for improving the model formulation.

The data from the 1974 and 1975 periods does not include an assessment of market mood, and although newspaper reports of the period give some evidence on the point, a sound retrospective evaluation of the optimism index which prevailed for each sale in the 1974 and 1975 period does not appear possible. A subjective assessment of the market mood over the 1975 period was nevertheless attempted in order to validate the model with data other than that which was used to develop it. The different weather conditions which prevailed over the 1975 period, notably the wet 1975-6 summer, are another consideration which, in the absence of a method for predicting the sale weights from a knowledge of the climatic variables, interferes with a full validation of the model.

The partial validation thus required the following steps:

(a) Using a subjective assessment of the market mood and its changes over the 1975 data period, and forming a revised beef price predictor for each sale. The effect of this is exhibited for sales following the date upon which the price guarantee became effective and result in the predictor being increasingly higher than the ruling price (the guarantee or the meat exporters' schedule for the reference grade, whichever is higher).

(b) Employing the parameter values for the model as were estimated from the 1974 data, except that the fixed cost component (F) is set constant at the value effective at the close of the 1974 data period. The inflation rate (A) is set at zero.

(c) Estimating the sale weights for the 1975 sales in the same manner as in the parameter estimation for the 1974 data. Hence the Z_i values derived are dependent upon the 1975 data and not first predicted from the known values for the climatic variables.

(d) Testing the values revealed for the sale weights (Z_i) against subjective expectations and re-running the model with the data using revised estimates for the optimism index. This continues until the pattern of the sale weights over the 1975 data period shows firstly, a fall from February to July; secondly, a rise to October, and thirdly a constant level thereafter. This pattern is considered consistent with the climatic conditions of 1975.

(e) Examining the relationships between the actual and predicted prices for each line of steers.

The results of the partial validation were encouraging. The correlation between the actual and predicted prices was $r = 0.92$, and variability of prices from predictions was no greater than found in the 1974 data. When attention is given to the lines of steers of breeds other than Angus, the variability of the actual prices by comparison with the predicted was found to be substantially greater, although the adjustment factors derived from the 1974 data (described in Appendix A) were employed. This gives confirmation that breed effects on price are subject to interaction with other effects. Thus further immediate development of price prediction is restricted to steers of a standard description.

From these results it is concluded that the investment model can yield price predictions which conform closely with the actual prices paid for steers in the Feilding store cattle market. The incomplete development of the model, which results from the limitation of time and from the restricted data series, prevents its immediate use as a fully effective predictor of store cattle prices. The between-sales sources of variability are shown to be capable of being modelled within the model structure that has been developed although the detailed relationship of the two main sources of variation with the indices which represent them in the model are not yet clear. These indices are the optimism index, which is used to improve the beef price predictor in response to market mood, and the sale weights, which reflect the seasonal and short term climatic effects. The variation in prices due to liveweight effects is modelled effectively by the investment value model, but the influences exerted by breed and animal condition have not been made clear.

2.5. The Generation of Price Predictions.

2.5.1. General

The purpose for which the investigation into store cattle prices is undertaken is the development of a price expectations model for use in the evaluation of feedlot viability. While the investment value model examined is incompletely developed for the purpose of accurately predicting cattle prices, the essential nature of the process of price formation as being consistent with investment behaviour is clear. Evidently price expectations for individual standard lines of cattle can be modelled if data of the quality that has been analysed is supplemented by additional information relating to the mood of the market. Quite clearly the accurate prediction of either the market mood or the weather conditions which will prevail at some future sale is not possible.

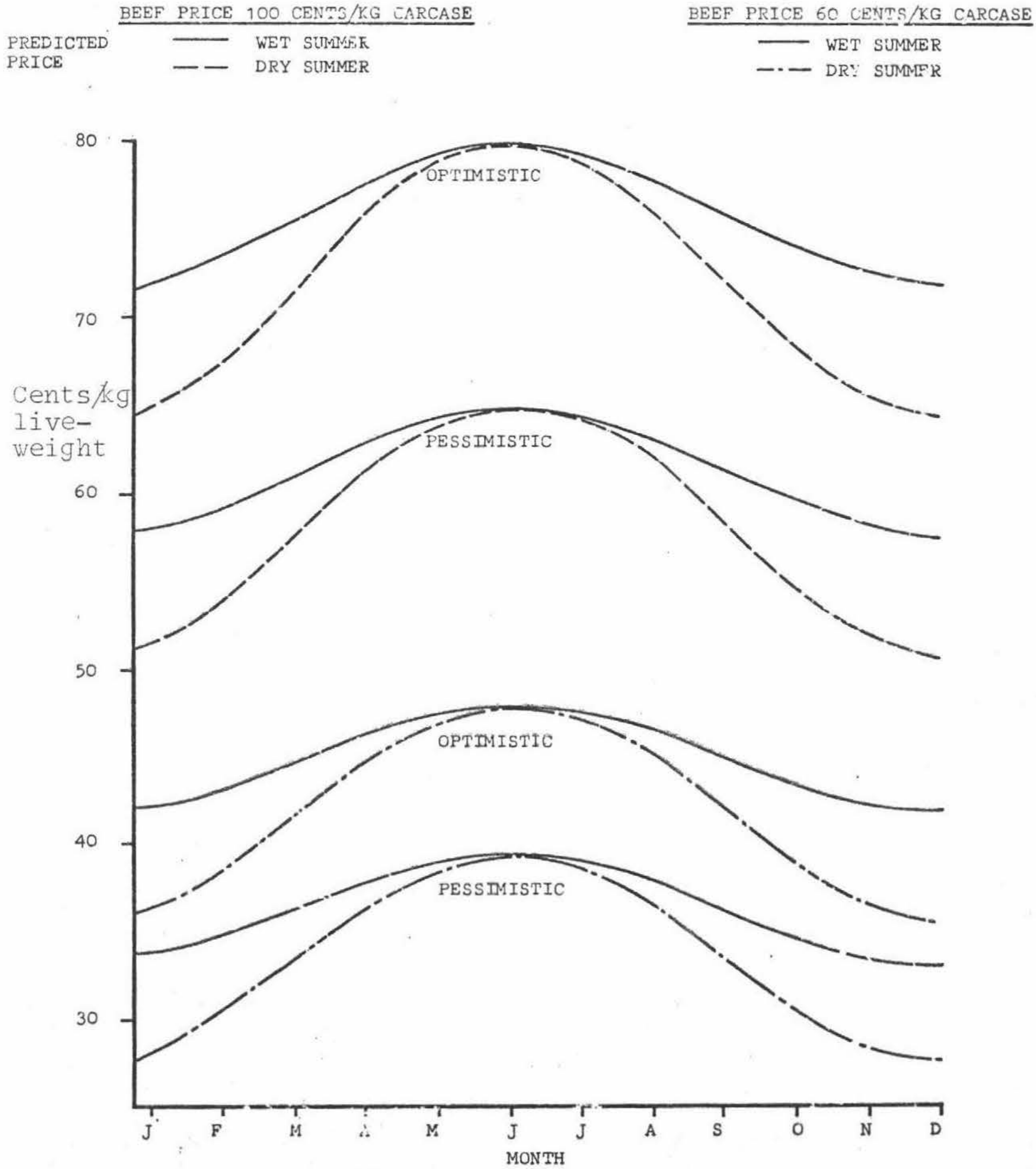
Perfection of the model can therefore be of little assistance in detailed price prediction, except when these variables are completely known, ie. at a sale in progress. But the requirements which must be met if the model is to be of assistance in the appraisal of feedlot viability differ from the needs for detailed price prediction - the need is for the effects of changes in these variables to be known and for the seasonal movement of prices to be understood.

2.5.2. The Prediction Generator.

The outcome of the investigation into the store cattle market is illustrated in the sample price curves of Figure 6a and 6b. These are produced by the prediction generator which incorporates the investment value model with the parameter values found applicable to the 1974-5 data, and which employs a simple cosine function to model the sale weights (Z_i) in response to the assumed climatic conditions. Only two kinds of seasonal conditions are presented - a wet winter preceded and followed by either a wet

FIGURE 6a.

Price Prediction Bands for a Steer of 450kg Liveweight.



summer or a dry summer. These are the combinations of the 1974-75 data period. The market mood is modelled by applying a factor, the optimism index, to the reference price from the ruling meat exporters' schedule to derive the beef price predictor.

The curves of Figure 6a are shown for two levels of schedule price - 60 cents/kg (lower) and 100 cents/kg (upper). If a constant schedule price is assumed throughout the year, the upper set of curves depicts the band of prices within which the price of a steer of the weight noted (450kgs) will move as the climatic conditions and the market mood fluctuate between the extremes shown.

Figure 6b illustrates the effect upon price of different liveweight levels under various assumptions. In reality, actual prices would at different sales be found on different curves as the sale variables of schedule price, weather, and market mood changed value from sale to sale.

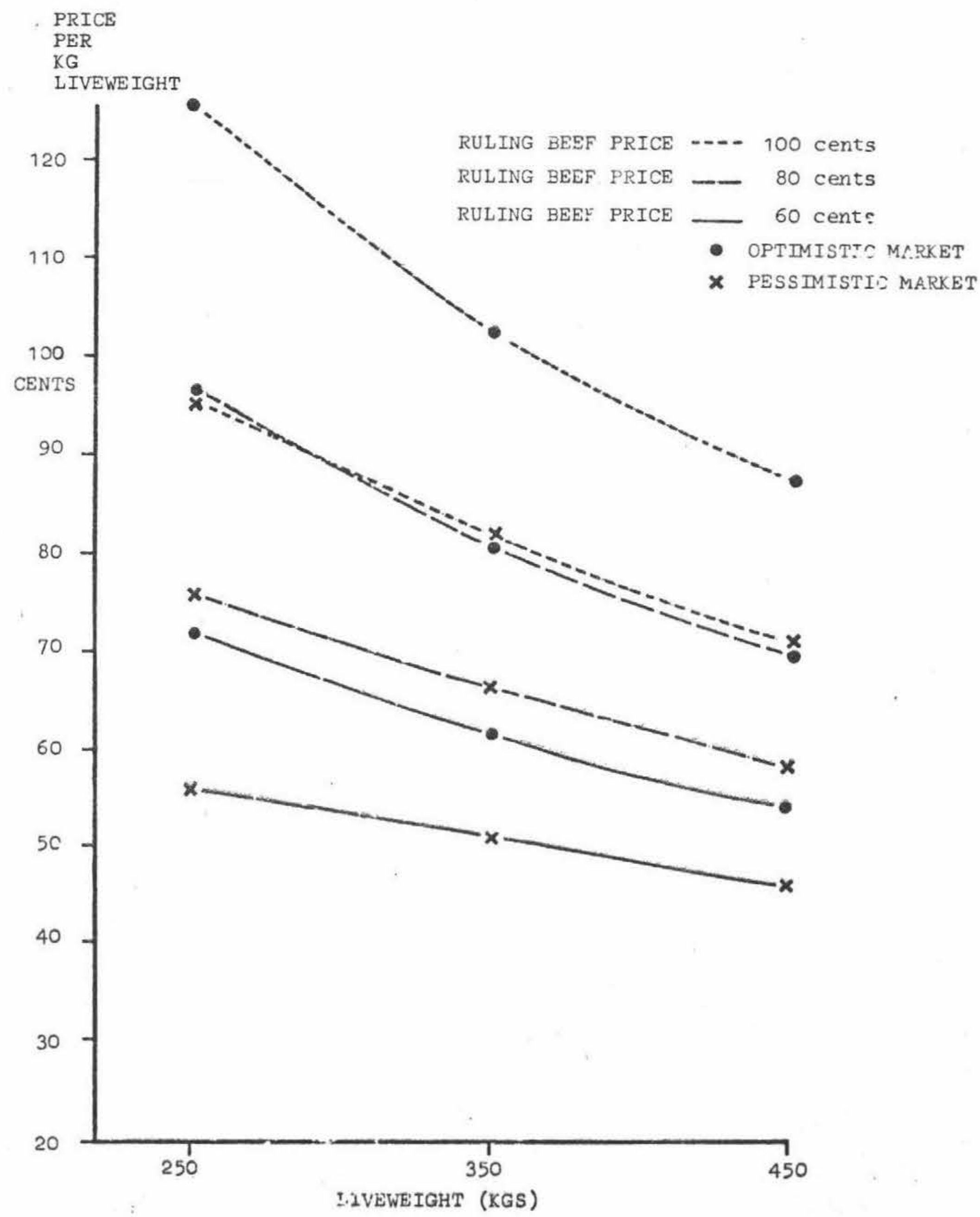
The prediction generator, because it employs the model parameter values derived from the data of 1974, is applicable to conditions where these parameters reflect the expectations of bidders in the store cattle market. While changes in some (e.g. the expected rate of daily gain) are improbable in the absence of technological change, others(eg. the assumed daily cost of holding) must reflect financial realities and can be expected to respond to such influences as inflation and cash availability. The effects of possible changes in parameter values upon the level of expected prices for store cattle can be investigated by means of the prediction generator.

Thus the parameters of the prediction generator must be considered characteristic of the data period and its use for prediction of prices over a time span where costs might be expected to change is of doubtful validity.

FIGURE 6b.

Predicted Prices for Standard Steer in the Month of April.

(Dry Summer Conditions)



2.6. The Analysis of Prices for Store Cattle - A Summary.

An examination of the normal procedures of livestock sale leads to a number of hypotheses being formulated:

(a) Prices discovered at auctions tend to become reference prices for all store cattle transactions;

(b) The auction process is conducted in such a manner that the limit bid tends to be discovered;

(c) Limit bids tend to be estimates of investment value;

(d) Under New Zealand conditions bidders tend to make identical estimates of investment value.

These hypotheses are used to formulate an investment value model, first on theoretical grounds and subsequently with the assistance of heuristic methods aimed at improving the fit of model predictions to data. Examination of model performance against the full data series reveal that while a high correlation of predicted with actual prices is obtained, the modelling of between sales variation is incomplete. The understanding of the influences of breed and animal condition upon prices is inadequate, and proposals for improving model performance are based upon a standard animal description with liveweight as the variable.

The limited data available, and the special circumstances of the period from which it is drawn, preclude a full analysis of the variables affecting between-sales price variation. The major influences are indentified as being derived from the mood of the market and from the climatic conditions, and the model structure is adequate to accommodate these variables in the form of indices. The relationship of the indices with measurements of these variables is not elucidated, but the range of variation of the indices resulting from the conditions of the data period is approximated.

The analysis is incomplete, but is carried far enough to permit the construction of a price prediction generator for use as a price expectations model, and to present tentative conclusions relating to the processes of price formation in the store cattle market.

These tentative conclusions, which may serve as hypotheses for future examination, depend upon the data from the weekly Feilding market.

(a) The prices of store cattle are consistent with estimates of investment value;

(b) A major source of price variation is found in the estimation of animal liveweight;

(c) The use of the ruling beef price as a naive expectations model of the beef price predictor is inconsistent with the results; a more sophisticated model including an adjustment for the market mood is required to reflect efficiently the behaviour of the market.

A classification of the situations which face a prospective investor in cattle is derived during the theoretical model development. This is based upon the ratio of beef price to expected daily costs and is proposed as a useful adjunct to further examination of livestock prices.

CHAPTER THREE

3. FEEDING AND GROWTH OF A STEER - THE GROWTHMODEL

3.1. General

To derive the stream of costs, the time horizon and output from the feeding of animals requires knowledge of the input-output relationships. Insofar as cattle fatteners and other purchasers of store cattle in New Zealand must in some way estimate these (see Chapter 2) it is apparent that experienced stockmen develop sufficient expertise in their own technology to do this sufficiently well. With new or different technology, the feedlot system being a case in point, New Zealand experience is probably inadequate. Information thus becomes necessary on the expected physical inputs and outputs from a feedlot steer if a prospective feedlot operator is to find himself in a position to estimate the present value to him of store cattle.

Feed inputs are customarily recorded in husbandry or nutrition experiments and trials and liveweight gains are likewise noted. However some deficiencies attach to the aggregation of data from such experiments, although the accumulated records are voluminous. Amongst these deficiencies:

(a) The short term of most such experiments, yielding in effect a static picture of the dynamics of feeding and growth;

(b) Varying and often ill-defined environmental conditions;

(c) Use of animals whose growth and intake characteristics are not comparable between experiments;

(d) Application of rationing procedures unrelated to maximizing productive performance;

(e) Use of experimental designs which have the purpose of removing the very variability which the present purpose requires to investigate;

(f) Feeding of experimental rations tailored to the needs of particular experimental purposes and reported only in relation to those purposes.

Generally therefore the use of data from such trials for the purpose of developing knowledge of the input/output relationships of a real world situation is not feasible. The work of Nelson (64) utilizing data from Culbertson et al (18) is an exception to this since the data were derived from a three year experiment designed for the very purpose of evaluating the most profitable feeders for purchase. The curves fitted by Nelson, of the family described by Brody (12) and by Hankins & Titus (34), are most useful as a yardstick for comparison, but for the present purpose the absence of ration variability in the data and the use of feeds characteristic only of the place and time of the trial reduces the usefulness of his studies.

In the absence of more applicable data from purpose-designed trials one possible approach is the design and execution of such experiments. The costs and the extended time scale of such a project renders this unlikely. The standardization of feeding trials performed for other purposes might well yield data of suitable quality and quantity, but again the time scale would be excessive. The exhortation by Mitchell (62) to New Zealand farmers to the effect that they should go out and "prove" the profitability of forage-farming is surely rhetorical when the multiplicity of choices in the discretional variables and the natural variation within the system are considered.

Where feed quantities form the independent variable, as in the work of Nelson (64) or the dependent variables are chosen to reflect a particular experimental situation, as in Curran et al (19) (where regression equations were fitted to the data to predict the voluntary intake of dairy cows), the production function can be estimated. As Curran et al are careful to note, the extrapolation of such results to other than identical animals under the same circumstances is risky. This caution is, of course, applicable to the results of any experiment.

Where feed quality is the variable of interest, and the results are intended for wide application, only one approach appears applicable. This is the modelling approach, which is used by Kennedy (43) and Grieg (32), amongst others, and which is mentioned by McDonough (54) in connection with the derivation of least cost ration formulation. The requirements which must be met by a model include:

(a) Applicability to the purpose (i.e. realistic constraints)

(b) Consistence with contemporary knowledge in the scientific fields of study, and

(c) Output which conforms to the practical experience of experts in cattle feeding.

A model of the feeding and growth of a steer is developed for use in this study. Chapter Three describes the development process and gives some detail of the final model. Apart from the needs for validation, the model is not employed independently in this study, but is incorporated into the computation process used in Chapter Five to investigate the "feedlot response surface". Thus the growth-model is one of the tools employed in the study, and the details of its construction are to some degree irrelevant to the decision process of the feedlot operator. It is felt, however, that a full description of the growth-model is not out of place here, particularly since references in the literature to such models are uninformative.

3.2. Model Construction

There are two aspects to the feeding/growing process. Obviously, these are feed intake and the use of the feed nutrients. Previous models for the same purpose have generally applied a rationing concept and this avoided the problem of determining levels of voluntary intake. Kennedy (43) is one writer who did not do so and in his model a quadratic function is used from Blaxter (9), who derived it through experimentation with sheep. Kennedy's work concluded that the optimal ration was that which had the lowest energy concentration while giving the requisite rate of gain, and this implies that choice of ration quality to optimize feed cost efficiency requires feeding to the level of voluntary intake. The first part of this section deals with this intake problem. It is followed by a description of the nutritional components of the model.

3.2.1. Voluntary Intake (Ration Characteristics).

Recent years have seen a determined effort by researchers to unravel the problems of intake control in ruminants. Some of the early work by Blaxter culminated in 1964 in his publication (9) of an intake function for sheep:

$$V = 9.1Q - 0.074Q^2 - 194 \quad \text{gms DM}/W^{.73} \quad ....(1)$$

where Q is the metabolizability of the gross energy.

Blaxter suggested that for cattle the intake levels should be raised 15% from those given by use of this function, and Kennedy's work concluded that an increase of 25% would be more in line with the data from commercial cattle feeding operations that he used to test his model. This difference may be due to the unmeasured waste feed which constitutes a major problem in the use of data from U.S. feedlots for the estimation of an intake function. (55). A second possible cause is proposed later in this section.

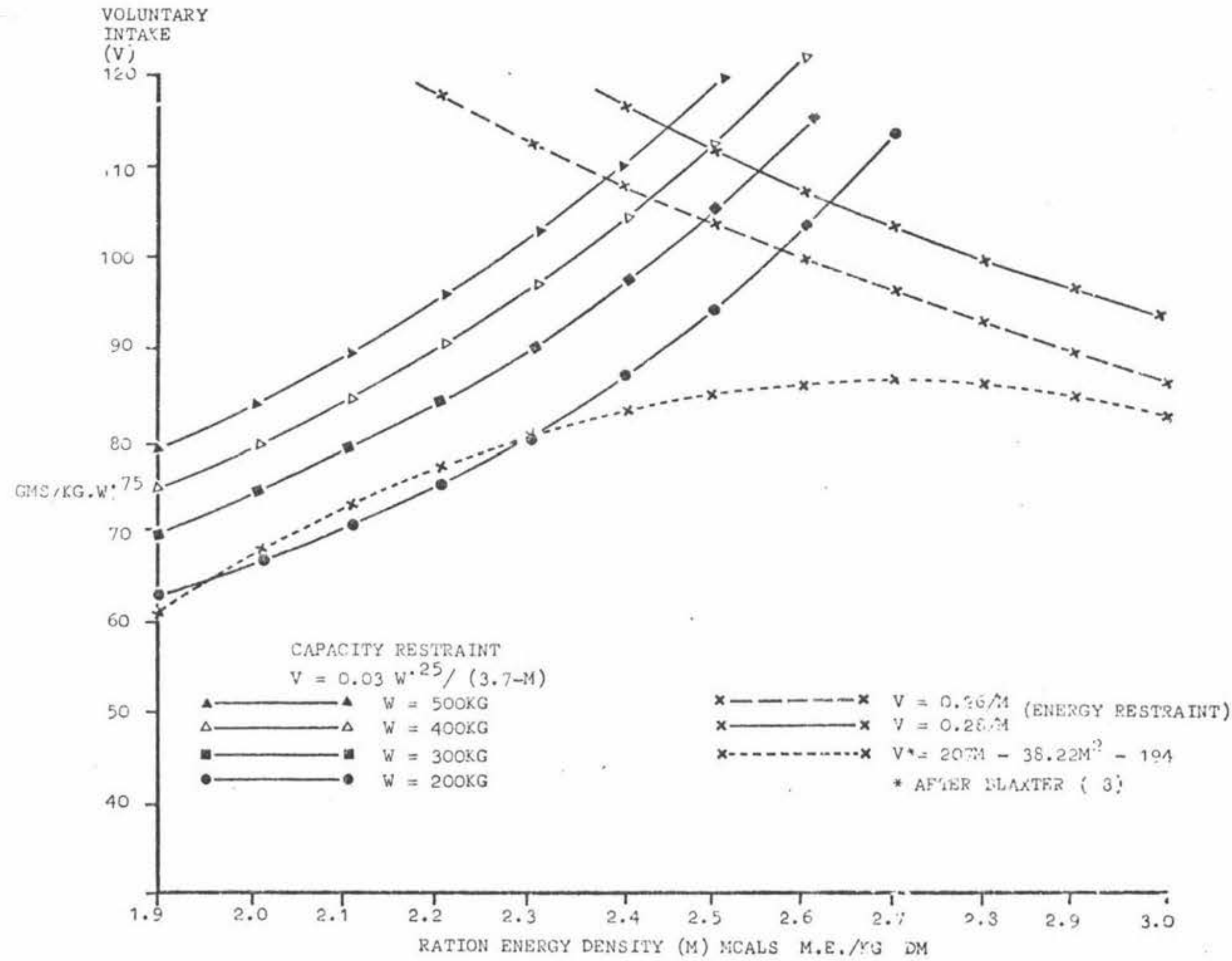
The valuable concept represented by this function is the dependence of voluntary intake upon Q, the metabolizability of the ration, or in other words upon the two factors; gross energy content of the feed, and the metabolizable energy content. This was an advance on the pioneering work, such as in Blaxter et al (10) 1963 where a simple intake function was based upon the digestible energy content of the ration.

Later work during the 1960s has thrown more light upon the factors which trigger the mechanisms controlling voluntary intake. Conrad et al (16) and Dinius & Baumgardt (23) record results which in many ways confirm those of Blaxter but demonstrate more clearly that as ration energy rises, intake increases to a peak and then falls. This sequence is characteristic of Blaxter's function also (in which the maximum intake level takes place at Q = 61.5%) but this later work presents evidence to show that this relationship involves a change in the intake control mechanisms. Whereas at low levels of metabolizable energy concentration control is essentially of physical capacity, at the higher ranges it is "metabolic" control. As Davey (22) makes clear, this division is arbitrary as the mechanisms are not independent and all are physiological in origin. Conrad et al nicely summarize the situation by stating that ruminants eat to a constant energy intake if the ration characteristics allow. The effect is shown graphically in Figure 7 in which the discontinuous curves derived from the results of Conrad et al contrast with the smooth curve of Blaxter's function.

While these spliced equations are believed to mirror the research work mentioned and apply to conditions where the only ration variable is its energy concentration, no stronger commitment has been found in the literature to the concept of an

FIGURE 7.

Some Intake Functions.



actual intake function. In McDonough (54) a passing mention is made of "an appropriate intake function" but he has made it clear that no realistic function has yet been derived from feedlot data in the U.S.A. The multitide of variable factors which in practice affect intake levels is quite clearly the fundamental reason for this caution. However, if ruminants are believed to behave in a consistent fashion and not to meter their intake randomly, and there seems to be general agreement on this, the existence of a real intake function under any set of assumed constraints cannot be doubted.

If an attempt is made to identify reasonable constraints for the conditions where,using ration energy concentration as the independent variable, an intake function will represent real intakes sufficiently well, the areas of interest might include: protein content, fibre content, fineness of comminution, content of soluble carbohydrates, concentration of appetite inhibiting compounds, moisture content, balance of minerals and vitamins - all factors relating to the ration itself. Other factors might relate to the animals, including age and physiological state, previous feeding history, genetic potential; and to the presentation of the fodder, such as environmental considerations of temperature and weather, competition between animals, water supplies and presence or absence of cumulative contamination in the food containers.

The ration characteristics are discussed below and some conclusions arrived at which assist in the expression of intake as a function with metabolizable energy as the only independent variable.

Protein Content. The work of Egan (25) in particular has shown that protein content of feeds is important in influencing intake. His conclusions are, if the sequence of intake control mentioned (physical capacity at low energy concentrations and "metabolic" at high) is appropriate, that protein content of feed plays an important part in adjusting the threshhold levels. Low Protein content reduces the rate of digestion, hence the rate of passage of digesta through the system, hence the "capacity" limitation on voluntary intake when this is applicable. When energy concentration is high enough for capacity to be non-limiting, low protein contents have their effect through restricting the attainable rate of production (e.g. growth) and hence limit intake by reducing the energy target below what otherwise would be the case.

Thus a strong interaction exists between protein content, energy concentration, and intake. There is general agreement, however, that above a certain minimum the effects upon intake of changes in protein concentration of the ration are small. According to the ARC Review (1) "..... all diets for ruminants should contain at least the equivalent of 9 per cent of crude protein in the dry matter even if this exceeds the factorial estimate of the minimum requirement." Kay (41) gives results which indicate a positive response to intake up to 15 - 17% crude protein. A conclusion from Kennedy (43) based on data from the U.K. that protein is not the limiting factor in least cost ration formulation encourages the setting of a high minimum, and this is supported by the results from formulation of least cost rations in Chapter Four . The lowest crude protein content in the ration dry matter is set at 11% in this study, with two higher levels tested as alternatives.

The day-to-day variability of a feedstuff in respect of its content of crude protein affects choice of a minimum level since in a large proportion of instances (depending upon the population distribution of protein content in the feedstuff) the actual content will fall below the mean value which is used. Where rations are formulated, as in the present study, with crude protein being derived from several feedstuffs, the variance of crude protein is expected to be lower in the mixed ration than in the constituent feedstuffs.

The inclusion of high crude protein levels in ruminant rations is in one sense an insurance against accidental lowering of crude protein content to the point where animal performance will suffer. This is the rationale of the two higher alternatives of 14.5% and 17% used in this study. Intake rates are assumed to be identical at crude protein levels above 11%.

Fibre Content. Roughages are so described on account of their content of fibre, and conceptually roughages form the proper diet for ruminants. The gross energy of such feeds is almost constant at 4.4 mcals/kg but there is evident almost as wide a range in digestibilities of roughages as is found over the whole spectrum of ruminant feeds. A major distinction between roughages hence is shown in their content of digestible energy and thus of metabolizable energy. Fibre digestion takes place after fermentation, a time consuming process, and assimilable portions of the fibre ration are delayed in the rumen, as are the non-assimilable portions for a period of time reaching into days. The first and most obvious effect, therefore, of varying fibre content of feeds, is an effect upon the rate of passage of the ration and hence upon the "physical" control mechanisms of voluntary intake.

Least cost rations of varying levels of metabolizable energy concentration in the absence of a fibre content constraint are inclined to show an inverse relationship between fibre content and energy density.

The intake characteristics of such alternative rations are therefore strongly affected by the fibre-content-dependent "physical" controls at the lower energy levels and only by "metabolic" controls at the upper levels. It becomes necessary in order to avoid this interaction, to constrain the identification of least cost rations to within a range of fibre contents the extremes of which do not significantly influence the physical controls on voluntary intake. Having regard to the New Zealand feed supply situation, and to the effects of the energy and protein requirements of the ration at each level of energy density, the introduction of a constraint requiring fibre content to lie between limits of 20% to 30% gives little disturbance to actual ration choices while removing the possibility of aberrations due to interractions between fibre content and energy content in the setting of voluntary intake levels.

As will be evident later, the intake model is of such a form that little difficulty would attach to the introduction of an explicit factor to represent fibre content as an independent variable.

Fineness of Comminution. The effects of milling and grinding upon feed intakes are well documented e.g. (53), (61). A consensus from the literature would suggest that maximum intake with least depression of digestibility from the theoretical maximum rate would be given by rolling of grains and short chaffing of roughages. Hammermilling often is used to approximate the needs in mixed rations.

Intakes are depressed with long straw and hay, and are again depressed with fine ground feed. Ration preparation methods for the feeds applied in this model are assumed to yield the intermediate degree of physical breakdown which is optimal in these terms. No attempt is made to define the technical methods which might be employed or to specify the particle size range.

Soluble carbohydrate concentration. The correlation of high contents of soluble carbohydrate with reduced fibre digestion is again well documented e.g. (42). The depression of straw digestibility given a grain supplement, or the effect of the high weight of cell contents in lucerne in giving rapid digestion and higher growth rates despite the lower digestibility of the cell walls, are examples of the practical expression of this correlation.

Another area in which this aspect influences both intake and digestibility is that of the so-called associative effects of ration mixes. The incorporation of a straw which is deficient in most nutrients into a ration with adequate levels of proteins and vitamins permits an important increase in the metabolizability of that straw. The further incorporation of grain supplements, or molasses often diminishes that increase.

Since rations containing higher proportions of soluble or easily digested carbohydrates are usually those with the higher density of metabolizable energy, and at the same time contain lower proportions of components whose metabolizability benefits from the associative effects of feed mixing, it is believed that no useful purpose will be served by constraining ration selection in respect of soluble carbohydrate content despite the undoubted interaction with the metabolizability of feeds of low digestibility and the impacts of this upon voluntary intake.

Appetite Inhibitors and Moisture Content. Lower than expected rates of output from animals fed silage have often been attributed to the presence of appetite inhibiting compounds. Some discussion of the problem is given by Jackson & Forbes (36) whose main conclusions are that dry matter is the most important factor in increasing consumption rates on silage. The problems seem slight when silages form less than 70% of the dry matter ration. To ensure minimum appetite depression therefore, rations in this study are constrained to a maximum silage content (DM) of 65% and to a maximum moisture content of 60%. Appetite inhibiting factors are assumed away.

In the event, the moisture content constraint proves ineffective and the least cost rations formulated all exhibit a moisture content of close to 54%. Coincidentally this compares with the silage-containing rations used by Culbertson et al (18) with a moisture content of 57%.

Balance of Minerals and Vitamins. Within the range of feeds considered for ration formulation under New Zealand conditions the cost of correcting any deficiencies or imbalances in these constituents is expected to be negligible. While practical feedlot management would undoubtedly monitor these factors, the ration formulations used in this study include 1% of their dry matter as an unspecified mineral/vitamin additive and are assumed to be adequate in all respects.

3.2.1.1 The Intake Model with Energy as the Control Variable. The constraints applied to ration choice are intended to remove all variability from candidate rations in those respects which may influence rates of voluntary intake, with the exception of energy density. None of the constraints are considered unreasonable or impracticable, and most in fact are among those which a prudent cattle-feeder would normally incorporate on intuitive grounds. These constraints can be considered the expression of real-world considerations weighing upon ration formulation, and while many real-world decisions may not be completely rational the explicit statement of the constraints is thought to add to rather than to detract from the realism of the model. At the same time, and this is the reason for identifying these constraints in this study, the ground is laid for describing voluntary intake as a function of only one ration characteristic, the concentration of metabolizable energy.

With the foregoing assumptions and qualifications, an intake function derived in large part from the work of Conrad et al (16), and consistent with the results reported by Owen et al (69), can be written:

$V = AW^{.25}/(3.7-M)$ kgs $DM/W^{.75}$/day....(2a)

when this value is lower than:

$V = B/M$ kgs $DM/W^{.75}$/day .... (2b)

where W is the liveweight (kgs)

M is the concentration of metabolizable energy (mcal/kg DM)

A and B are control parameters.

The control parameters, A and B, relate to the physical intake control (A) and the alternative "metabolic" control (B), with the capacity control prevailing only should the intake of energy not exceed the ceiling set by the metabolic control. It is noteworthy that this spliced function indicates that while intake per unit of metabolic weight is independent of liveweight in the case of function 2b, this is not so in 2a, where liveweight influences intake per unit of liveweight. This is consistent with the capacity constraint being a function of volume (=kW) whereas the metabolic constraint is a function of metabolic weight. ($=W^K$). Graphs of these functions are shown in Figure 7 with the quadratic function of Blaxter also appearing for comparison. It is to be noted that Blaxter's function parallels the general behaviour of the spliced function, without the marked discontinuity, but takes no cognizance of the effect of liveweight upon the intake in the lower range of metabolizable energy. Since it was derived from sheep, of low weight variance, this is not surprising. The downward bias found by Kennedy might also be partly explained by this independence of liveweight, compensated for by Kennedy with a blanket increase of 25%.

The values assigned to the control parameters as a result of the original derivation are:

$A = 0.03$

$B = 0.26$

These values are subject to modification from two sources. The first is animal variation, discussed in the following section; the second is operator variation reflecting the differing abilities of feedlot managers as stockmen. The personalized nature of the model will receive emphasis in a later section.

3.2.2. Voluntary Intake (Animal Characteristics).

The preceding subsection developed an intake function as far as experimental research work could lead it - to the point where two factors are supposed to influence voluntary intake, the factors of ration description and of animal liveweight. Throughout the research literature references can be found to "between animal variation", "dynamic control", "integration of past history", "physiological status" and so on, but the essence of these complicating factors has not been captured. Yet most, if not all, of the sources of intake variation dependent upon animal characteristics have individually been investigated and the direction of their action identified.

Again, if animal intakes are not determined capriciously, the possibility must be accepted that these elusive factors must be susceptible to measurement and prediction. This section describes an attempt to so predict, the only criterion of success being found in the ability of the resulting model to predict intakes indistinguishable from those expected by persons with experience in feeding cattle. While not offering a description of the processes which determine voluntary intake, the resultant model may well offer insights into the process not easily derived from consideration of the process itself.

Age and Maturity. As an animal grows it eventually reaches a stage where its liveweight fails to increase further. The extreme delicacy of a control system which can achieve this is self evident. It can be supposed that innumerable interactions are involved in this process, the essential facet of which is the asymptotic nature of the growth curve as liveweight increases. This is discussed at length by Taylor (75) and by Brody (12). With cattle in general and steers in particular, the increasing proportion of fat in the liveweight gain as liveweight increases is commonly observed. The ARC Review (1) (Table 6.22) shows this in the relationship between the calorific value of gain, the rate of gain, and the liveweight. Since no evidence has been brought forward to show that digestive efficiency decreases with increasing liveweight or fatness, it is apparent that the mechanism by which growth is slowed must act through a control on intake. An alternative lies in the belief that the added inefficiency of maintenance at liveweight levels approaching the mature ceiling cause the feed intake to be fully used in maintenance, leaving none for production, growth, or fat deposition. It can be shown quite clearly that without an intake diminution the extra needs for maintenance are insufficient to halt growth at realistic liveweights.

A paper (33) by Hadjipieris et al states "...for grazing sheep intake was directly related to weight. Aged sheep consumed only about 2/3 of the DOM consumed by the younger sheep." McCullough (52) finds "As the animals became heavier they had lower intakes on the all-concentrate diet, but higher intakes with the higher roughage rations." Both these studies point out the inability of animals with a high energy demand (as for rapid growth) to ingest enough when given high roughage rations. And both show that older, bigger animals are able to consume more roughage but in fact have a lower demand for energy intake.

A model of the process requires to capture its essence, and a convenient feedback for the purpose of model construction is given by the calorific value of gain at each level of liveweight. It may be supposed that at any age and liveweight level a steer has a genetically determined "target" growth rate which, given access to adequate feed and the ability to consume sufficient of that feed, it will adjust towards. Beyond the calf stage it may be supposed that this target growth rate first increases with increasing liveweight, and then decreases, ultimately to zero. (These suppositions are solely for rendering the process of intake control amenable to representation in modelling; there is no intention to define the real mechanisms.)

From the relevant section of the ARC Review the calorific value of the gains (CVG) which result at any given liveweight and any given rate of gain can be estimated - this permits the model to compare the recorded CVG with that of the target rate of gain at any stage and to use this information to adjust subsequent daily intake by a small increment (or decrement) directed at a change in the CVG (and the rate of gain) towards the target level.

With particular assumptions on the target rate of gain at various liveweights, a covenient linear expression for the corresponding CVG is:

$$CVG^* = 2.52 + 0.0014W \text{ mcals/kg} \quad ....(3)$$

This information feeds back the direction of change of intake. It is incorporated within a function determining the rate of change of intake, designed so that the speed of convergence to the intake rate needed to give the target rate of gain is increased the nearer liveweight is to mature liveweight.

Physiological State. This study concerns itself with steers only, of ages beyond the calf stage. The effects of lactation, pregnancy, and calfhood are of no concern. Different states do, however, make themselves felt even within this restricted class. These differences are in general associated with previous feeding history, and an intake model to be realistic must be able to represent the effects of, for instance, compensatory growth and its obverse. Under normal New Zealand grassland farming systems the effectiveness of this process in cancelling the ill effects of prior starvation has been shown to be doubtful (38). Since the phenomenon is undoubtedly real, and well documented (e.g. (67)), the reasons for this ineffectiveness may well lie in the special characteristics of New Zealand management systems for cattle on grazing. The temporary nature of feed gluts and the usual restriction of intake to levels well below those needed for cattle to attain their potential growth rates as evidenced in the growth rates recorded in (21), and (28), can be expected to minimize the impact of tendencies to compensatory growth.

Feedlot conditions, with ad lib feeding defined fully to meet the demands of voluntary intake, offer a contrasting situation. The nature of the cattle input, from the population of steers common to the normal New Zealand farming system, implies that steers entering the feedlot could have feeding histories which differ, some of which will have prepared the animals for a period of compensatory growth. Steers described as thin would be expected to fall in this category. And fat steers might well record lower growth rates and intake rates than those of the average animal.

Bines et al (7) propose that "both rumen distension factors and energy ceiling factors are flexible, with different values for thin and for fat cows." But in both cases growth rates would tend over time to converge to the normal rates, described above as target rates. Since therefore, the state of abnormal thinness or fatness will not persist, and all animals will tend towards the normal rates of intake and growth, and to the normal state, the model requires to adjust intake rates according to the condition of the steer only once - at the start of feeding.

This is done by application of a factor to the values of the parameters "A" and "B" in the model, the factor being determined by the liveweight and condition of the steer at entry. Thin animals, with higher expected rates of daily intake, are characterized by a factor greater than unity and fat animals by a factor equal to unity. In all cases this factor is then adjusted according to the initial liveweight in order to model the reduction of intake rates which occurs with increasing liveweight. The formulation used is:

FACTOR = 1.2 -(0.001*W)*(0.75+0.05*C)
where W is the initial liveweight (kgs);
and C is the condition grading on a scale of
1 = Thin; 9 = Fat.

The daily readjustment of intake acts cumulatively upon the values for "A" and "B", using the feedback information of the calorific value of gain laid down on the preceding day and its relationship with the calorific value of the gain at "target" rate of gain as described above. The formulation employed is:

TARG = 2.52 + 0.0014W
RES = $900/(1 + e^{.006W})$
DAYCH = (RES + TARG/CVG)/(RES + 0.9)
A = A* DAYCH
B = B * DAYCH

where: TARG is the target value for calorific value of gains (CVG*);
RES is used to increase the response as liveweight increases;
DAYCH is the resulting adjustment to the control parameters;
CVG is the calorific value of the gain laid down on the preceding day.

Genotype. In fact, steers of different breeds tend to exhibit different mature weights and differing characteristic (target?) rates of gain. Further, steers from different regions, although of the same breed tend to be of different bloodlines and to show similar differences.

The parts of the model dealing with animal characteristics are so constructed that specific expected differences can be incorporated by the operator. Where the operator wishes to compare the effects upon intake and growth of such genetic differences he is able to introduce them explicitly into the model. For instance, the impact of physical capacity upon determination of voluntary intake is expressed through "A". Where animals are considered which are believed to have greater than normal gut capacity by comparison with liveweight, this will be reflected by a higher initial value for "A". Animals believed to possess lower "potential", i.e. to exhibit lower "target" rates of gain, would be modelled by a lower initial "B" value in equation (2).

3.2.3. Nutritional Relationships.

The discussion of the model components constituting the intake function takes place only with full awareness of its interaction with the nutritional relationships of nutrient intake and animal performance. These are discussed in the present section, and while closely following the principles enunciated in the ARC Review, (1), the discussion takes the same liberties with strictly defined relationships as did the development of the intake model. The criterion of success in modelling the utilization of intake by the animal is, once again, conformity with the expectations of the experienced operator.

This section is based entirely upon the relevant parts of the ARC Review, and follows very closely the model development process described by Kennedy. (43) The necessary caution in applying feeding standards to individual animals is not questioned although it must be emphasised that expected applications of the complete model can refer to lines or mobs of cattle, rather than to individual steers. The use of the singular in the discussion is no more than a convenience for purposes of exposition.

Three equations are presented in the ARC Review which form the cornerstones of the system. Other relationships are described in tabular form, namely those for fasting heat production and for the calorific value of gain.

k_m = the efficiency with which metabolizable energy is used for maintenance purposes
$= 54.6 + 6.75M$ .... (5)

k_f = the efficiency with which metabolizable energy is used for purposes of growth and fattening
$= 3.0 + 18.4M$ .... (6)

M* = the true metabolizable energy concentration

$$= M(1 - \frac{0.418DL}{M} + 0.11DL) \quad \text{........} \quad (7)$$

where M is metabolizable energy concentration (mcals/kg DM);

M* is the metabolizable energy concentration corrected for the feeding level;

DL is the proportional excess of energy intake over maintenance needs.

The energy needs for maintenance are taken in the Review to be defined by the fasting metabolism and given in Table 6.12 of the Review are the preferred mean values for fasting heat production according to age. The sources of this information are listed in the Review, and a consideration of these permits an approximation by a linear function of liveweight:

HP = heat production at maintenance

= requirements for nett energy at maintenance

$$= (117 - 0.06W) \text{ kcals/Wg}^{.75} \quad \text{........} \quad (8)$$

The Review emphasises the between-animal variation in fasting heat production, and suggests that the range of variation is of the order of $\pm$ 11%. An opportunity is therefore given for expected differences in animal efficiency to be modelled by varying the constant term in equation (8).

The weight of liveweight gain produced from a given quantity of nett energy available for the purpose is dependent upon both the liveweight level of the animal and upon the quantity of nett energy available for retention or gain.

The Review (Table 6.22) lists equations for estimating the calorific value of gain in terms of these two variables. These equations are of the form: cv = a + bs where a and b are constants which take different values according to the liveweight and s is the energy retained (nett energy for growth) in kcals/head/day. The reformulation of the equations as a single equation of the form cv = a' + b'W + c'WN + d'N, is consistent with Table 6.22 and use of OLS to fit this equation to data derived from the equations in the Table gave:

$$CVG = 1.45 + 0.0035W + 0.0001WN + 0.2326N \text{ mcals/kg gain.} \quad \ldots\ldots\ldots\ldots \quad (9)$$

where CVG is the calorific value of gains;

W is the liveweight (kgs);

N is the NE_g (mcals/day);

The model uses equation (9) to convert nett energy retention to rates of daily gain.

The equations numbered (5) to (9) constitute the nutritional relationships incorporated in the model. These have been derived strictly from the data given and the framework of the ARC system except that information given in tabular form has been modified to be accessible in continuous form. This involves a degree of approximation which may be far below the variance of the data transformed. The whole area of variation , which the present approach tends to disregard, is summarized by Blaxter (8):

"....Between animal variation in their needs for food energy probably accounts for about one third of the total discrepancy between expected performance on a calculated ration and actual performance. The remaining part must be due to errors in the estimation of the nutritive value of the feeds actually employed." The model, as constructed, faithfully (with the exceptions noted) corresponds to the ARC system. If applied to individual animals its accuracy would be as suspect as direct application of the feeding standards derived from the ARC system. The intended use of the model is in evaluating the performance of groups of animals, and even of populations of animals. In this situation its adequacy can be no less than that of the ARC system itself. The primary source of error will lie in the estimations of energy values of candidate rations.

An implicit assumption in the preceding discussion of the nutritional relationships is the absence of nutritional constraints upon growth other than the energy constraint. It will be recalled that similar assumption in relation to the voluntary intake were made and justified by:

(a) Constraining crude protein content higher than 11%, and

(b) Assuming minerals and vitamins present in adequate supply and proper balance, and

(c) Setting other variables of importance to within ranges where the effect of variation on intake was expected to be insignificant.

These same constraints apply also with respect to the nutritional relationships, since the application of the two sectors of the model are simultaneous.

3.3. Model Operation and Validation.

3.3.1. Establishment and Operation.

The model is constructed to use the same time scale as actual feeding of animals. As enshrined in the literature this uses time increments of one day, with all requirements and factors relating to the feeding of a daily ration. This degree of subdivision accentuates the dynamic nature of the feeding operation, allowing readjustment of the factors which respond to feedback in increments or decrements which can be supposed to minimize the discrepancies from the factual readjustments which take place continuously in the animal being modelled. In a sense this approach is intermediate between that which views the process of feeding and growth as a static process with predetermined parameters, and that represented by the real world. Of the compromises available the use of daily time increments would seem to offer the best which enables capture of the dynamism of the process without necessitating prohibitive computation.

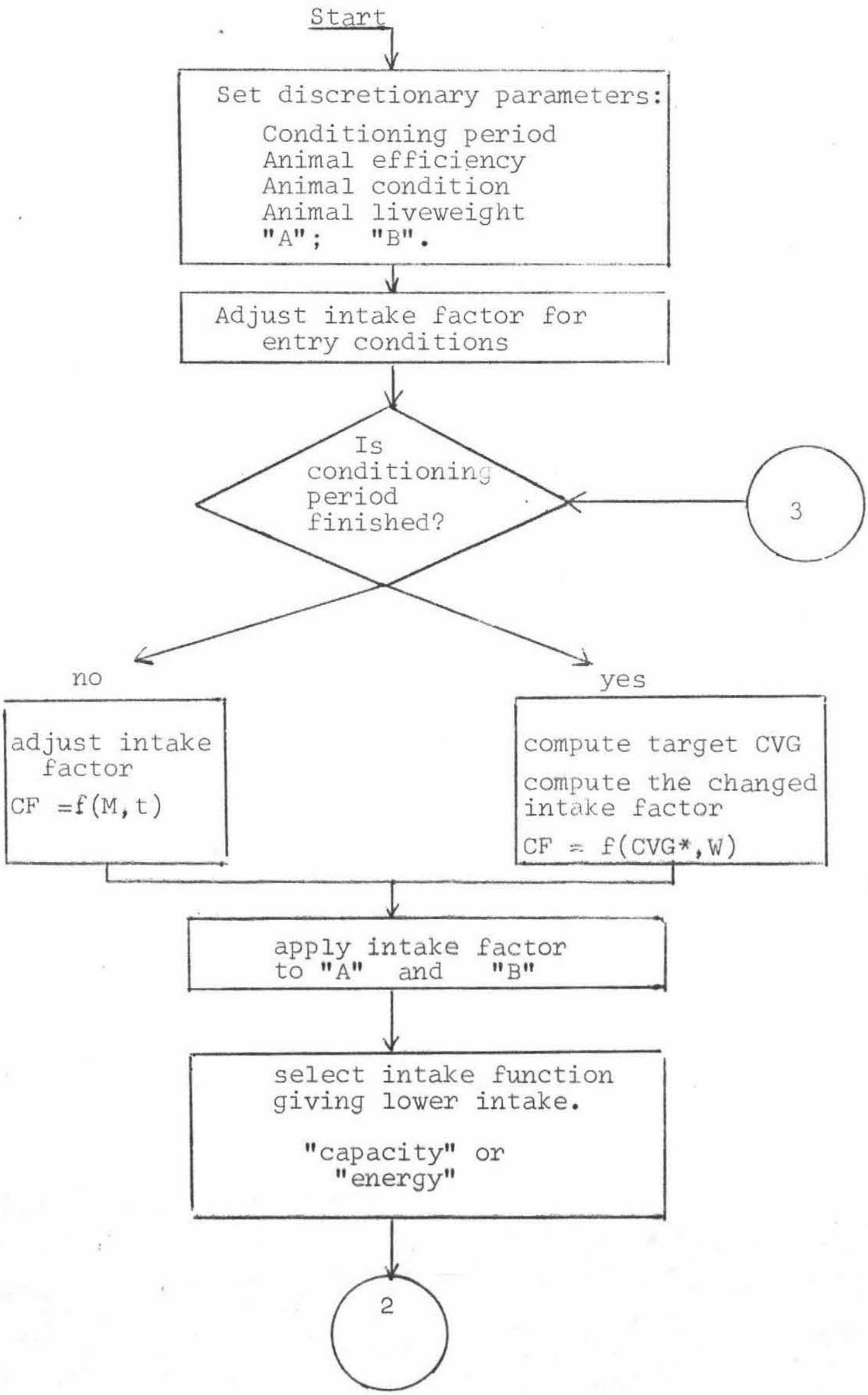
Parameters set at the commencement of a run include the underlying factor conveying the effect of animal condition upon voluntary intake level, and the liveweight level at start. In combination these parameters set the magnitude of the factors "A" and "B" and determine the rate at which further adjustments to these factors are made in response to departures from the "target" rates of gain. It is to be noted that the evaluation of animal condition, with its repercussions upon intake rate and growth rate, is the responsibility of the operator who can only use his subjective judgement.

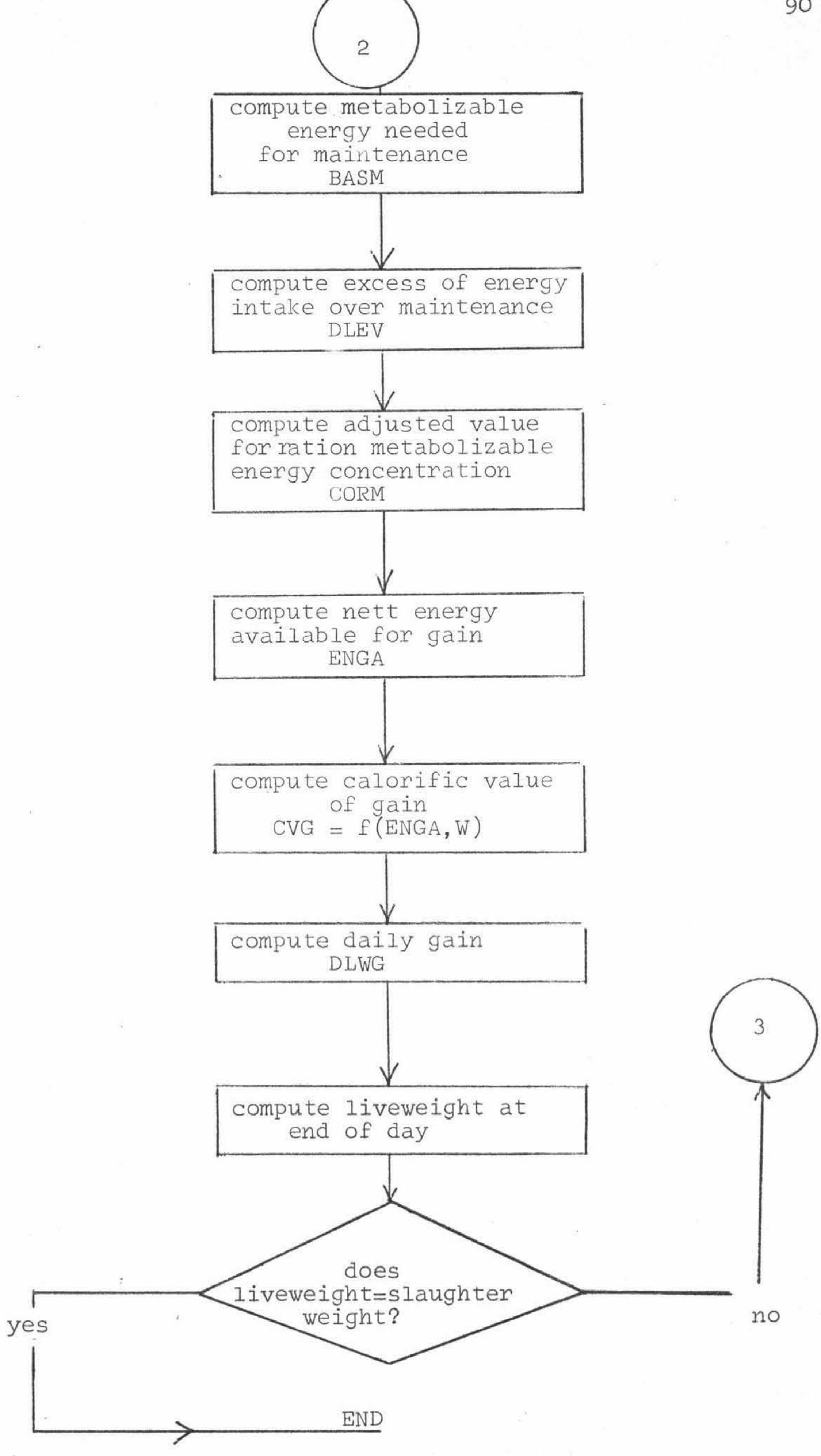
The effect upon ruminant performance of changes in ration composition is in the nature of a temporary depression of intake and digestive efficiency during the period when the rumen microflora respond to the new demands. This period is often referred to as "conditioning" or "adjustment". Under the New Zealand situation steers entering a feedlot will have been accustomed to either a pasture ration, or a hay ration, or some combination of these. It is possible that some will have been fed silage. The adjustment period will therefore not be protracted, and will not involve important loss of production unless the feedlot ration is the higher energy type. A duration of 15 days has arbitrarily been given for this adjustment period, with intake being determined not by the normal adjustment process, but by a linear function of the days in the feedlot, the slope of the function being set by the energy concentration of the ration. This is a gross approximation to reality, taken on the grounds that while depression of intake and performance is undoubtedly real when the final ration is fed from the first day (and in fact the need to avoid metabolic diseases would dictate a slow introduction through a succession of rations) the details of the conditioning period will not significantly affect economic performance as between animals or between feeds.

The model reverts to the normal readjustments of intake on the final day of the conditioning period, with feedback of the calorific value of gain used to set the magnitude and direction of the change to the intake rate for the next day. The sequence is illustrated in the flow chart of Figure 8.

FIGURE 8.

GROWTHMODEL - FLOW DIAGRAM




2
compute metabolizable energy needed for maintenance BASM
compute excess of energy intake over maintenance DLEV
compute adjusted value for ration metabolizable energy concentration CORM
compute nett energy available for gain ENGA
compute calorific value of gain CVG = f(ENGA,W)
compute daily gain DLWG
compute liveweight at end of day
does liveweight=slaughter weight?
yes
no
3
END

3.3.2. Validation.

The construction of the growth model has been carried out with two major objectives. These are:

(a) To incorporate established nutritional relationships and

(b) To permit flexibility in operation through use of subjective parameters decided by the operator.

Validation therefore can take place at two levels - the general, and the personalized. On the general level it can be confirmed that growth curves produced by the model are consistent with the shape of growth curves produced by data fitting. Some of the curves are shown in Figures 9 and 10. Using the method applied by Nelson (64) similar functions can be fitted to these artificial curves as were fitted by him to the data from Culbertson. As has been emphasized repeatedly, actual conditions under which growth is recorded are defined by the operator according to his interpretation of the parameters of importance - the data used by Nelson led to a standard error in his curves of the order of $\pm$ 50 pounds at liveweights of about 1,000 pounds. For the purposes of model construction, the sources of variation are removed, the operator making the choice of the actual value to be taken for those parameters which in reality might be stochastic in nature.

As an instance, the voluntary intake is assumed throughout to be absolutely determined by the model. Yet frequency distributions showing the variations in total digestible nutrients consumed by steers under ad lib feeding are presented by Knapp & Baker (46) indicating that voluntary intake is subject to variation from unidentified sources.

Figure 11 shows the envelope of growth curves derived by Nelson for a steer of initial weight

FIGURE 9.

The Growthmodel - Sample Curves.

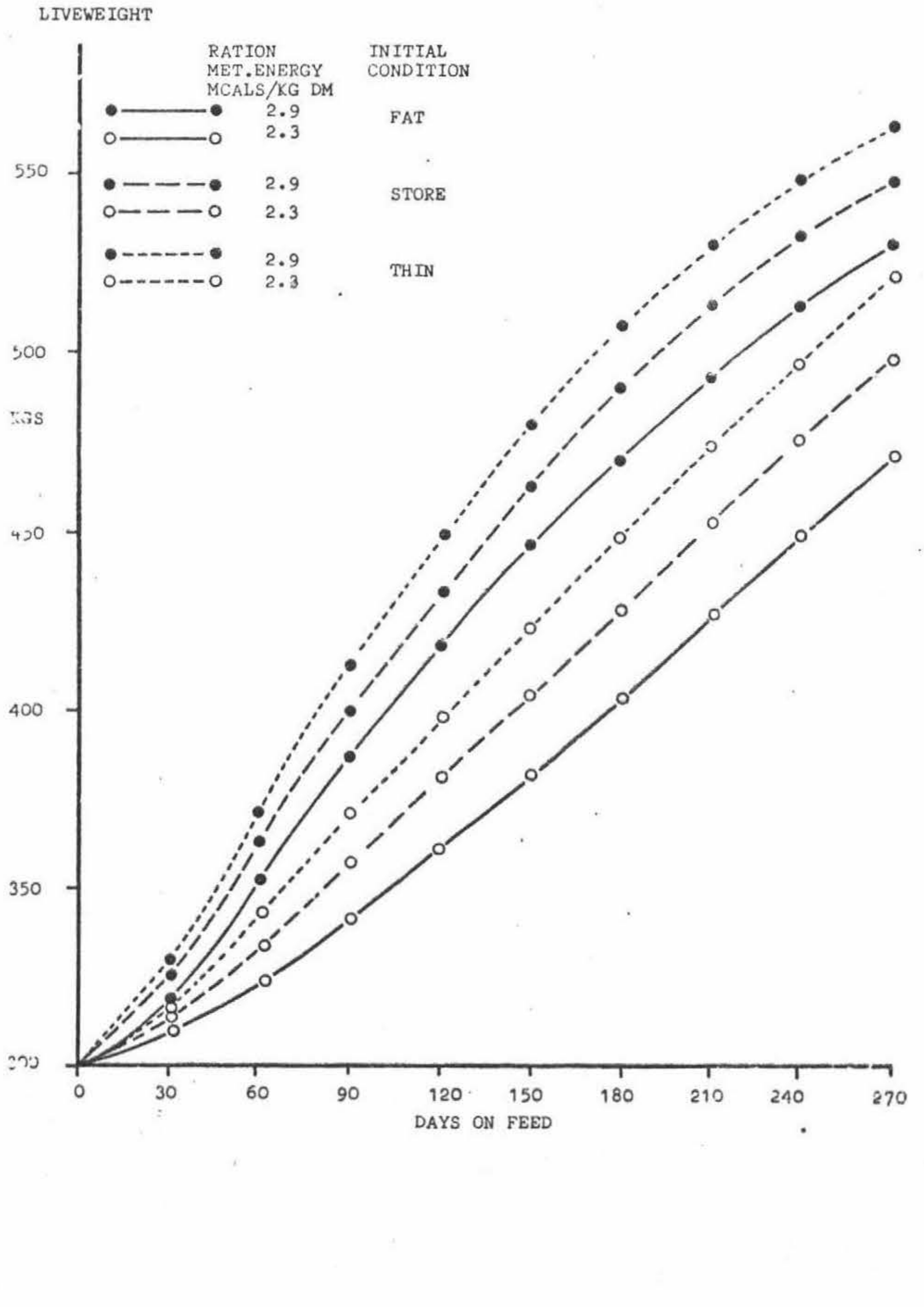


FIGURE 10.

The Growthmodel - Sample Curves.

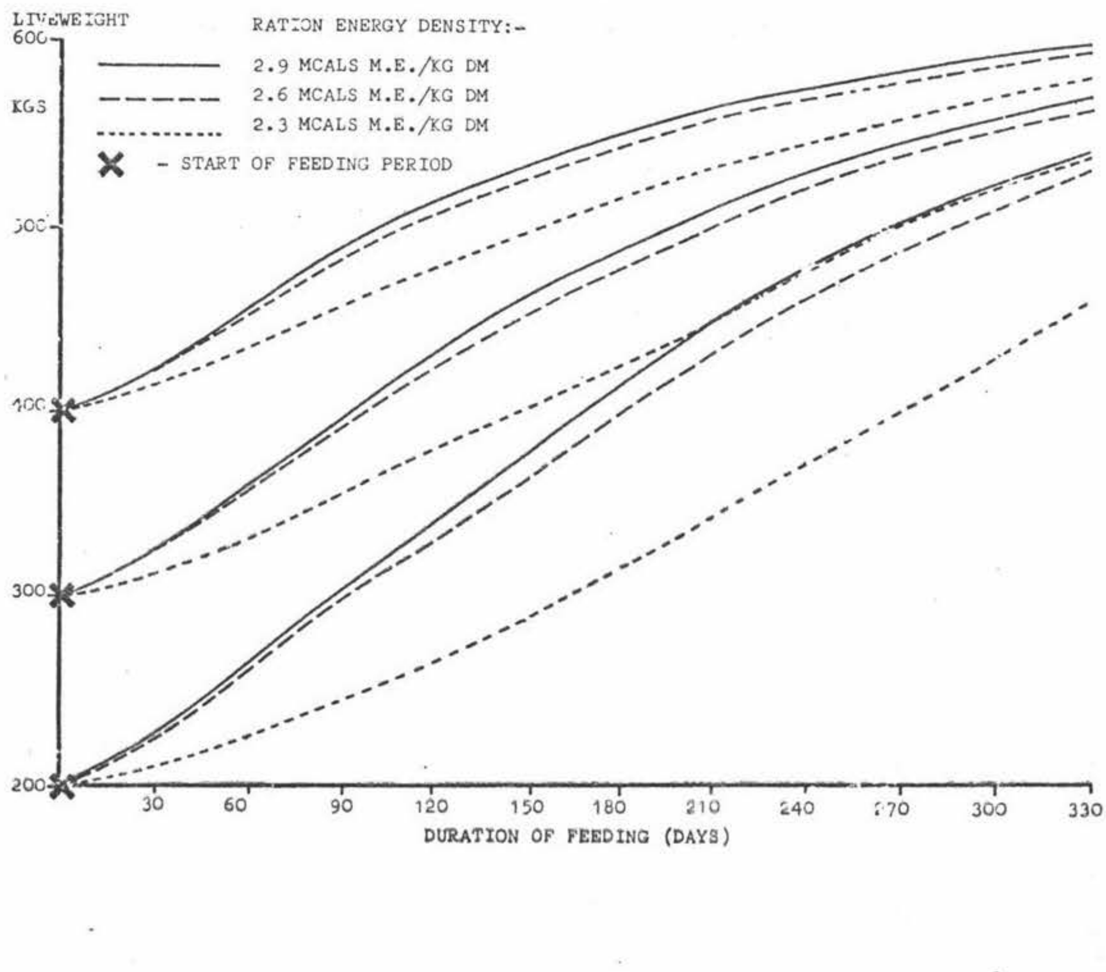
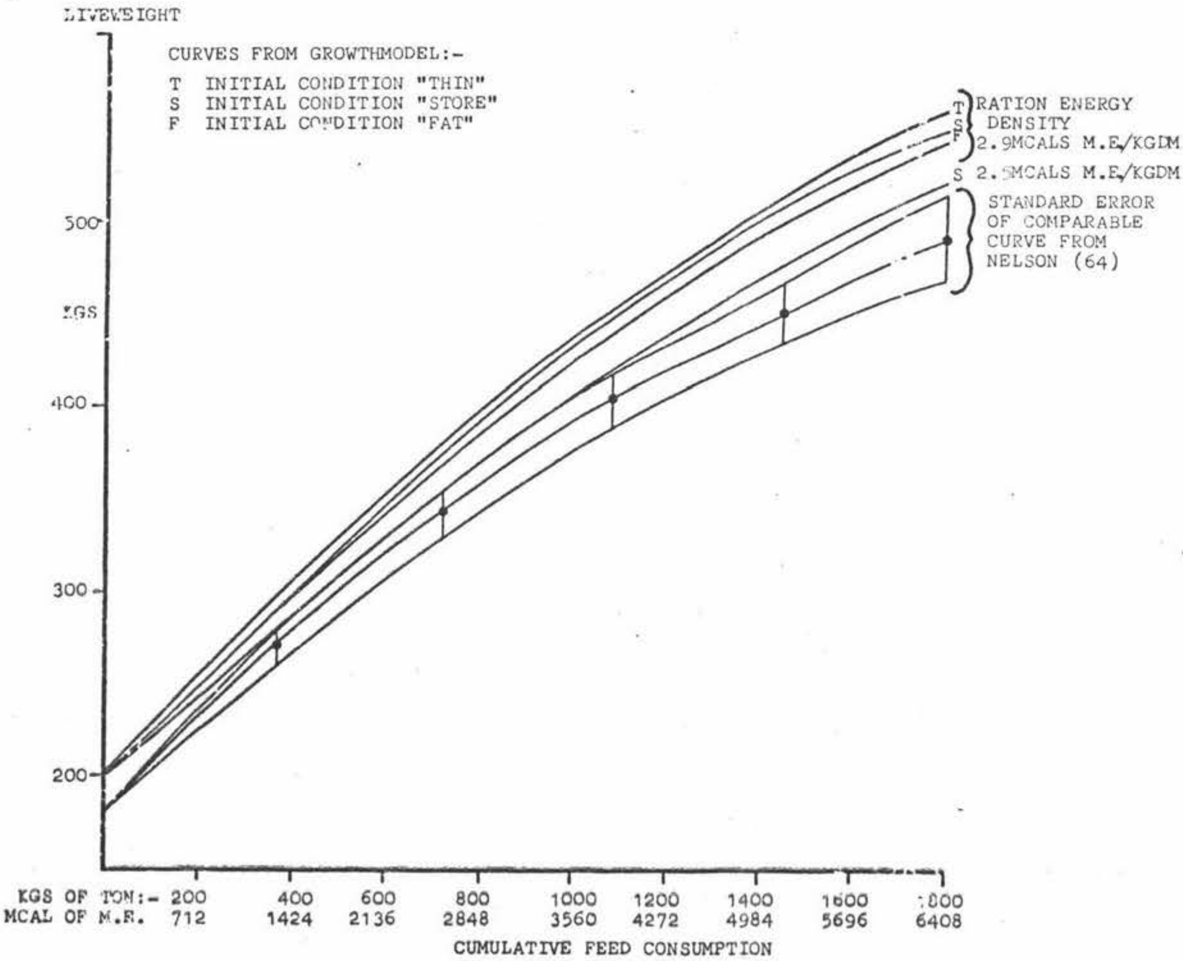


FIGURE 11.

The Growthmodel - Comparison with curves fitted to data.



400 pounds. The standard error of the curve represented by the envelope is derived from the data, and demonstrates the variation within the biological system. By comparison the four curves from growthmodel representing animals of starting weight 200 kgs are shown as single lines since the input to the growthmodel is deterministic.

Comparison of the curves shows that the shape and slope of the growthmodel output is consistent with the upper limit of Nelson's envelope, and the variation between the different curves is not great. The replacement of the time scale by a scale of consumption, the format of Nelson, conceals the very real differences between the model outputs on the basis of rates of gain per unit time, but indicates clearly that the process which has been modelled is indeed close to that which created the data of Culbertson et al used in Nelson's work.

The position of the growthmodel output, at the upper edge of Nelson's growth envelope (remembering the different starting weights) is not unreasonable as a reflection of improved animal efficiency since 1930. The differences in shape of curve, between the animal of initial store condition fed on a ration of 2.9mcals/ME/kg DM and that fed on a ration of 2.5mcals/kg is to be noted. The flattening of the curve is exaggerated further as might be expected with lower energy concentrations. The rations on which were fed the animals from which Nelson's data came are estimated to approximate 2.9mcals/kg concentration of metabolizable energy.

When the performance of the model is viewed from the standpoint of ability to predict the animal performance expected by the operator, validation need only be personal. In the present instance the model has been constructed to give predictions consistent with the expectations of the author. An operator who uses the model when its results are inconsistent with his beliefs will not be evaluating a situation of relevance.

Evidently, validation and parameter estimation will be carried out simultaneously by a model user. He will set the parameters which will yield the answers in which he will have confidence. This will be done by a series of ceteris paribus decisions e.g. "by how much does the voluntary intake of a thin animal differ from that of a fat?" and so on. There is no reason why an operator who wishes should not incorporate the between-animal variability into the model with a series of stochastic simulations yielding an expected value for output, in place of the present use of expected values for the parameters.

The output of the model which results from incorporation of each modification acts as feedback for the subsequent modification. Information such as the cumulative total consumption, the conversion rate of feed to liveweight, the intake as a percentage of the liveweight - all measures which animal feeders commonly use - are of value as feedback.

The completion of parameter fixing is then by definition the completion of validation. Some sample outputs of the growthmodel at the stage which is considered final are shown in the tables of Appendix B.1. Of special interest is the intake as a percentage of liveweight. This is the relationship which formed the basis of Greig's (32) intake function which is of the form:

$$I = 0.5 + 5D - 0.0055W$$

where I is the intake of dry matter as a percentage of liveweight;
D is the digestibility of the ration varying from 0.6 to 0.8;
W is the liveweight in kilograms.

No direct comparison is possible between the growthmodel output and that from the model of Greig, but it is evident that within the medium range of liveweights (250 - 500kgs) the action from both models is similar. This tends to confirm the validity of the model. Outside that range the linear formulation of Greig's model leads to apparently excessive intakes at low liveweights and to negative intakes at high liveweights. The absence in Greig's model of provision for effects of animal condition upon intake clearly reduces its effectiveness for other than the restricted degree of variation for which it was designed. The growthmodel intake function is believed to be effective at all liveweights, for all condition gradings, and for all levels of ration concentration of metabolizable energy.

The final form of the growthmodel is incorporated in the feedlot function of Chapter Five.

CHAPTER FOUR

4. CANDIDATE FEEDSTUFFS AND RATION FORMULATION.

4.1. The Costs. of Feedstuffs

4.1.1. Non-marketed Feeds.

New Zealand livestock farming, based on pasture production and grazing, comprises production units which are essentially self-contained for feed supplies. Normally the feed is derived from pasture and is consumed in situ. The seasonal variation in pasture is smoothed to more nearly conform to the demands of livestock by conservation measures which permit seasonal surpluses to be held over into times of feed deficiency. This practice is traditionally applied through the making of hay, and surpluses conserved in this way are readily traded in the market.

The same pasture surpluses alternatively can be conserved as silage, as can various crops cultivated specially for conservation. The characteristics of silage, high moisture content and instability upon exposure to air, make quality difficult to evaluate and do not encourage long distance transport. These difficulties are sufficient to preclude free trading of silage.

While pasture is bought and sold for grazing in situ, and silage on occasion is transferred between neighbours, these materials comprise the only feeds for which there is no established market. This study does not attempt to examine feedlots based upon the use of grazing, although there is no reason why the methodology cannot be extended to investigate the traditional system. It is therefore necessary to identify costs of production of various silages, in order to specify their input prices to a livestock enterprise.

The concept of opportunity cost is not commonly applied by farmers in New Zealand, yet use of market price as the cost of traded feed brings this concept into focus. Consistency therefore demands that appròpriate opportunity costs be included in the cost of those feeds for which cost-of-production is the only measure of cost.

The multiplicity of activities on many New Zealand farms tends to make difficult the identification of the opportunity cost associated with any one activity. On a whole farm basis it is clear that the opportunity cost associated with any one combination of activities is the nett revenue accruing from that combination which is optimal in the particular environment. Not only is the optimal combination not known with certainty in the face of climatic and price variations but each combination commonly includes activities which move over different time cycles e.g. cereal cropping and grazing; pastoral farming and forestry; livestock breeding and livestock feeding.

However, in the context of a prospective feedlot operator who is uninvolved in farming activities and whose feedlot will be structurally independent of a farming system employing land, silage production will involve only marginal contact with the complexities of farm costing. In particular, such an operator can view his tenure of land for silage production as leasehold in some fashion. The cost of his lease will enter into his costs whether he uses the land for silage production or for its best alternative use. Rent, or interest on investment in land, need not enter into his computation.

Four alternative methods of producing silage are here investigated. They are listed below with the applicable opportunity cost:

1. Lucerne silage - Hay for sale
2. Maize silage - Maize grain for sale

3. Winter Cereal silage – Proportional share of livestock grazing Gross Margin

4. Silage from surplus pasture – Hay for sale

Quite obviously, the best possible use for land may well be such high return crops as potatoes or onions. In the present context the requisite skills are presumed lacking. In the cases 1 and 2 above, the best alternative use of the land is taken as the alternative disposal of the chosen crop. Case 3 above, using land from May to October only, presents some difficulties. A reasonable alternative, representing a rent chargeable for the period, can be found in the proportional contribution to livestock grazing which might have been offered to the owner if he had retained the land for that period. In the computations which follow an estimate of this charge is the gross margin from prime beef production as estimated in (66). In case 4 above silage production from surplus grass on a farm not owned by the feedlot operator must be subject to the opportunity cost of the hay which the landowner could have produced and sold from the same grass.

The following cost calculations depend heavily for data upon (66) and (85) and are shown in full to permit comparison with the more common simple direct cost method, since conclusions based on the two costing methods tend to differ.

Lucerne Silage.

(a) Hay as the best alternative:

The MAF standard weight for a cured bale of lucerne hay gives 30 bales to the ton, and the moisture content of a cured bale is 15% in Manawatu conditions. The weight of dry matter in a bale of hay is therefore taken to be 28.333kgs.

The direct cost of making hay using large scale contractor's plant is estimated as 48 cents per bale, and the standard selling price (in the paddock) is estimated at $1.50 per bale. The margin per bale is $1.02. The nett revenue from a lucerne crop yielding D kgs of dry matter/ha. of which 15% is wasted in field losses is:

Nett revenue from hay = 3.06D cents

<u>Opportunity cost 3.06 cents/kg DM</u>

(b) <u>Silage production</u>:

Field evidence has been evaluated to indicate that the cost of making wilted silage using large scale contractor's plant is $2.50 per ton of silage at a moisture content of 70%. Since charges for such plant are normally on an hourly basis and the time taken is independent of moisture content after wilting (due to transport capacity being limited by bulk and not by weight), the cost of making silage, can be calculated for a yield of Dkgs of dry matter per hectare:

Weight of silage at 70% moisture	D/0.3kgs
Cost of making	$2.50/ton
Direct cost of silage making	0.25 x D/0.3 cents/ha
	= 0.833D cents cents/ha
	<u>i.e. 0.833 cents/kg DM</u>

Field losses are considered negligible and as the cost of establishment and maintenance are identical for hay and for silage production, they are disregarded. The total cost of making silage is therefore the sum of the direct cost and of the opportunity cost.

<u>Total cost of silage = 3.893 cents/kg DM stored</u>.

Maize Silage.

(a) Grain as the best alternative:

Yield of grain Y tons/ha (dried to 14% moisture)

Total costs for harvest and grain handling = $19.4Y/ha

Sales of grain = $79.0Y/ha

Nett revenue from grain = $59.6Y/ha

But, the yield of silage dry matter can be estimated as 1.7Y, so:

Opportunity cost for silage = 3.506 cents/kg DM

(b) Silage production:

Yield of silage dry matter = 1.7Y tons/ha
Yield of silage (64% moisture) = 4.722Y tons/ha
With large scale contractor's plant the direct cost of silage making is estimated at $2.00 per ton of silage.
Direct cost of silage making = $9.444 Y/ha
= 0.555 cents/kg DM

The costs of cultivation and crop husbandry are taken to be identical for both end uses. The total cost of making silage is therefore the sum of the direct cost and of the opportunity cost.

Total cost of silage = 4.06 cents/kg DM stored

Silage from Winter Cereals (e.g. Oats, Tama, etc.)

(a) The best alternative - Prime Beef Production

(under permanent pasture)

Annual Gross Margin from Prime Beef	\$278/ha
Winter contribution (40%)	111.2/ha

(b) Silage Production

Weight of dry matter	T tons/ha
Weight of silage (35%DM)	T/0.35 tons/ha
Direct costs of silage making at \$2.50/ton	\$ 7.14T/ha
Direct costs of cultivation	\$ 74.00/ha

The costs per kilogram at different yield levels are shown in Table V below:-

Table V

Effect of yield on silage costs (Winter Cereals)

Yield of dry matter/ha (T)		7	9	11
Total direct costs	\$/ton DM	17.71	15.36	13.86
	cents/kg DM	1.77	1.54	1.39
Opportunity cost	cents/kg DM	1.59	1.24	1.01
Total	cents/kg DM	3.36	2.78	2.40

(c) Combination of Maize Silage and Winter cereals Silage (rotation)

The total cost of the mixed product at different levels of yield is shown in Table VI below:-

Table VI

Effect of yield on cost of mixed silage.
(cents/kg DM stored)

Yield of Maize tons DM/ha	14	17	20
Yield of Cereal tons DM/ha			
7	3.83	3.86	3.88
9	3.56	3.62	3.66
11	3.33	3.41	3.47

Silage from Pasture Surplus

(a) Hay as the best alternative:

The MAF standard weight for a bale of cured meadow hay gives 35 to the ton, and the equilibrium moisture content in the Manawatu is 85%. The weight of dry matter in a standard bale of meadow hay is therefore 24.28kgs.
The direct cost of making hay using large scale contractor's plant is estimated as 48 cents per bale, and the standard selling price (in the paddock) is estimated at $1.00 per bale. The margin per bale is 52 cents. Field losses in making meadow hay are low by comparison with lucerne hay and are assumed to be zero.
The nett revenue from a paddock of surplus grass yielding Z kgs of dry matter is:

Nett revenue from hay = 2.14Z cents

Opportunity cost = 2.14 cents/kg DM

(b) Silage production:

Weight of silage at 65% moisture is Z/0.35kgs
Cost of making 0.25 cents/kg
So, direct cost of silage making 0.25Z/0.35cents
= 0.714 cents/kg DM

The other costs of pasture maintenance and so on are unchanged between uses, so the total cost of making silage is the sum of the direct and opportunity costs:

Total cost of silage making = 2.854 cents/kg stored

Selection of Point Costs for Silages.

Many simplifying assumptions have been taken in deriving the sample costs presented in the foregoing subsections. Even within this frame of assumptions, which is much less generous than that facing any potential silage maker, the cost of silage dry-matter remains the subject of considerable doubt. An average figure in the context of formulating least-cost rations would be meaningless.

Any prospective feedlot operator wishing to analyse the profit potential of his own skills and resources must in the matter of feed costs, as in the sectors of marketing and animal management, identify the performances and costs applicable to his own operation. Hence in the selection of silage costs an operator will derive particular cost curves for the alternatives, incorporating his personalised expectations, and make best estimates for the point at which he expects to perform on each curve.

For the purpose of this study, in the absence of an involved prospective feedlot operator, it becomes necessary to choose a cost schedule from the foregoing information to serve as a proxy. This schedule is shown in Table VII.

Table VII.

Schedule of Silage Costs, Wastage, and Nett Cost of Silage Dry Matter.

Kind	Maize Silage	Winter Cereal Silage	Mixed Silage	Lucerne Silage	Grass Silage
Silage Cost (cents/kg DM)	4.06	2.78	3.62	3.89	2.85
Wastage Factor (loss between ensiling and consumption)	0.15	0.20	0.17	0.20	0.25
Feed Cost (cents/kg DM)	4.78	3.48	4.36	4.86	3.80

The nett cost of silage dry matter used as feed (feed cost) as shown in Table VII. will be used in the formulation of least cost rations at each step of metabolizable energy density. In the computation of least cost rations these costs will be associated with the subjectively assessed "quality" characteristics described in Table IX. This will not in any way give a definitive solution to the problem of assessing the costs of nutrients in alternative silages and cannot be taken to form part of an evaluation of "average" feedlot profit opportunity. The use of these particular cost estimates can lead only to an analysis of the individual to whom these costs pertain and to whom the various other expectations and performance rates relate.

The resulting least-cost ration mixtures apply similarly only to this individual upon whose beliefs and expectations they are founded. Results later to be derived cannot support generalizations about the relative values of different feeds.

4.1.2. Marketed Feeds.

Expected costs of large scale purchases of the various grains, straws, hays, byproducts and special compounds for the 1976 year have been formulated with the assistance of experts in the trade. Some materials, not generally traded but likely to become available if demand is expressed, have been costed as well. Again, the caveat must be made that each potential operator will find a personal cost schedule, which differs from that of his competitors by reason of his locality, his contacts, and his negotiating skills. The costs given in Table VIII constitute a proxy schedule.

Table VIII.

Unit costs of Marketed Feedstuffs.

Feed	%DM	$/tonne	cents/kg DM
Lucerne Hay	85	50	5.9
Meadow Hay	85	55	6.4
Dried Lucerne (meal)	90	140	15.5
Barley Straw	85	30	3.6
Wheat Straw	85	30	3.5
Ryegrass Straw	86	40	4.7
Barley Grain	88	95	10.8
Maize Grain	88	98	11.1
Wheat Grain	88	110	12.6
White Lupin Seed	87	157	18.0
Rape Seed	90	150	16.7
Soybean Meal	90	180	20.0
Molasses	73	146	20.0
Meatmeal	93	188	20.2
Urea	90	220	24.4
Mineral/Vit.	90	54	6.0
Prot. Tallow	85	235	20.0

4.2. Quality of Candidate Feedstuffs.

The details given in Table IX summarize the quality characteristics of the candidate feeds being considered and include the point cost estimates derived from the preceding section. The complete schedule will be used as a proxy for the personal schedule of a potential feedlot operator. The sources from which these estimates are drawn include Morrison (63), McDonald et al (53), with subjective modifications where these are thought to improve internal consistency and to reflect New Zealand conditions. By no means can these estimates represent other than the view of one man at one time, where he accepts a need to represent by means of constant values attributes which vary over time.

Table IX

Proxy Schedule of Cost and Quality for Candidate Feedstuffs

Dry Matter Basis

Feed	Cost cts/kgDM	Cr.Protein %	Fibre %	Met.Energy mcals/kgDM
Grass Silage **(HQ)	3.8	15.7	25	2.5
Grass Silage **(LQ)	3.6	13.3	32	2.3
Winter cereal Silage	3.6	18.0	24	2.4
Lucerne silage	4.86	17.5	30	2.2
Maize Silage	4.78	11.0	32	2.6
Mixed Silage (Maize & Cereal)	4.41	13.0	27	2.53
Meadow Hay (HQ)	6.4	15.4	33	2.3
Meadow Hay (LQ)	6.0	8.8	40	2.0
Lucerne Hay (HQ)	5.9	18.0	30	2.25
Lucerne Hay (LQ)	5.4	15.0	36	2.18

TABLE IX (Contd.)

Feed	Cost cts/kgDM	Cr.Protein %	Fibre %	Met.Energy mcals/kgDM
Lucerne Hay (LQ)	5.4	15.0	36	2.18
Lucerne Meal	15.5	19.6	30	2.2
Barley Straw (HQ)	3.6	4.3	38	2.0 *
Barley Straw (LQ)	3.5	0.0	42	1.9 *
Wheat Straw	3.5	0.0	45	1.85*
Ryegrass Straw	4.7	2.8	45	1.95*
Barley grain	10.8	9.0	9	3.06
Maize grain	11.1	8.0	3	3.2
Wheat grain	12.6	8.0	4	3.2
Lupin seed	18.0	44.0	16	3.0
Rape seed	16.7	22.6	7	4.6
Soybean meal	20.0	49.0	6	3.1
Protected Tallow	20.0	36.0	0	5.0
Molasses	20.0	4.1	0	2.7
Urea	24.4	240.0	0	0
Supplement	6.0	0	0	0

* The concentration of metabolizable energy in these feedstuffs is adjusted upwards as an approximation of the "associative effect" of combining low quality materials in a ration with adequate protein.

** Where two quality levels of the same name are included they are distinguished by HQ (high quality) and LQ (low quality).

4.3. Ration Formulation.

4.3.1. The Constraints.

The essential characteristics of rations for feeding to growing and fattening steers are taken to be:

(a) Concentration of metabolizable energy;

(b) Concentration of crude protein;

(c) Unit cost.

The energy and protein concentrations represent quality, and within the limits imposed by the individual costs of the feedstuffs which are candidate for inclusion, cost is dependent upon quality. Other factors influence the quality attribute e.g. fibre content, balance of minerals and vitamins, presence of particular components or compounds in amounts which tend to depress animal performance.

Table X

Ration Constraints
(Dry Matter Basis)

Factor				
Crude Protein*	(min)	11.0%	14.5%	17.0%
Dry Matter	(min)	40%		
Fibre	(min)	20%		
	(max)	30%		
Supplement	(min)	1%		
Silage	(max)	65%		
High fat feed	(max)	15%	- applies to prot. tallow and rape seed.	
Non-protein N	(max)	25%	of total N	

* Three alternative assumptions are given.

The approach taken in this study is to constrain the crude protein level and these other characteristics to values or within ranges where their effects upon animal intake and performance can be assumed neutral as between rations of different energy concentration. Under these conditions, animal performance and financial outcome from feeding depend upon only the unit costs and the energy concentration of the ration.

The constraints applied to ration formulation are those described in Chapter Three and are listed in Table X.

4.3.2. Least Cost Rations.

It is evident that a feedlot operator who selects a ration of a specific concentration of metabolizable energy on grounds related to that energy level, will prefer to select the components of that ration in such a way that the unit cost is minimized. This is not necessarily so when the energy level and the composition are determined conarrently (as in Brokken (13) or McDonough (54), whose objective functions were more complicated). In the present context the use of other than least cost rations will indicate a sub-optimal strategy.

The "TEMPO" package on the Burroughs B6700 Computer was used and least cost curves obtained over the rate of energy densities which are candidate for use. Different levels of minimum crude protein were considered (11%, 14.5%, and 17%), as shown in Table X, and different feed availability situations (all feeds, no grass silage, neither grass silage nor winter cereal silage). The candidate feedstuffs have been described in Table IX.

Some general conclusions might be made, always bearing in mind the danger of extrapolating, about the composition of the minimum cost rations which were formulated at each level of energy density.

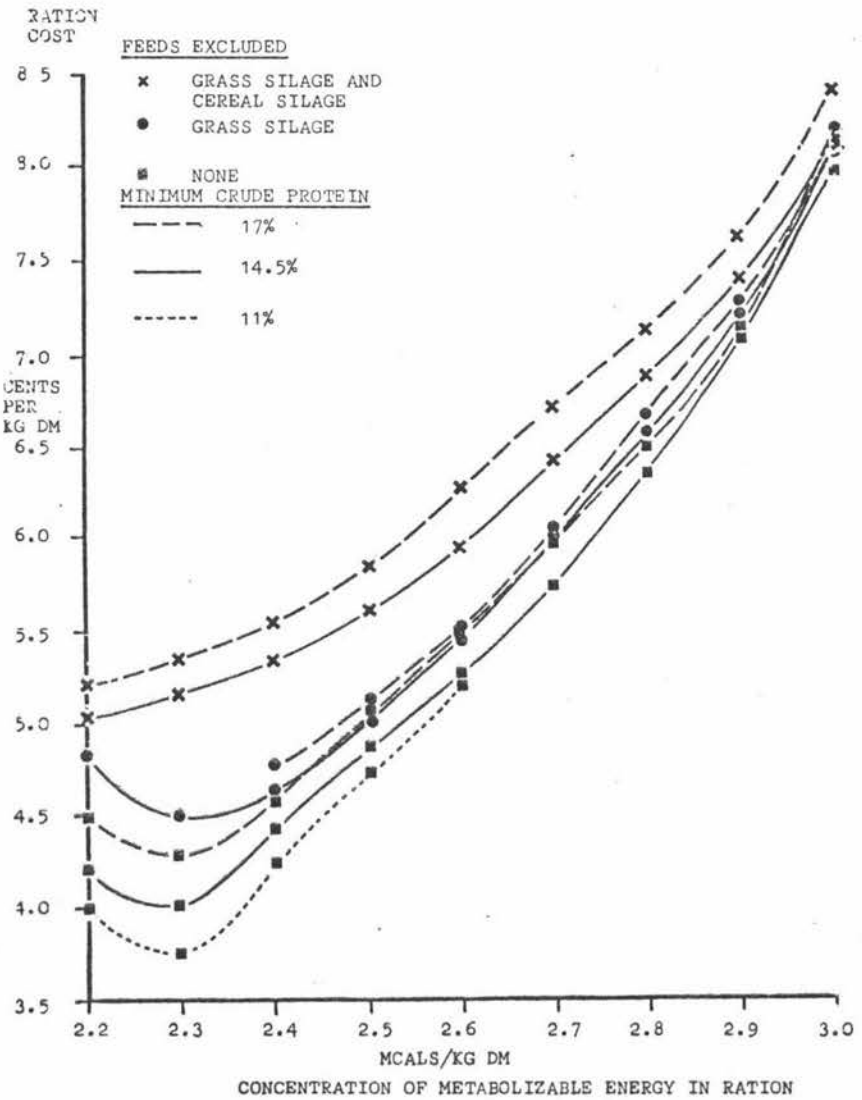
(a) Except at low energy concentrations (below 2.6mcals ME/kg DM) the assumption of an 11% minimum level for crude protein gives no cost advantages over the 14.5% level.

(b) At the 14.5% protein assumption the different levels of feed availability show little effect upon unit feed cost. At the 17% assumption the costs of rations of the same energy level differ importantly in response to the availability of grass silage or of winter cereal silage.

FIGURE 12.

Least Cost Rations.

Unit costs at varying energy concentration levels under various assumptions of feedstuff availability and minimum crude protein levels.



The effects of the protein level assumption and of the feed availability constraints are illustrated in Figure 12.

(c) When it is available, grass silage is selected for rations at every energy level; in its absence the feed described as winter cereal silage is generally chosen, with maize silage becoming important only at the highest energy levels. In no case does the mixed silage (maize silage and winter cereal silage in the proportions which land in a winter/summer rotation would produce) enter the ration in significant quantities. This would seem to indicate that these materials cannot properly be described as "complementary"). When maize silage and lucerne silage are the only silages available, the latter is not selected (lucerne hay being chosen), the full silage component being made up from the maize silage. The exclusion of lucerne silage seems to be a response to the fractional advantage given to lucerne hay in crude protein and energy apparently outweighing the lower cost of the lucerne silage. This is but one instance of the interactions involved in ration formulation.

(d) The quality descriptions given the candidate feedstuffs are clearly as important as their costs. However, there appears to be some grounds for supposing that grass silage, winter cereal silage, and maize silage in that order, would form the preferred bulky feeds. Maize silage is of increasing importance at the higher energy levels when it is further supplemented by maize grain. The other candidate grains are not called upon.

(e) The most important components at the highest energy levels, are rape seed and the high energy protected tallow. Neither of these are freely available on the market, and both the quality descriptions and costs imputed would undoubtedly need revision. It is apparent, nevertheless, that if high energy rations are to be fed, these or similar materials will be demanded. The applicability of the modelled intake functions might also be questioned in respect of rations with significant proportions of these materials, although the upper level of inclusion of 15% should avoid any nutritional ill effects.

(f) Urea supplementation is not often resorted to, possibly owing to the high protein contents assumed for the protected tallow and the rape-seed. Only with the assumption of the 17% crude protein minimum is it included in the higher energy rations.

(g) Barley straw is commonly a component of the rations at the lower energy levels - used in effect to dilute the silages which have been given higher crude protein levels than the complete ration. The combination of straw and grain in a ration does not occur and has not been further tested. It might be supposed to be necessary only in circumstances where the bulk feeds (hay and silage) which also supply protein are unavailable.

(h) Where a lower quality material has been included as a candidate with a higher quality material of the same description but higher price, the better material has invariably been selected. Clearly, the price differential between good hay and bad, good silage and bad, for instance, requires to be much wider than assumed. A consideration of the shadow prices indicates that poor materials require to be discounted by 25% or more before being selected.

The ration cost curves applicable to the seven alternative assumptions which are illustrated in Figure 12 are used in conjunction with the growthmodel from Chapter Three in the determination of admissible feeding strategies which is described in Chapter Five. Some representatives least cost rations are listed in Appendix B.2.

CHAPTER FIVE

5. THE EVALUATION OF FEEDING STRATEGIES.

5.1. General.

The management of a feedlot has the ability to control the operations of feeding and marketing. The purpose of any improvement in management is to increase the margin of profit, or to increase the price payable for candidate steers.

This Chapter describes the use of full feedlot model which incorporates the growthmodel and the proxy schedule of least cost rations costs and which is designed to identify the strategies which maximize the nett discounted present value of candidate steers.

Discussion first takes place under the assumed absence of costs other than basic costs of feedstuff purchase. Later the effect of relaxing this assumption is examined. Finally, a representative set of mean situations is selected for testing the feasibility of actual purchase taking place at the indicated price.

The full feedlot model includes assumptions which reflect the subjective expectations of the operator. Additional to those which have been discussed in relation to the growthmodel and the proxy feedstuff schedule, the assumptions relate to the relationship of liveweight with carcase weight and with beef price.

These relationships are modelled in a very simple manner. Beef price is assumed independent of liveweight, and carcase yield is assumed to be a function of liveweight:

$$Y_W = Y_i + kW$$

where Y_W is the carcase yield at liveweight W;

Y_i is the carcase yield at $W = 0$.

Both assumptions are weak, and the importance of employing the personal expectations of the operator is emphasised.

5.1.1. The Method of Solution.

A program which includes the growthmodel (Chapter Three) and the proxy schedule of least cost rations (Chapter Four), has been written in Fortran and run on the Massey University Burroughs B6700 computer. This program identifies the ration energy density and duration of feeding which maximizes the nett present discounted value of a candidate steer under any of a number of sets of input assumptions. The response surface is thus two-dimensional, the dimensions being E (concentration of metabolizable energy in the ration, measured as megacalories of M.E. per kilogram liveweight), and t (feeding duration in days). The combination which is selected is described as an "optimal strategy".

The shape of the response surface is not simple, and the degree of complication is related to the assumptions made with respect to the relationships of liveweight with carcase yield and with beef price. Some sections through a sample series of surfaces are illustrated in Figures 13, 14, and 15. These relate to a single assumption set of ration crude protein minimum level (17%), feed availability (neither grass silage nor winter cereal silage), initial liveweight (350 kgs), and initial condition (thin). The Figures show the situation for three alternative levels of the beef price predictor.

The program uses the first and second derivatives of the objective function with respect to time in order to identify the maxima. The procedure is described in more detail in Appendix C. Three alternative constraining decision rules are used. Rule 1 is no constraint; Rule 2 requires slaughter (sale) at a fixed liveweight; Rule 3 requires slaughter (sale) after a fixed feeding period. These rules are tested as being relevant to the considerations which are effective in practice.

While the outcomes are described as "strategies", insofar as the full range of management decisions of feedlot management is concerned no more than a single sector is being investigated. It is clear that maximization of profit in an operational feedlot will demand an effective replacement strategy. One approach to this problem is described by Faris (29), and an alternative is mentioned in section 7.3.3. of this thesis. Both approaches require knowledge of the outcomes of this study, of the expected market prices for store cattle and of the output price for feedlot beef. Hence the determination of a replacement strategy must be subsequent to the selection of a feeding strategy.

The following examination of the full feedlot model depends upon a version which incorporates a discount rate of 10% per annum, a rate of mortality of 2% per annum, and in which the parameters for computing the carcase yield are set at
$Y_o = 0.42$, $k = 0.0003$.

The data underlying Figures 13, 14, and 15, which follow are taken from the same feed assumption situation and apply to candidate steers of the same description as described below:

Initial liveweight	350 kgs
Initial condition	thin
Minimum assumed crude protein	17%
Feeds unavailable	grass and cereal silage

The three Figures illustrate the effects of feeding rations of varying energy density for periods of up to 28 weeks.

Each Figure refers to a particular level of the beef price predictor.

FIGURE 13.

Present Value Curves

(Beef Price Predictor of 80 cents/kg carcase)

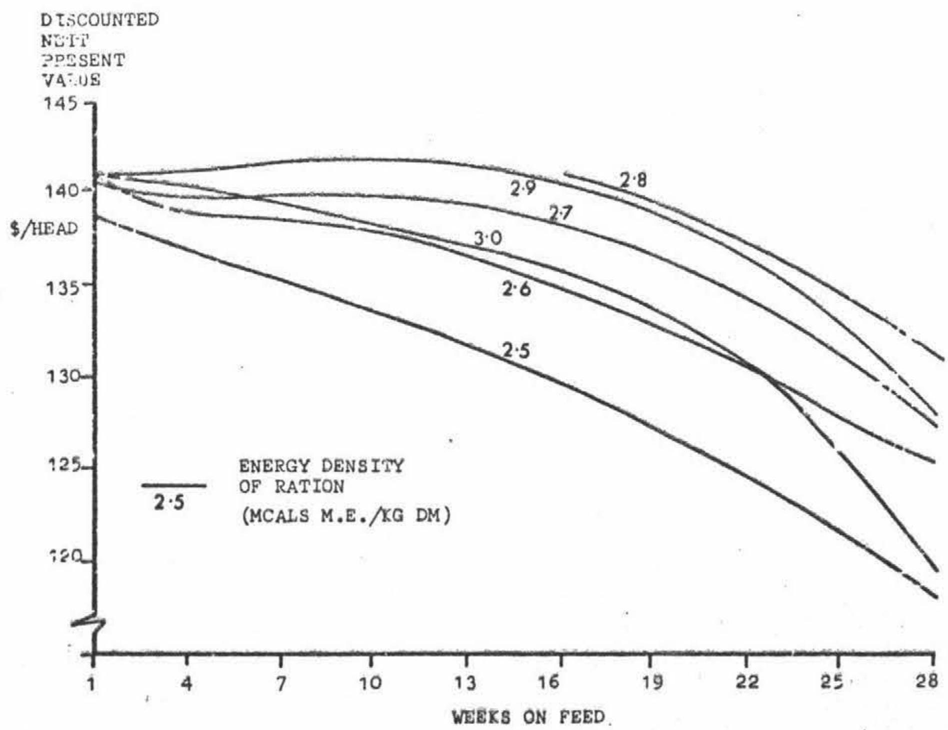


FIGURE 14

Present Value Curves

(Beef Price Predictor of 100 cents/kg carcase)

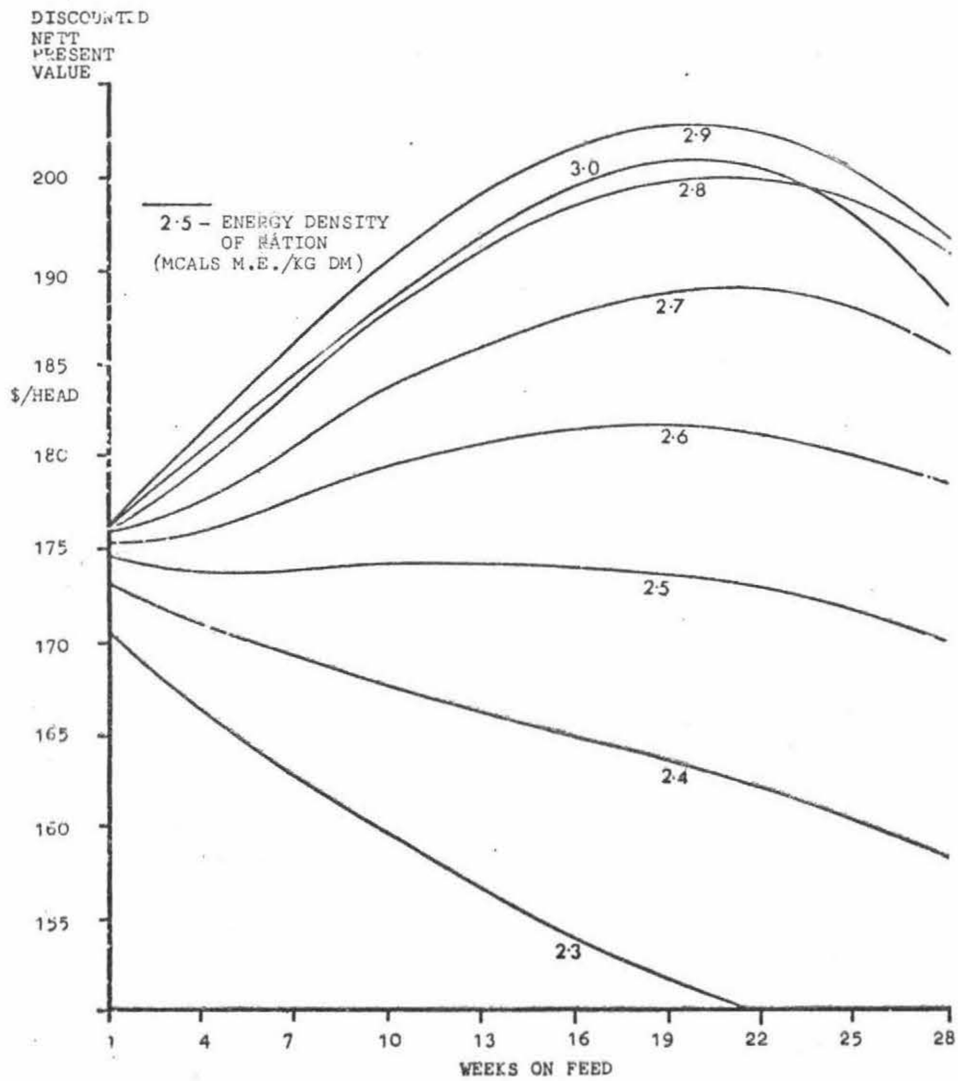
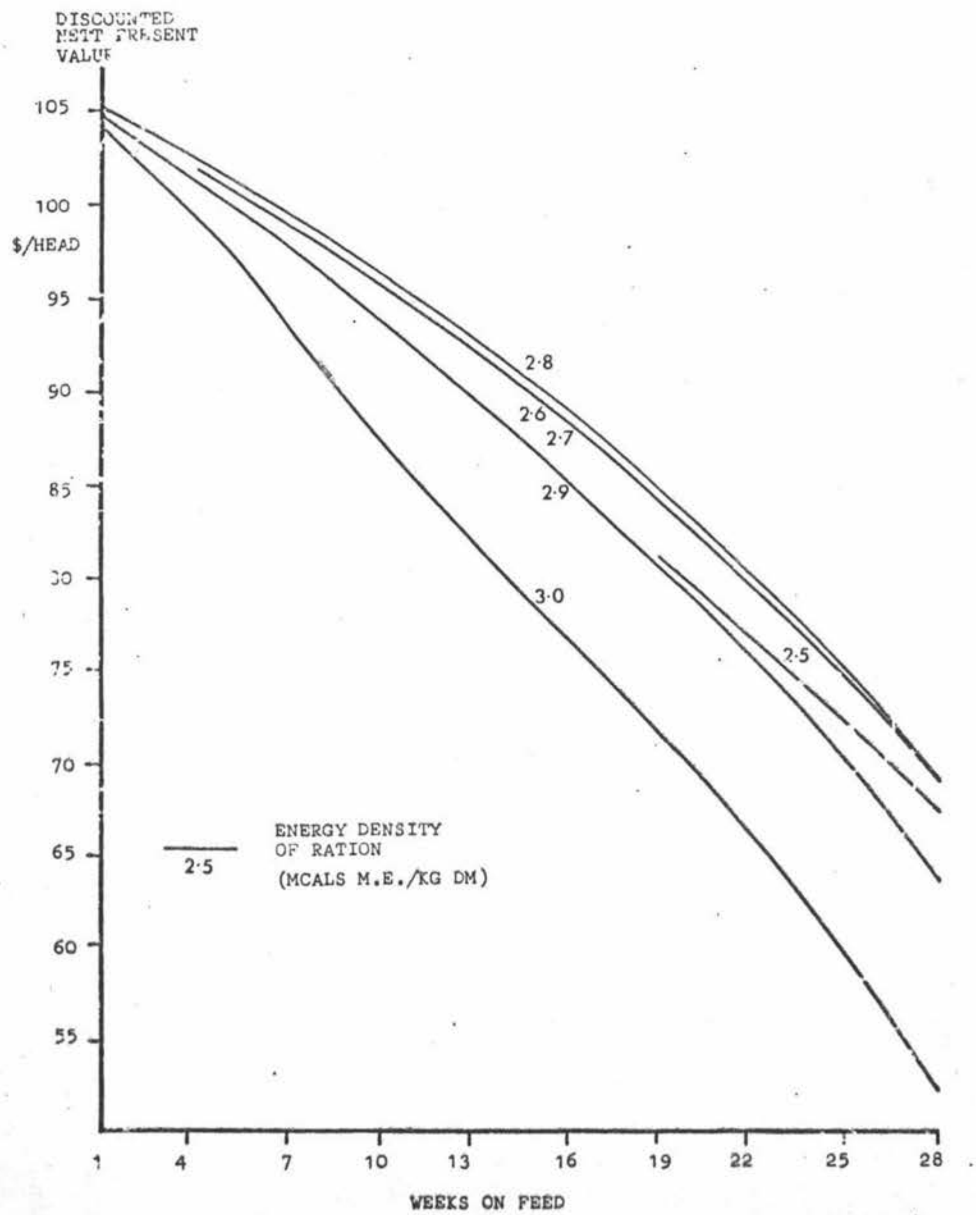


FIGURE 15

Present Value Curves

(Beef Price Predictor of 60 cents/kg carcase)



5.2. Interpretion of Results -Sensitivity Analysis Admissible Feeding Strategies and their Sensitivity to the Variables.

A number of the inputs to the system have been varied and the sensitivity of the composite model analysed in respect to each of them. These inputs include:

Initial Liveweight
Initial condition
Animal efficiency
An assumption of minimum ration protein level
The availability of certain feedstuffs
A decision rule for termination of feeding
The beef price predictor

The number of different combinations of the assumptions tested is 1134. The inputs will be examined in order of their apparent importance in affecting the outcome.

5.2.1. Animal Efficiency.

It will be recollected that the energy needs for maintenance were modelled by a linear equation:

$$BASM = f(HP - 0.06W)$$

The heat production at zero energy balance, HP, has been given two different values, 122, representing the less efficient animals, and 114, for the more efficient. The direct effect from increasing the value given HP is to divert more energy to maintenance purposes and less to growth and production. Hence from the standpoint of production, an animal attributed a higher value for HP is less efficient.

The effects of this upon the results are small. With a representative set of results, using the unconstrained maximization of present value as the decision rule, the present value of steers from the optimal strategy is increased by 2.5% (with initial weight 250 kgs) and 1% (initial weight 450 kgs). The duration of feeding is increased for the more efficient animals, with resultant higher liveweights (by some 2½%).

Faced with the choice of "more efficient" or "less efficient" livestock, the feedlot operator should pay rather more for the more efficient, feed them longer, and sell them at a higher weight. The relationship between the proxy used for efficiency in the model and the differing efficiencies of livestock in the real world is not known. A more realistic expression of efficiency from the point of view of use of nutrients for production might be derived from a reduction in the intake function for less efficient animals. The economic effect would be similar.

The effects of the two efficiency levels upon present value, with maximization unconstrained, are shown in Table XI below.

Table XI

The present values of selected candidate steers, with different initial condition grading and liveweights, and two levels of assumed efficiency.*

Initial Condition	Cents/kg Liveweight: Fat		Store		Thin	
Efficiency	Low	High	Low	High	Low	High
Initial Liveweight (kgs)	With Beef Predictor 80 cents/kg Carcase					
450	43.20	43.52	43.23	43.76	43.41	43.92
350	42.02	42.98	42.28	43.20	42.45	43.37
250	43.29	44.90	43.47	45.17	43.72	45.37
	With Beef Predictor 100 cents/kg Carcase					
450	56.88	57.83	57.37	58.25	57.68	58.50
350	58.62	60.06	58.96	60.32	59.32	60.69
250	65.28	67.80	65.77	68.19	66.16	68.50

* Under the assumption that all feedstuffs are available and that the minimum crude protein level is 17%.

5.2.2. Initial Condition.

The condition of a steer as it affects intake and rate of gain is relatively neutral insofar as the effect upon its present value is concerned. If any effect is discernible, it is that better conditioned animals are fractionally less valuable at the same liveweight. A sample of the effects of condition can be found in Table XI above.

The expected large benefit of the compensatory gains from thinner animals being placed upon ad lib feeding does not show, despite the improved feed conversion rates at least in the early stages of feeding. It is apparent that the effects of compensatory gain from thinner animals as formulated in the growthmodel, have a nearly self-defeating result, in that the rate of gain, while showing a higher early peak, declines more rapidly by comparison with steers whose initial condition is better. The final result is that lower conditioned animals under any of the 7 feeding regimes examined find their optimal feeding strategy with only slightly extended feeding periods, slaughter weights, and slightly higher total consumption of feed, by comparison with fatter animals, with nett present values only fractionally better.

This result tends to confirm the judgement of buyers of store cattle who do not attribute higher unit value to animals of lower condition. The inference is that buyers of cattle for feedlots should behave likewise.

5.2.3. Feedstuff Availability.

Three degrees of availability were tested - all candidate feeds as listed, all except grass silage, all except grass silage and winter cereal silage. These situations were investigated since with all feeds available, least cost rations all included grass silage; and when this was excluded, winter cereal silage formed a major component. While these ration selections are a consequence of the cost and quality definitions given the feeds, and hence the conclusions are applicable in detail to those definitions only, the circumstances of having a chosen feed unavailable is not uncommon, and the results, even with specific reference to only one schedule of costs and qualities, are of general interest. The effect upon the ration cost schedules can be seen in Figure12 and this lifting of the schedule by exclusion of a favoured candidate feed would normally be expected. Since however, the objective function involves use of the ration by a feedlot, the results as they affect the present value of candidate steers are not a foregone conclusion.

The direct effects of feedstuff availability upon the present value of steers are summarized by the sample shown in Table XII below. As would be expected, non-availability of favoured feeds reduces the value of steers. The effect is hardly significant for animals at the heavier weights but rises to give an advantage of 6-8% for full availability over the case where both grass and winter cereal silage is absent with animals of 250kgs liveweight.

Table XII

Selected Present Value from Optimal Strategies;
Paired values from the high and low crude protein assumption;
Three levels of feed availablity.

Cents/kg Liveweight						
Feed Availability	All		No Grass		No Grass or V.C.	
Protein Assumption	17%	14.5%	17%	14.5%	17%	14.5%
Initial Liveweight (kgs)	With Beef Predictor 100 cents/kg					
450	57.37	57.57	57.13	57.24	56.23	56.86
350	58.96	59.33	58.51	58.71	56.82	57.98
250	65.77	66.77	65.00	65.31	61.37	63.54
	With Beef Predictor 80 cents/kg					
450	43.23	43.42	43.09	43.14	42.58	42.83
350	42.28	44.69	41.98	43.10	40.69	41.40
250	43.47	44.55	42.98	43.29	40.13	41.66

5.2.4. Minimum Protein Assumption.

Three levels of minimum crude protein in the ration were successively tested - 17%, 14.5% 11%. The optimal feeding strategies selected indicated that the 11% level was irrelevant as no ration was selected with an energy level low enough to include rations having different costs at the 11% and the 14.5% levels. (See least cost ration cost curves in Figure 12). This result suggests that if profit is the criterion, and the assumed feedstuff costs and qualities prevail, no advantage accrues from attempting to save money by economizing on protein below about the 14.5% level.

The comparison of the results with the 17% and 14.5% levels are shown in Table XII above. From the evidence given, it can be concluded that if the growth rates are not constrained by protein intake, the economies gained by using a 14.5% minimum level are significant, though small.

In practical animal feeding it is usually held that heavier animals, whose liveweight gain is proportionally less of protein than that of lighter cattle, require a lower concentration of protein in the ration. While the model cannot test this hypothesis, it does indicate that if it is correct some economies are possible through changing rations as the liveweight increases. These savings, under the feed cost and quality assumptions taken, are hardly significant. With liveweight of 450kgs the switch to lower protein feed increases the present value of the steer by up to 0.22 cents/kg with the beef predictor at 80 cents. In relation to the same steer at an initial liveweight of 250 kgs, this implies an increase of the present value of up to 0.38 cents/kg - the equivalent of about 1%.

The economic benefits from identifying exactly the protein proportions which just meet the needs of growth at any given liveweight and growth rate and then modifying rations as steers grow, according to those protein needs, are too low to warrant the countervailing risks of inhibiting growth to which the animals will then be exposed should the variations in feedstuff quality then cause an even temporary depression in the ration protein content below the minimum. This is a judgement, not a conclusion supported by statistical evidence.

5.2.5. Initial Liveweight.

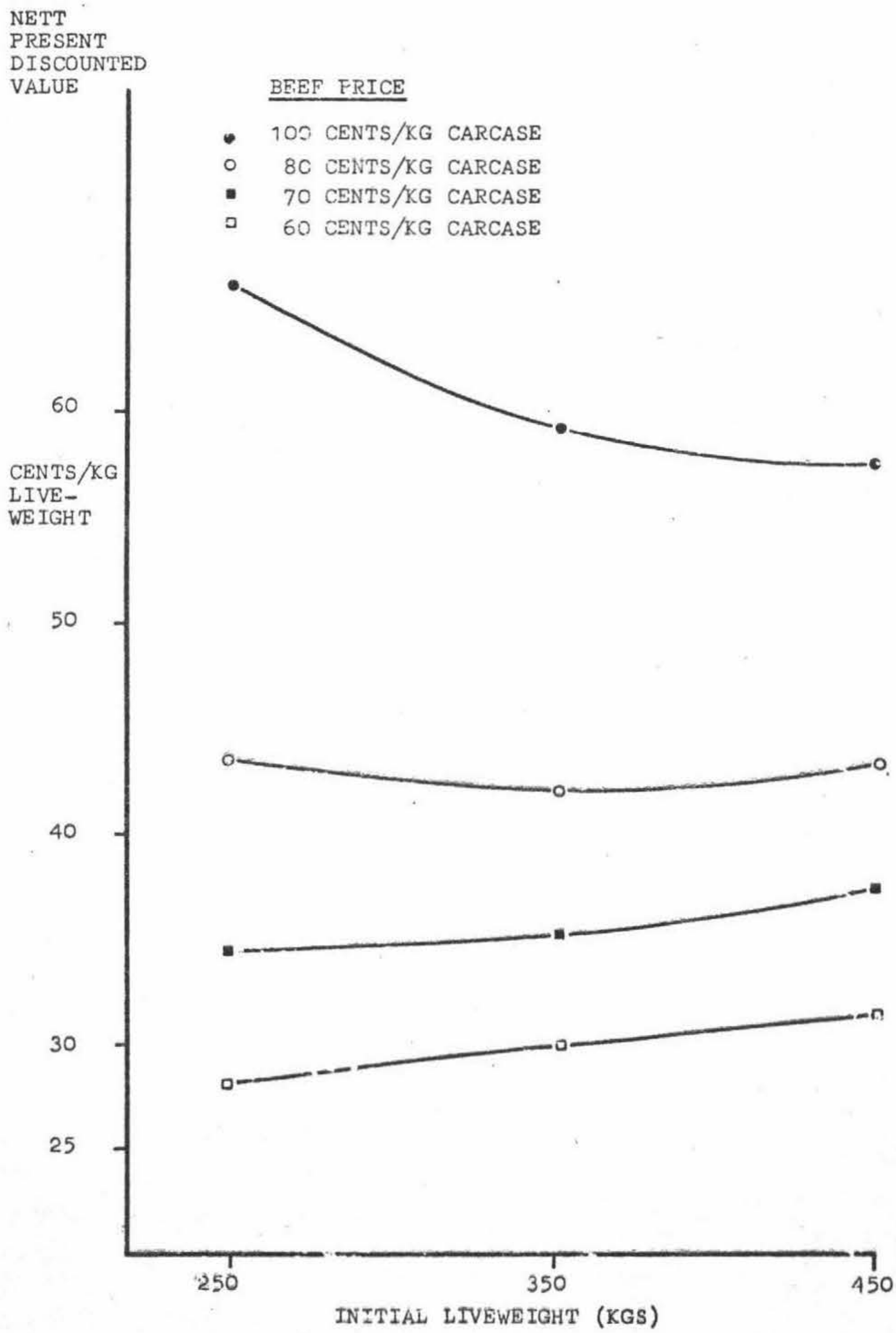
Some sample plots of present value against liveweight are shown in Figure 16. Despite the assumption that costs are restricted to purchase cost of feedstuffs only, these curves reveal that at beef prices lower than about 80 cents the relationship of unit value with liveweight is the reverse of that found to prevail in the market for store cattle (see Chapter Two). This shows that heavier cattle are more valuable per unit liveweight to the feedlot operator when the beef price is below this level. The relaxation of the assumption of zero feedlot costs will be shown to lift still higher the beef price at which the feedlot operator finds the lighter cattle to be of equal unit value.

This reverse slope in the plot of unit value against liveweight is a most important accompaniment of the feedlot technology.

FIGURE 16.

The full feedlot model - Relationship of present value with initial liveweight.

(See Text)



5.2.6. Beef Price Predictor.

The most important effect upon present values is derived from the beef price predictor. This is no more than confirmation of everyday experience. The interaction of the beef price predictor with initial liveweight is shown in Figure 16 and has been described above.

Since these conclusions have been reached with a set of ration cost schedules based upon a single schedule of feedstuff costs it is clear that the response which is shown to changes in the beef price predictor is conditional upon use of the same feedstuff cost schedule. To extrapolate directly to the real world, with its varying feedcost schedules is dangerous, and the real world in subsequent sections will continue to be represented by a single feedstuff cost schedule.

The ratio of feed prices to beef prices has been used above for explaining changes in the relationship of unit value with cattle liveweight. This ratio would seem to be the most useful single summary of the economic environment facing a feedlot. However, for New Zealand conditions, where feedlot operation is not widespread, some difficulty will be found in defining the components of the feedstuff cost denominator, and it is not likely that it can come into common usage.

5.2.7. Decision Rule.

The effects of the inputs upon present value have been discussed above on the assumption that feeding is terminated when the present value is maximized, unconstrained by prior decisions of feeding duration or slaughter liveweight. (Decision Rule 1). If this assumption is now relaxed, and the effect of constraining the maximization by application of such prior decisions is investigated, the results are:

(a) Decision Rule 2. (Feeding to fixed slaughter weight).

First and most obvious, present value from any given combination of the inputs is reduced by comparison with the unconstrained maximization. The extent of the reduction is the greater as the fixed slaughter weight diverges from the slaughter weight of the unconstrained solution. This is evident from the sample solutions given in Table XIII.

Table XIII.

Effect of Decision Rule upon Value.
(Sample results)

	Present Value Cents/kg LW			Feeding Period Days			Slaughter LW. kg.		
Decision * Rule	1.	2.	3.	1.	2.	3.	1.	2.	3.
Initial Liveweight	Beef Price Predictor 80 cents/kg								
450	43.09	43.07	38.01	63	53	200	534	520	605
350	41.98	41.93	39.76	108	122	200	504	520	562
250	42.98	42.70	42.81	176	184	200	480	520	506
	Beef Price Predictor 100 cents/kg.								
450	57.13	55.72	52.75	100	53	200	589	520	621
350	58.51	57.82	57.27	147	122	200	568	520	584
250	65.00	64.49	64.91	212	184	200	548	520	537

* Rule 1 is unconstrained maximization;
Rule 2 is a fixed slaughter weight of 520kg;
Rule 3 is a fixed feeding period of 200 days.

It is not uncommon for a change of decision rule to result in a change in the ration energy concentration used in the then optimal strategy, an implication not expected.

Examination of Table XIII shows that for use of a fixed slaughter weight to result in near optimal solutions (by comparison with the unconstrained optimum) the choice of the slaughter weight requires to be adjusted according to the initial liveweight. Since the slaughter liveweight of the unconstrained solution is dependent upon the beef price predictor to a marked extent and upon the other inputs to the system to a less marked extent, a general rule to determine target slaughter weights which give near maximum values can be only in the form "the lower the initial liveweight, the lower the best target liveweight". This is not of great assistance to a decision maker.

(b) Decision Rule 3. (Feeding for a fixed period).

The effects of applying this rule are similar to those from Rule 2. By comparison with the unconstrained maximization Rule 3 gives a lower present value to candidate steers. Where the fixed period is greatly different from that of the optimal strategy, so is the present value greatly depressed. Again, the best feeding duration is dependent upon the initial liveweight of the candidate animals - "the lighter the animal, the longer the period"; and upon the beef price predictor - "the higher the price, the longer the period".

It is evident that use of a constraining decision rule offers risks of unnecessarily depressing the maximum buying price at which profit is possible, and hence in the long run of depressing profits or of converting profits to losses. In the practical world of feedlot operation, however, some real world rule must be used to determine when to quit an animal. Marginal rates of profit are not susceptible to quick and easy calculation for each of the many selling decisions. Furthermore, considerations of selling contracts and regularity of sales, which are negotiated in order to hedge against price fluctuations and to ensure a market for finished stock, are of almost universal application. Thus the durations for feeding and the slaughter liveweights are often predetermined, and feeding an animal on a regime which maximizes its present value at purchase disregarding these constraints is irrelevant.

Hence as a matter of practical operation, the decision rules applying to value determination must be of the kind represented by Rule 2 and Rule 3. So management requires to take steps to ensure that the contract considerations which set the constraints are of a kind which do not unnecessarily depress the maximum buying price of candidate steers.

Only by use of the information given by the solutions to the unconstrained problem can these constraints be so set. In a world of fluctuating feed prices and of changing conditions of feed availability, of seasonal cattle availability and of changes in the beef price predictor, it would seem that the best information to assist in setting targets is that given by the solution to the unconstrained maximization of present value of candidate steers.

Market requirements which set slaughter weight, for instance would be met by a feeding strategy which yielded that slaughter weight when unconstrained. This implies that the factor to be adjusted would best be the initial liveweight. Hence it can be concluded that for each real attribute required of the feeding strategy, whether it be slaughter weight or feeding duration, there is an unconstrained optimal strategy which meets the requirement.

This analysis of the effects of the decision rules upon the selection of the optimal strategy and hence upon the value of a candidate steer is made independently of the market upon which the steers must be bought. The interactions between liveweight and price on the market, and liveweight and value to the feedlot operator could well upset the simplicity of the decision criterion. This qualification will therefore require to be borne in mind by the operator faced with deciding between alternative lines of candidate steers. In the context of this study, which aims to define the conditions in which profit opportunities might be found, this difficulty does not arise.

5.2.8. Optimal Strategies - the selection of rations.

The rations selected to maximize the present value of candidate steers under each of the combinations of the discretionary inputs discussed above show quite remarkable consistency.

Energy concentrations of 2.8 and 2.9 mcals/ME/kg DM are chosen as part of the optimal feeding strategy in a very large proportion of input combinations. The higher energy ration of 3.0 mcals/kg is selected only in 7 instances both involving animals which were thin in condition and of 450kg liveweight.

With decision Rule 1, unconstrained maximization, the energy level of 2.7 mcals/kg is selected only twice, when beef predictor is 100 cents/kg(for the 250kg steer which is more efficient and of fat initial condition) but becomes more common when the beef predictor is at 80 cents, (when efficiency is higher, with lighter animals, and with the cheaper ration costs). With the beef predictor 60 cents/kg this tendency is even more pronounced, although not so consistently associated with the light steers.

The same pattern is apparent under decision Rule 2, when the slaughter weight is fixed at 520 kgs.

However, when decision Rule 3 is applied (a fixed feeding period of 200 days), while similar ration choices are found with the highest level of the beef predictor, the predominant ration choice when the predictor is 80 cents is found to be 2.7 mcals/kg; and when the predictor is 60 cents, rations of 2.6 mcals/kg are usual, with heavier animals under cheaper ration cost schedules utilizing rations of as low as 2.3 mcals/kg.

Insofar as this information is to be of use to prospective feedlot operators attention should be focussed on the rations selected for unconstrained maximization (Rule 1), since, as pointed out in the preceding section, the choice of a set time or a set slaughter weight (for application of Rules 2 and 3) should be made in conformity with the duration or weight of the relevant optimal procedure. This implies that rations of 2.8 or 2.9 mcals/kg are optimal over the whole range of beef predictor price levels with some tendency towards 2.7 at the lower levels of beef price. While use of decision Rules 2 or 3 will render the strategy suboptimal, a small departure of the constraint selected from the period or weight in the optimal strategy will minimize the consequent reduction in present value of the candidate steer. A wide departure will result in a large reduction in that present value, and as shown in the results from the model, this can then only be partly compensated for by use of a lower energy ration of cheaper unit cost.

In other words, poor choice of targets will result in a strategy which is much worse than the optimal strategy and which will make use of cheaper, low energy rations, as a means of minimizing the comparative loss. This is rather at variance with the intuitive appreciation of the situation when a low beef price predictor applies. The point should be made that feeding cheap rations in response to low beef prices is not optimal - it is a moderating reaction to a failure to revise slaughter-weight or feeding periods in line with the changed beef price predictor.

It is concluded that rations of energy concentration 2.8 - 2.9 mcals ME/kg DM are the "best" rations in the sense that they have been selected to form part of optimal strategies under Rule 1. This needs qualification. It is strictly valid only under the assumptions of feedstuff cost and quality which have been taken, i.e. is personal to an operator for which these assumptions are correct. All of these assumptions may be questioned, but in particular the protected tallow supplement of high energy and high protein content, and the rapeseed supplement, are uncertain as to supply, quality, and price. In the absence of these supplements, or where their price is higher or their qualities lower than assumed, the ration cost schedule will be lifted with possibly important effects upon the optimal strategies. Whatever the energy densities selected for optimal strategies under thoseconditions, it is certain that the present value of steers will be reduced by comparison with their value under the schedule of costs and qualities examined. This should be borne in mind when the composition of these rations is examined below.

The feedstuffs which were selected from the candidate list to comprise the least cost rations at the two energy levels shown to be generally included in the optimal strategies are listed in Table XIV below.

Table XIV

Selected Least Cost Rations -
Constituent Feedstuffs
(As Percentage of Total Dry Matter)

*Assumption	1.		2.		3.		4.		5.		6.	
Energy Level mcals/kg DM	2.8	2.9	2.8	2.9	2.8	2.9	2.8	2.9	2.8	2.9	2.8	2.9
Grass Silage	65	51	-	-	-	-	65	49	-	-	-	-
Winter Cereal Silage		14	65	58	-	-	-	3	65	44	-	-
Maize Silage	-	-	-	7	65	65	-	13	-	21	65	65
Lucerne Hay	14	-	4	-	20	13	-	-	-	-	20	13
Barley Straw	-	5	1	-	-	-	10	3	5	-	-	-
Maize Grain	5	14	13	19	-	5	9	16	14	19	-	6
Prot. Tallow	3	13	-	7	13	15	-	-	-	-	4	9
Rapeseed	12	2	15	8	-	-	15	15	15	15	10	6
Urea					x	x						
Supplement	1	1	1	1	1	1	1	1	1	1	1	1

*The assumptions are:

1 - 17%	CP minimum;	all feeds available
2 - 17%		no grass silage
3 - 17%		no grass or cereal silage
4 - 14.5%		all feeds
5 - 14.5%		no grass silage
6 - 14.5%		no grass or cereal silage

x - urea included at less than 1%

The totals are inaccurate due to rounding.

The rations described in Table XIV are not exempt from certain impractical features characteristic of least cost rations. For instance, the inclusion of small quantities of barley straw in such rations would be viewed sceptically by a feedlot operator whose preferred action would be to leave it out thus producing a ration of slightly higher energy concentration at slightly higher cost. Similarly, the mixture of small quantities of winter cereal silage with large quantities of either grass silage or maize silage would be regarded as "splitting hairs" and again the winter cereal silage would be left out. There are some similar instances to be found.

The real world, therefore, is likely to be faced not only with variable quality specifications in the candidate feedstuffs, but also with a rather cavalier response to the indicated recipes. In actual execution of strategies, therefore, the ration energy levels are likely to differ somewhat from the expected, and the unit cost to exceed somewhat the expected. Execution of a strategy will therefore be accompanied by, usually, a reduction in economic efficiency by comparison with the computed (model) strategy. This effect will be summarized by, ex post, an actual maximum present value of any steer at purchase which is rather below that of the modelled strategy. In practice, also, the other details of the actual operation will differ, e.g. duration of feeding and rates of intake and gain, as between the modelled activity and the actual execution. For the same reasons these aberrations will reinforce the real world loss of maximum present value. Some allowance will be made for this in a later discussion of buying decisions.

5.2.9. Optimal Strategies - the duration of feeding and the slaughter weight.

A sample of the weight/feeding period combinations constitute optimal strategies is shown in Table XIII above. The general tendency is for feeding period to increase with decreasing initial liveweight and for slaughter weight to increase with increasing initial liveweight. Higher beef predictor prices support strategies with higher slaughter weights and longer feeding periods. Intuitive expectations are thus confirmed by model output.

These results make it clear that the treatment given the beef price predictor in the model is unrealistic. It is incorrect to assert that the beef price predictor is independent of liveweight. Even the assumption that an operator expects to produce cattle of the "best" grade is inadequate, although it may be sound when constant output liveweights are envisaged. Over the range of weights selected as parts of optimal strategies the assumption is not compatible with known experience. Model outputs in Table XIII alone show a range of slaughter liveweights of 480 kgs to 589 kgs.

Due to limitations of time the model was not rerun to determine the effect of incorporating for instance a liveweight-based grading system. It can be concluded, however, that the employment of lower beef prices for lightest carcases would lead to the selection of longer feeding periods, higher slaughter weights, and reduced nett present discounted values in those instances where the optimal strategy involved slaughter at light weights. In the same way, the strategies which included slaughter at very high liveweights would overstate the nett present value by reason of the normal reduction of beef price for overweight carcases.

However, the errors given by the present formulation are clearly one-sided - the present values for steers for which the optimal strategy indicates slaughter at most liveweights are rather higher than use of a liveweight-related beef predictor would indicate. As will be seen in para. 5.2.10. there are several other considerations which, in the translation of the model output into a decision criterion, act in the same direction.

5.2.10. The Effect of Feedlot Costs.

In actual operation of feedlots a number of costs are incurred in addition to the actual costs of feedstuffs. The magnitude of these costs in relation to each individual animal fed, or each animal/day of feeding, cannot be identified *a priori* since critical to them is the scale of operations. It is possible that the incidence of these other costs may drastically alter the shape of the response surface and that their inclusion in the model, were they known, could lead to completely different conclusions, and to different strategies.

Whatever the magnitude of these costs, be they oriented to overhead servicing, animal servicing, or feed storage, their impact will be felt in one of three ways - as a fixed cost for trading each steer, a time-dependent daily charge on each animal, or as a consumption-dependent charge on each kilogram of feed consumed.

Overhead Charges. Included under this head are, e.g. costs of management, of maintaining facilities, of servicing the capital investment, and the like. For any design of feedlot an appropriate cost curve can be constructed to reflect the total of these charges per animal day, were the total animal days known. Not only are the animal days unknown at the input stage of the present model, they are no better known at its output stage and only subsequent to an examination of potential marketing strategies - replacement strategies - in an economic environment meeting the needs of potential profit which is defined by the output of the present model, can marketing strategies be examined.

This must therefore remain an area of ignorance throughout the present study. Nevertheless, the effect of changes in the magnitude of the per-animal overhead charges must be considered.

Direct Animal Handling Charges. These will be of two kinds - the fixed charges of commission and transport associated with the buying and selling operation, and the daily charges derived from the daily routine of the feedlot.

The former is dependent upon factors peculiar to a given feedlot - location, and the particular trade contacts and negotiating ability of its operator. Each operator making use of the model will therefore modify the model output by subtracting the fixed charges applicable to his feedlot from the computed present value of candidate steers. Such fixed charges offer no serious complication.

The daily charges of animal handling include a component of labour, of veterinary expenses, and the like. They therefore augment the per animal/day overhead charge and affect the outcome in the same way as that charge.

Feed Processing and Storage Costs. The production season for many of the candidate feedstuffs in New Zealand is short. Even the concept of continuous ensilage over the year as expounded by Mitchell (62) and examined by McClatchy (51) and Grieg (32) involves discontinuous operation and hence storage facilities in excess of that needed for, say, daily or monthly consumption rate. As seen by these writers the technology of the system has included vertical silos and a high degree of specialised mechanization, and the costs stemming from this have not been subject to critical examination. One writer who is deeply involved in feedlot operation is Marshall (60) who has recently (59) developed his original concept with a view to increasing efficiency and reducing costs.

Marshall's system involves the use of horizontal bunkers for storage of both grain and silage, with airtight sealing using the well-tried system of plastic sheeting, and handling by means of front-end loaders and mobile feeder-mixers. This method offers gains in economy of capital requirement and in cheapness of operation over the vertical silo system, although this is not a certain outcome. Use of the bunkers for storage of "wet" grain under airtight conditions avoids further costs for crushing or rolling normally necessary when dry grain is used for animal feed.

This offers some practical advantages in analysing the effect of changes in these costs on the output of the decision model, since all candidate feeds can be thought of as subject to the same unit costs of storage and processing.

The treatment of these categories of cost is illustrated in Figure 17. The sensitivity of model output to changes in them has been analysed using the model at one level of beef price predictor only. These effects are summarized in Table XV.

FIGURE 17.

Flow Diagram - Treatment of Costs in Present Value Computation.

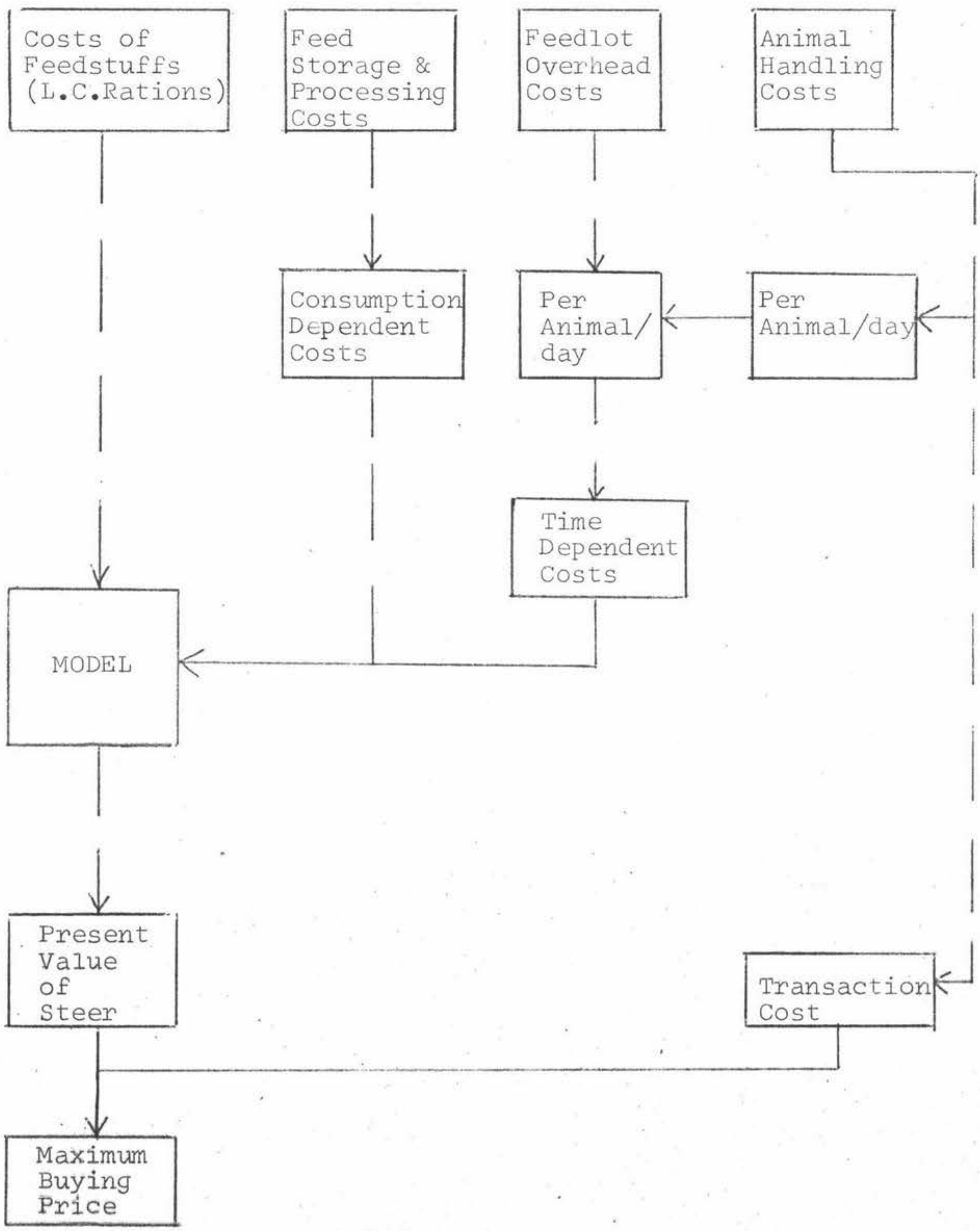


Table XV

Effect of Feedlot Costs upon Optimal Strategies

(Selected Examples)*

Initial Liveweight (kgs)		Cents/kg Liveweight 450		350		250	
Feed Processing cost (cents/kg DM)	Fixed & Variable costs (cents/hd /day)	PV	days	PV	days	PV	days
0	0	56.88	99	58.61	149	65.28	217
1	5	54.17	70	53.16	114	54.64	164
1	10	53.48	54	51.68	95	51.63	143
1	15	53.01	28	50.53	66	49.13	109
1	20	52.78	<u>20</u>	49.91	<u>20</u>	47.44	62

*Initial condition is "thin", efficiency "low", and beef price predictor set at 100 cents/kg carcase weight. Decision Rule 1, unconstrained maximization of present value, is applied.

As can be seen from Table XV the major technical effect of increased costs upon the design of optimal strategies is the reduction in duration of feeding. The choice of ration (not shown) is apparently unaffected, or affected to an extent not significant in practical terms. In consequence of this shortening of the feeding period, the slaughter weight of the optimal strategies is reduced until, with costs reaching the highest level shown above, the selected slaughter liveweights are impractically low. (It should be noted that the programme had an inbuilt minimum feeding period of 20 days - in the cases where this period is selected, the implication is that the feeding activity is not profitable, i.e. does not increase the computed maximum present value, and that the trading activity to make use of any price advantage in the slaughter market is the potentially profitable activity).

The effect of increased cost levels upon the relationship of present value per unit liveweight with changing liveweight is also noteworthy. As costs increase, the initially higher value of the smaller steer falls faster than that of the larger animal. With the highest level of costs analysed the increase in unit value with increasing liveweight becomes quite steep.

This effect is of assistance in confirming the analysis of Chapter Two relating to the changes in price with changing liveweight in the contrasting markets for store cattle in the United States and in New Zealand. A high cost structure is evidently associated with a tendency to reduced unit values of lighter as compared with heavier steers. This carries with it, in the conditions of the New Zealand store market, the corollary that use of feedlot technology to prepare animals of low initial weight for slaughter at normal (high) weights is perhaps the most unlikely development, owing to the characteristic reverse price/liveweight relationship of the New Zealand store cattle market.

It is of interest that one of the near-profitable strategies used in the analysis of Grieg (32) was the over-wintering of weaners for sale on the store market in the spring. Clearly this strategy, arising from customary practices of grassland farming, is not likely to enable profits to be made from using feedlot technology with weaners or other animals of low liveweight; it is not a strategy for which forward selling contracts are possible, and only low-cost operations are able to compete.

With heavy steers, as illustrated in the first columns of Table XV, the changes in maximum present value which results from increasing levels of feedlot costs are surprisingly small. While this is evidently an effect of the shorter feeding period and the larger number of kilograms over which the added costs are spread, and does not depend upon any more obscure effects, the possibilities of profitable feeding of heavy animals are not greatly reduced by the imposition of a high level of feedlot costs other than the purchase cost of feedstuffs.

5.3. The Values of Candidate Steers - Use in Purchase Decisions.

The analysis described in the preceding section permitted some conclusions to be taken. These may be summarized:

(a) While in practice, purchase of steers for placing in a feedlot will take place for either a predetermined duration of feeding or a target slaughter liveweight, the chosen targets should be selected in conformity with the optimal strategy when no constraints are imposed. Choice of targets which diverge greatly from that optimal strategy necessarily involve reductions in the value of candidate steers and hence lower probabilities of purchase of those steers at prices allowing profit.

(b) Under the feedstuff cost schedule used, the input which has greatest effect upon the value of candidate steers is the level of the beef price predictor. The interaction of initial liveweight with the predictor is important. By comparison with these factors the other animal variables (condition and efficiency) and the ration assumption alternatives (feedstuff availability and the assumed crude protein minimum) do not affect the value to a degree which is significant in practice.

(c) Increasing the level of costs other than those of feedstuff purchase affects the value of lighter candidate steers to a far greater extent than that of heavy animals. This effect operates through a reduction of the feeding duration and slaughter weight of the optimal strategies. At any realistic level for these costs, the value of lighter animals per unit liveweight falls below that of heavier animals.

(d) Rations of high energy density form part of optimal strategies. Where it is decided to impose constraints which severely reduce the present value of candidate steers, a common accompaniment is the use of cheaper, lower quality, feed.

The selection of values from the model output for use as decision criteria is assisted by these conclusions and will take the form of maximum buying prices for each liveweight level and each level of feedlot costs. A similar schedule can be constructed for each level taken by the beef price predictor. A sample selection is shown in Table XVI, where a beef predictor of 100 cents/kg carcase is assumed. In the construction of this table, the effects of the condition and efficiency of candidate steers are disregarded, as are the effects of the different ration formulation assumptions. The elements of the table are drawn from the model output relating to steers of intermediate condition grading ("store"), lower efficiency rating, and rations based on full feed availability and an assumption of a 14.5% minimum level of crude protein in the ration.

Table XVI.

The values for candidate steers as criteria for purchasing decisions, with an assumed feedlot beef price predictor of 100 cents/kg carcase (Cents/kg Liveweight)

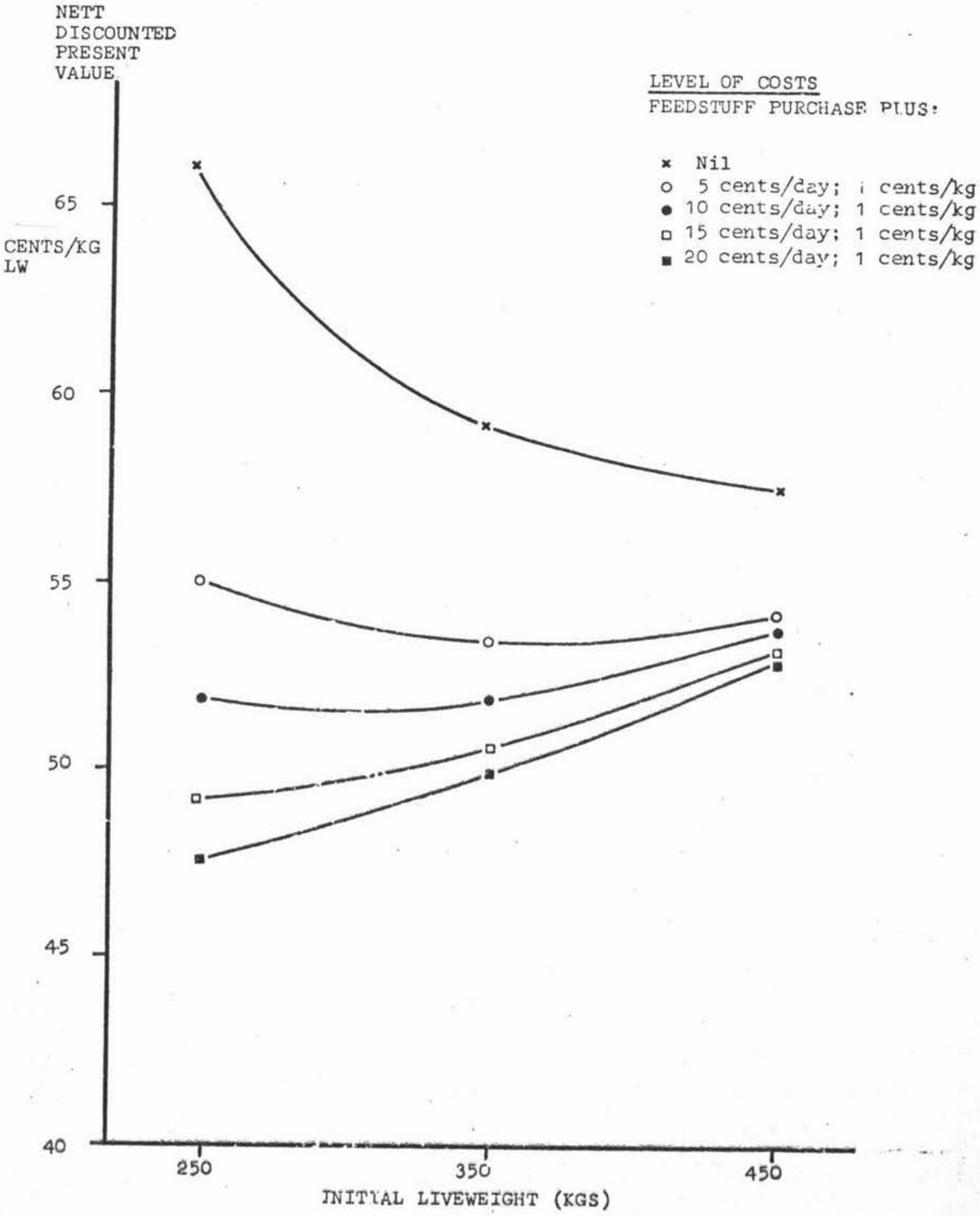
Feed Processing and storage costs (cents/kg DM)	0	1	1	1	1
Other feedlot costs (cents/head/day)	0	5	10	15	20
Initial liveweight (kg)					
450	57.57	54.57	53.80	53.23	52.98
350	59.33	53.60	52.06	50.80	50.08
250	66.77	55.76	52.53	49.76	47.72

The information presented in Table XVI is illustrated graphically in Figure 18 which summarizes the output of the full feedlot model in a form which makes it useful as a tool for investigating the feasibility of feedlot operation.

The shapes of the curves shown in Figure 18 may be compared with the shapes of the curves classified in Chapter Two and there illustrated in Figure 1. Since the unit price at slaughter weight relative to Figure 18 is 59 cents/kg liveweight it is evident that each of the curves is of Class II, concave upwards, but falling below the unit price at slaughter. The curves representing the higher cost situations tend to remain below the unit price at slaughter at all weights less than slaughter weight. This compares with the apparent pricing relationships on the United States feeder market described in Chapter Two where feeder prices under the same beef price is 100 cents/kg carcase tended to lie between 16 - 20 cents/lb liveweight (35 - 44 cents/kg liveweight) with an upward trend associated with reduced liveweight at the lower end of the weight range, but with all prices well below the unit price at slaughter, which in the U.S.A. might be expected to be related to a higher carcase yield than in New Zealand and to be of the order of 63 cents/kg liveweight with the beef price of 100 cents. The data from which the curves in Figure 18 are drawn, unlike the market prices from Table III, have no component of fixed cost deducted to allow for transport and trading costs. Comparison of the absolute values between the two situations is therefore not possible. It is however evident that the processes which generated the data of Table XVI shown in Figure 17 are very closely similar to those which led to the prices for feeder cattle in the Chicago market in 1954-6.

FIGURE 18.

The full feedlot model - The effect of non-feed costs upon value of candidate steers.



5.4. A Summary of the Results of Chapter Five.

A sensitivity analysis of the effects of changing input levels upon the nett present discounted value of candidate steers shows that the major influence is the beef price. Optimal feeding strategies are shown to utilize rations of high energy density except where there are constraints applied, in which case the relative losses due to the enforced choice of a sub-optimal strategy are reduced through choice of cheap lower energy rations.

A high level of costs is an accompaniment of feedlot technology and this results in the value of candidate steers (per unit liveweight) falling below the value at slaughter. This was described in Chapter Two as characteristic of Class II or Class III investment situations, depending upon the ratio of beef price to daily cost of holding (P/C ratio.)

CHAPTER SIX

6. DETERMINATION OF FEEDLOT VIABILITY.

6.1. General.

This Chapter brings together the results from the analysis of the full feedlot model given in Chapter Five and the conclusions reached by the analysis of the store cattle market described in Chapter Two. The outcome is an evaluation of the viability of the feedlot technology in the beef industry of New Zealand.

Two approaches are described - firstly the particular, where all the variables applicable to the feedlot are known, and where management employs the optimal feeding strategy applicable to each input liveweight; and secondly the general, where a fixed slaughter weight is assumed and use is made of findings from the full feedlot model to construct a simplified feedlot model.

6.2. Feedlot Feasibility with known Output Price.

The sample results shown in Figure 18 of Chapter Five are re-presented in Figure 19 with the addition of store cattle price lines derived from the price predictions illustrated in Figure 6b of Chapter Two. These price lines are based upon export schedule prices of 60 cents and 80 cents per kg carcase, below the assumed feedlot beef price of 100 cents/kg. It is clear that only with a beef price for the feedlot at a higher level than that applicable to the market at large will the price lines fall below the value curves of Figure 19. Since potential profit is indicated only when the value curve is the higher a first conclusion is found:

For Profitable feedlot operation the beef price must exceed the beef price applicable to store cattle buyers at large.

A second matter of practical importance emerges from this general rule. Because the mood of the market responds to knowledge about beef prices, the existence of the high price levels needed for profitable feedlot operation must be known by the market at large which will tend to respond by being price-optimistic. Where the high feedlot beef price is associated with export trade, the necessary conditions include ready demand for beef abroad and thus an upward pressure on price of all beef meat. The optimism in the store cattle market which high feedlot beef prices cause is therefore usually justified. Only in the very short term can it be supposed that the store cattle market at large will remain in ignorance of high feedlot beef prices, and hence only in the very short term can a feedlot receiving these prices be able to purchase store stock on a market set by pessimistic bidders.

A second conclusion is:
The store stock prices facing a profitable feedlot operator will tend to be those of an optimistic market.

The analysis of Chapter Two showed that Class I investment model curves were consistent with the New Zealand store market prices, except at very low levels of ruling beef price. This has the effect of giving price lines a negative slope on such a graph as Figure 19. The higher the beef price predictor, the steeper the slope. The feedlot value curves on Figure 19 are consistent with a Class II situation, and are therefore expected to show a negative slope only at low liveweights. Furthermore, this negative gradient is slight except when unrealistically low levels of feedlot costs are envisaged, as shown by the upper curve in Figure 19 where costs other than feedstuff purchase costs are disregarded. The consequence of these relative gradients is that market price lines which intersect the feedlot value curves will do so at a steep angle and price lines based on higher beef prices will have this point of intersection at higher levels of liveweight. This leads to a third major conclusion: <u>If a steer of a given liveweight is shown to be a profitable purchase then so also will steers of higher liveweights</u>,

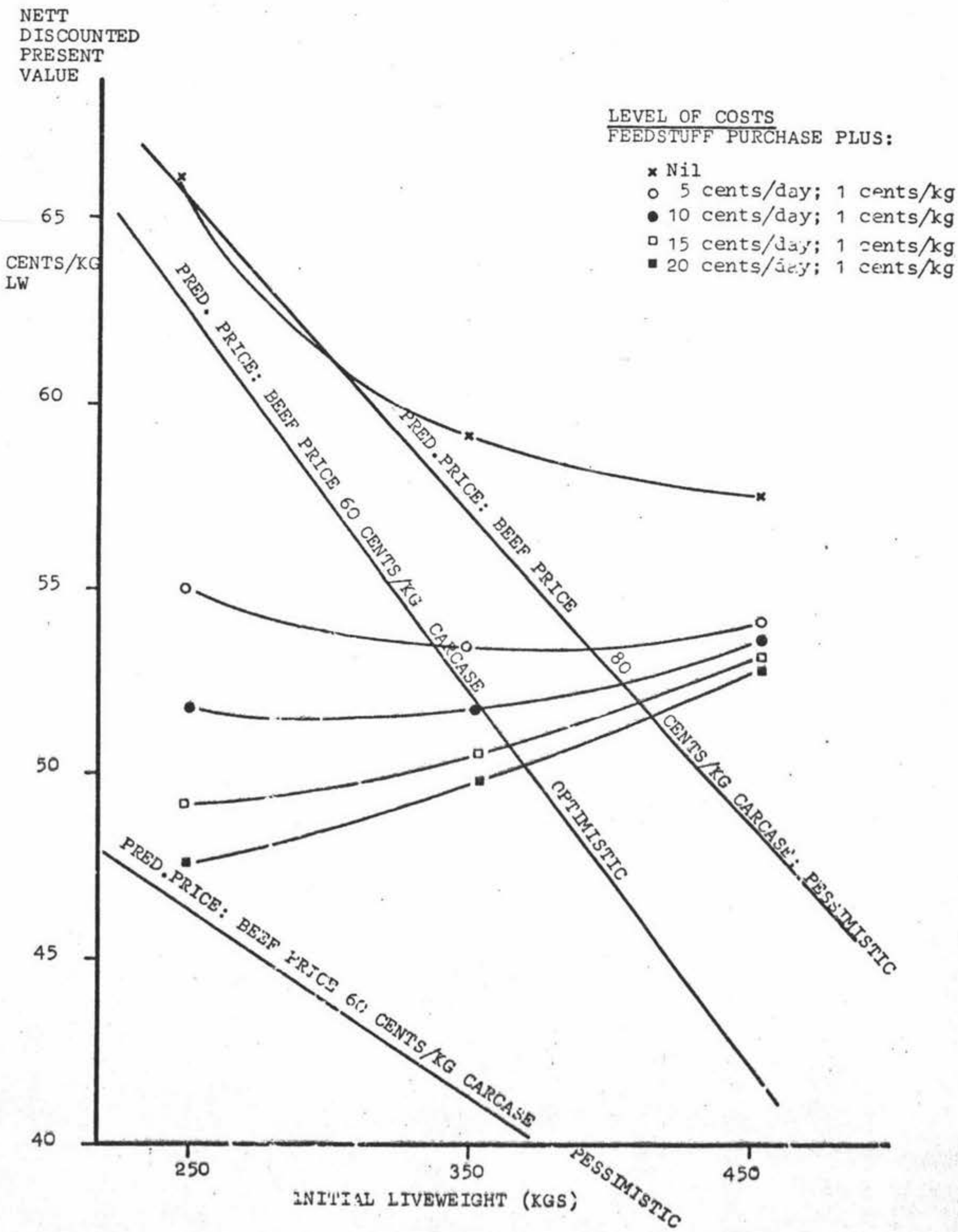
As was made clear by the price prediction bands illustrated in Figure 6a the seasonal fluctuation of prices is of a significant magnitude. The choice of a particular month's market price expectations is thus critical to an evaluation of feedlot viability. This choice, however, cannot be made on the basis of price only, since profitable feedlot operation demands a throughput adequate to hold the fixed costs per head to an appropriate level and throughput depends upon supply as well as price in the store cattle market. Hence evaluation of feasibility on the basis of prices predicted for, say, the months of December and January will necessarily be qualified by a requirement that purchases occur only in those months, since prices in other months, <u>ceteris paribus</u>, will be higher. The restriction is serious, since it implies limited numbers of candidate steers and no more than a single

FIGURE 19.

Intersection of price lines with value curves

(Expected feedlot beef price-100 cent/kg carcase)

(see text)



use of feedlot facilities in the year, resulting in a high level of non-feed costs. On the other hand, use of June-July as the reference month for market price expectations permits the purchase of steers at the indicated price over the full year, and hence allows the most favourable supply situation for store cattle. This is accompanied by a high level of predicted prices for candidate cattle. At the operational stage, optimal purchasing strategies will balance price and supply considerations month by month but for appraisal at the planning stage choice of reference month will be a compromise. That used in the preparation of Figure 19 is April (and, from the symmetry of the seasonal fluctuation, August). In this instance, only in the winter months of May, June, July, will market prices be expected to exceed the reference price level. In making a practical decision, the prospective operator will need to make his own choice of reference month, bearing these considerations in mind.

The foregoing discussion sets the situation for a description of use of the full feedlot model by a prospective operator. This will involve all the stages of feedstuff costing and analysis and least cost ration formulation of Chapter Four; the revision of the growthmodel of Chapter Three to conform with his own expectations of animal performance; and the derivation of the expected nett present discounted value curves resulting from operation under whatever constraining decision rules apply. The beef predictor price employed will be that known on the basis of forward offers by prospective buyers of the output, and may be expressed as a function of liveweight. These curves, exemplified by those shown in Figure 19 will then require to be displaced downwards according to the per kilogram costs of trading and transport which are peculiar to the operator and to the location of the prospective feedlot.

The predicted price lines at each level of the ruling beef price (meat exporters' schedule) incorporating the adjustment for market optimism, will intersect the feedlot value curves. Profitable operation will be possible should the point of intersection be found at a liveweight level sufficiently below the slaughter liveweight. At the conditions defined by the price line and the feedlot curve which intersect, steers of liveweights in the range between that of the intersection and the slaughter liveweight offer prospects of profit.

Only one market price line based on optimistic circumstances is shown in Figure 19, and the feedlot value curves have not been displaced downwards by a transport and trading cost. The conclusions depicted by Figure 19 therefore are limited but are clearly to the effect that the combination of a meat exporters' schedule of 60 cents/kg carcase and a feedlot beef price predictor of 100 cents, profitable purchases of steers in excess of 340 - 370 kgs liveweight (according to level of feedlot fixed cost) will be possible in all months except May, June, July, provided that trading and transport costs are insignificant. Where transport and trading costs amount to 10 cents per head, the displacement of the curves will be such that only steers in excess of about 450 kgs liveweight can be profitably purchased. More accurate decisions are possible by reference to the single curve representing the actual level of per head fixed feedlot costs.

Quite clearly as a method of evaluating the viability of a single situation this procedure is inefficient and tedious; as a method of investigating the potential viability of feedlots it is cumbrous. A simplification is thus required.

6.3. The Co-existence of Competing Investment Value Models.

The classification of investment value models from Chapter Two offers a covenient starting point. It was shown that investment value situations comprise three classes, each of which exhibits a characteristic curve in the plot of $V_k = f(W)$. The situation exemplified by the store cattle market in New Zealand was shown normally to be of Class I (concave upwards, unit price always higher than that at slaughter). Varying the ratio P/C was shown to alter the shape of the curve, and boundary values for P/C identifying the transition to Class II and Class III curves were shown to depend upon the value taken by g when the other variables in the model are held constant. The first difference between the simple Class I situation and the feedlot situation is to be found in the increased value for a feedlot of the variable C, the daily cost of holding. It is of interest to find whether the curves of two investment situations differing in this one respect intersect at any value of W, the initial liveweight, other than when W = L, the liveweight at slaughter.

A simple algebraic manipulation of the model demonstrates that for a steer of liveweight lower than that at slaughter to be valued equally under two investment situations requires that at least two of the model parameters must differ as between the situations. This implies, for instance, that a higher expected rate of gain in the situation with the higher daily cost of holding will permit a steer to be valued equally in each situation at some weight below slaughter weight.

However, the variation in cost levels which is met by such adjustment in rate of liveweight gain within the limits set by the known practical process is found to be small. An increase of a few cents in daily cost can be met by an appropriate adjustment in rate of gain. Where discount rate is the other parameter which differs between situations this practical limitation is also found; similarly when both rate of gain and discount rate are adjusted in response to a change in the daily cost of holding. Where the daily cost of holding in one situation is as much as twice that in the other it is possible that a feasible combination of discount rate and gain rate could be found which allows a steer in situation 2 to be valued equally with one in situation 1 at a liveweight level lower than slaughter weight. Such a pair of investment situations might be characteristic of two enterprises using the same technology but with management showing minor differences. The high correlation between the values found for pairs of parameters in the investment value model during the analysis of the Feilding data supports this conclusion, showing that the model fits the data equally well with several sets of parameter values.

However, the divergence between the daily cost of a feedlot and that of the grazing technology evidenced by the analysis of the Feilding data is much wider than can be practically compensated for by modification of rate of gain, carcase yield, and discount rate between the two situations. Hence, if a steer of less than slaughter weight is to be of equal value in each situation the beef price predictor must also differ between the two situations. Thus the conclusion that a feedlot requires a higher beef price than is available to the store cattle market at large is confirmed.

Using the same model (2) as was described in Chapter Two, with the fixed cost component unadjusted, the intersection of the two curves $V_k = f(W)$ may be expressed as:

$$(a_1L_1P_1 + C_1)e^{-r_1t_1} - C_1/r_1 - WF_1 =$$

$$(a_2L_2P_2 + C_2/r_2)e^{-r_2t_2} - C_2/r_2 - WF_2 \ldots\ldots\ldots (5.1.)$$

Manipulation of the expression (5.1.) under the assumption that $r_1 = r_2$, ie. the two situations involve the same rate of discounting, shows that the value for P_2 which permits equality in value to be reached in the two situations is:

$$P_2 = \frac{(ra_1L_1P_1 + C_1)e^{r(t_2-t_1)} + (C_2 + rW(F_2-F_1) - C_1)e^{rt_2} - C_2}{ra_2L_2} \quad \text{.............(5.2.)}$$

The formulation (5.2.) permits the two situations to have different values for all the parameters of the model except the discount rate. The two exponential terms are dependent upon the value taken by W when the value of the steer in each situation reaches equality, and upon the differing expected rates of gain and total gain.

6.4. A General Appraisal of Potential Feedlot Viability.

The simple model (5.2.) meets the needs for a tool to evaluate the viability of a feedlot (situation 2) in an environment where the prices of store cattle are set by bidders who use a grazing technology (situation 1). The information from the full feedlot model permits values to be given to the parameters with the subscript 2 in (5.2.). These represent the most promising feeding strategy and thus are proxy for the technology in general rather than for any subsection of the feedlot technology. In the same way, the parameters with subscript 1 in (5.2.) take values derived from the analysis of Chapter Two, and represent the price expectations for the chosen month(April). The initial liveweight, W, is set at 450 kgs. Simplification of (5.2.), then leads to:

$$P_2 = 1.176P_1 + 0.374C_2 + 16.67 \quad ....(5.3.)$$

where C_2 is the non-feed component of daily holding costs in situation 2, and the fixed costs are assumed equal in both situations.

Model (5.3.) summarizes all the information which has been generated by the analysis of the data from the Feilding market and the modelling of the full feedlot operation, and enables the viability of the feedlot technology to be evaluated. By substituting alternative values for the variables in model (5.2.), whilst ensuring consistency with the full feedlot model and with the price prediction analysis, similar formulations to that shown in (5.3.) may be found. Little variation in the coefficients results, and the model (5.3.) appears to give reliable basis for evaluating a feedlot which will use the feedstuff schedule assumed in this thesis.

Table XVII illustrates the values given for P_2, the feedlot breakeven beef price, by use of model (5.3.) for a number of values for P_1 and for

C_2, the daily per head feedlot costs other than assumed feedstuff purchase and processing costs.

Table XVII

The Breakeven Beef Prices for Feedlot Operation with Varying Levels of Ruling Beef Price and Non-feed Feedlot Costs. (From Model 5.3.)

cents/kg carcase

Ruling Beef Price P_1	50	60	70	80	90	100
Non-Feed Costs (cents/head/day) C_2			P_2			
0	75.6	87.3	99.0	110.7	122.4	134.1
5	77.5	89.2	100.9	112.6	124.3	136.0
10	79.4	91.1	102.8	114.5	126.2	137.9
15	81.3	93.0	104.7	116.4	128.1	139.8
20	83.3	95.0	106.7	118.4	130.1	141.8
25	85.2	96.9	108.6	120.3	132.0	143.7

While model (5.3.) represents the results of combining all the aspects of feedlot operation and market price determination as analysed in the preceding chapters, it is an approximation only.

A reiteration of the assumptions which underlie the model (5.3.) makes clear some of the restrictions to its application;

(a) The analysis of the Feilding market for store cattle gives results which are representative of the processes of price formation and discovery which prevail in all regions which are prospective sources of supply to a feedlot;

(b) The expected physical performance of steers conforms with the growthmodel;

(c) Optimal strategies with feeding to the level of voluntary intake dominate all strategies involving restricted feeding.

(d) Costs and qualities of feedstuffs, and the availability of the non-conventional feeds described, are as outlined in the proxy schedule;

(e) Entry of a new (feedlot) demand for store cattle does not disturb the mechanism of price formation in the markets nor change the level of prices;

(f) The formulation of the least cost rations at the energy level selected in the optimal feeding strategy is not inconsistent with practical use;

(g) The non-feed feedlot costs including trading, transport, management return, and deaths, are of the same order as the fixed costs estimated from the 1974 Feilding data (ie. about 2% of total price/value).

These assumptions impose very severe restrictions upon the wider application of model (5.3.) in appraising the viability of the feedlot technology. For instance a further examination of the 1954-56 feeder market in the United States reveals the need for an assumed fixed cost of the magnitude of 10 - 14 cents/kg for the model to fit the data. This indicates that assumption (g) above is very weak and that feedlot operators are likely to incur a fixed cost of significant magnitude.

Nevertheless, the summary of model output shown in Table XVII permits identification to be made of the approximate beef price needed by a feedlot before the full feedlot model is used for a detailed examination.

The required feedlot beef price depends upon the allocation of non-feed costs, and with a realistic level for these costs of 20 - 25 cents/head/day the necessary price is approached when it exceeds the ruling meat exporters' schedule price by some 40 cents. The sensitivity of the breakeven feedlot beef price to changes in either the beef price facing other producers or the feedlot daily cost can be tested by means of the coefficients in Model (5.3.), recalling that daily feed consumption is estimated to be 6 kgs dry matter. The effects of no more than small changes in feed costs can be tested in this way, since wider movements might result in a different set of optimal strategies from the full feedlot model which would be reflected in a different coefficient for C_2 , and a different constant term, in model (5.3.).

6.5. A Summary of the Results of Chapter Six.

Under the set of assumptions which have been taken in this thesis a condition for the profitable operation of feedlots is shown to be access to a beef price higher than that which faces users of the traditional grassland technology.

The full feedlot model yields conclusions which permit the construction of a simple linear model to identify the magnitude of the feedlot beef price advantage necessary to ensure that candidate steers are available on the store market at prices below their nett present discounted value to the feedlot operator.

The magnitude of the beef price advantage required for profitable operation under the set of assumptions taken is indicated to be of the order of 40 cents/kg. This implies that for a meat exporters' schedule price of 60 cents/kg carcase for the reference weight/grade, a feedlot requires a price of 100 cents if it is to compete for steers in the liveweight range where profit opportunities are best.

CHAPTER SEVEN

7. SUMMARY AND CONCLUSIONS.

As an introduction to this chapter, and to draw together the strands of investigation which constitute the study, a summary is first presented of the whole thesis. This is followed by an evaluation of the methods employed and of the potential development of the approaches. By way of a final conclusion, an appraisal is made of the prospects for use of feedlot technology to prepare cattle for slaughter in New Zealand.

7.1. Summary of the thesis.

The thesis describes an investigation into the application of feedlot technology under the conditions found in New Zealand. This is done by:

(a) Developing a computer model ("growthmodel") of the feeding and growth of a steer given alternative rations differing in their concentration of metabolizable energy;

(b) Describing a proxy schedule of feedstuff costs and qualities from which cattle rations may be prepared;

(c) Formulating least cost rations under the constraints imposed by the design of the growthmodel;

(d) Identifying feeding strategies which maximize the present nett discounted value of steers candidate for entry to a feedlot;

(e) Developing a price expectations model of the store cattle market with the aid of data from the weekly Feilding market;

(f) Comparing the computed value of a steer to the feedlot operator with its expected price on the store cattle market, thus finding the conditions needed to sustain feedlot viability as measured by the capacity to buy store cattle.

The model structure is amenable to any set of assumptions, and the personal and individual nature of feedlot management is emphasised at every stage. Thus the full feedlot model can be used to investigate the optimal feeding strategies open to any prospective operator. The results which are presented are applicable in detail only to the restricted situation where the series of assumptions taken accurately represents the expectations of the prospective operator.

The investment value model of the store cattle market prices is developed upon a hypothesis that the auction procedure tends to elicit limit bids, that these limit bids are estimates of investment value, and that the bidders at New Zealand livestock auctions by sharing a common technology and holding common expectations tend to make similar estimates of investment value. Model development is not carried to completion, but sufficient understanding is gained to employ the model to generate broad band price expectations for steers.

When the results from use of the full feedlot model are considered in conjunction with these market price expectations, the conditions under which the profitable purchase of steers for a feedlot is seen to be possible are found to include access to a higher beef price. The beef price level required by the feedlot under any combination of liveweight, ruling beef price (for the market at large), and non-feed feedlot cost level, is shown to be identifiable by graphical methods.

This full modelling exercise permits some valuable conclusions to be taken and these in turn allow the construction of a simple linear expression to estimate the breakeven feedlot beef price. While this simplification is applicable only to the set of assumptions from which it is derived, most importantly the assumptions of feedstuff costs and qualities, its use is proposed as a means of finding the difference between market beef price and feedlot beef price which is required before more detailed investigation of feedlot viability is called for.

It is evident that at the time of this study, the necessary beef price advantage to feedlots did not exist.

7.2. The Methodology - An Evaluation.

7.2.1. The Price Expectations Model.

The development of the non-linear model is incomplete and is based upon limited data. Nevertheless, this data is the most comprehensive available and the process of price formation in the New Zealand store cattle market is subject to a closer examination in this thesis than in any prior study. Thus the relationship of a prospective investor in cattle with his source of candidate cattle is better understood than in earlier studies of feedlot feasibility.

The classification of investment situations which is derived from the theoretical examination of the model offers a ready summary of a potential cattle feeding activity on the basis of the relationship of the factors of cost, product price, and animal growth rate. It is probable that other livestock production processes would be amenable to examination in the same manner. Further development of this tool offers prospects of giving a deeper understanding of the complex inter-relationships between the technical processes of animal management and their ultimate financial outcomes.

The price expectations model, too, has potential for further development to yield a better insight into the various factors which influence prices. While some of these factors have not yet been satisfactorily analysed, (eg. animal breed and condition), the relationship of others with the model indices has not been fully established (eg. market mood and weather conditions), and the effect of yet others (eg. size and location of the sale) has not been investigated, the investment value model appears to offer a convenient framework by which all these factors can be further examined.

The particular model structure used in this study is deficient in some respects, and the estimation of parameter values involves some degree of complication. However, the derivation of the model as a reflection of bidder behaviour rather than as a convenient formulation from the analytical point of view, leads to advantages of interpretation which are not found in, eg. linear models. Refinement in the computational procedures will probably overcome some of the shortcomings made evident. With more data of the quality used in this study, improved conclusions might be expected to come from further model development. With better data, including perhaps the objective measurement of some of the cattle attributes, it is possible that stronger conclusions may be reached. The requirements for improvement in the economic efficiency of the store cattle market might be identified as the result of development along these lines.

Thus the examination of store cattle prices has led to an advance in knowledge and to the formulation of an approach which offers potential for still further improvement in the understanding of store cattle marketing.

7.2.2. The Growthmodel.

The modelling of the processes of feed intake and liveweight gain is undertaken for the purpose of developing a subsidiary tool for use in evaluating feeding strategies. With the benefit of hindsight, it is evident that in many respects the modelling process could achieve the same result rather more simply. This is a result of the learning process which tends to accompany modelling activity. The particular constraints upon ration formulation which are found to follow the assumptions behind the growthmodel form another outcome of this learning process.

The growthmodel is constructed in a manner which permits modification according to the expectations of the operator. The validation process is carried sufficiently far to show that growthcurves can be produced in conformity with those found from empirical evidence and with individual belief. Hence no particular virtue attaches to the particular parameter values employed except that they are realistic and conform to the beliefs of a fictitious feedlot operator.

The modelling of voluntary intake in a dynamic manner constitutes an advance. It is made clear that the scientific literature contains all the evidence required for an understanding of voluntary intake as a dynamic process, but no record is found of prior synthesis of an intake model which incorporates this understanding.

Animal intake is influenced by environmental considerations as well as by the characteristics of the feed and of the animal. The assumptions underlying the growthmodel include that of an "optimal" unvarying environment, and of animals unaffected by disease or by the effects of competition. Invariable feed quality is another important assumption. Hence the growthmodel takes a deterministic stance which is not very representative of the actual conditions under which animals apparently given ad lib access to feed do in fact meter their intake. However, the assumptions which are made are directed in such a manner that the growthmodel output can be viewed as an "expected" outcome. Further development of the growthmodel would usefully investigate the nature of intake and growth rate variations.

7.2.3. Least Cost Ration Formulation.

As noted above the constraints applied to ration formulation are derived from the assumptions made in the development of the growthmodel. These constraints are found to be quite reasonable in a practical sense. The proxy schedule of feedstuff costs and qualities is presented as personal to the fictitious feedlot operator and thus is completely accurate. However, the use of the results from the full analysis to evaluate feedlot technology in general depends on an assumption that the feedstuff schedule is at least representative of the more competent potential operators of feedlots. The basis of feedstuff costing and of quality evaluation thus requires to withstand a critical examination.

The costing of non-traded feedstuffs, the various silages, on the basis of a selected opportunity cost is believed to be an accurate interpretation of the real situation. The choice of a single cost esimate to represent a fodder which in reality is highly variable is an extreme simplification, but again is proposed as a sound representation of the position of a potential operator. The use of an "average" cost would seem by comparison to be an unsatisfactory method. The costs of traded feedstuffs are taken from market quotations and are accurate for the period under review. Two materials, "protected" tallow and rapeseed, are not traditional ruminant feedstuffs in New Zealand and are not freely available on the market. The unit cost attributed to these feedstuffs is thus more questionable.

These comments made with regard to the estimation of the costs of candidate feedstuffs are equally relevant to the estimation of their nutrient analyses. While an estimate of metabolizable energy concentration and crude protein content at the upper bounds of possibility could be made for each feedstuff and the final outcome of the full study then applied to this "best" situation, the decision is made to represent a real range of candidate feedstuffs through rather conservative expectations of the levels of energy and protein. Thus the situation of a prudent entrepreneur is more nearly approximated. The fact that feed quality is normally beyond the control of the feedlot operator, except that he is in a position to accept or refuse the offers of suppliers, carries some weight in the choice of this approach.

The whole question of variation is avoided by the use of the proxy schedule. This is a field of study which may well repay further investigation should feedlot technology become competitive. The present approach is considered appropriate to the non-competitive nature of feedlots disclosed by this study.

7.2.4. Selection of Feeding Strategies.

The isolation of technical feedlot operation from the considerations of cattle trading is the most important characteristic of the approach used in this thesis. The independent appraisal of competitive sub-sections of the feedlot technology thus becomes possible without interference from the external market. The ability to identify "optimal" feeding strategies, and thus to evaluate the feeding technology on the basis of the "best", permits the conclusions of the study to be applicable to feedlot technology in general and not to be restricted to intuitively selected sub-sections.

However, the use of the growthmodel giving expression to the assumptions of the operator, rather than of a universally "true" representation of the process of feeding and growth, reduces the generality of the solution and makes it clear that general solutions are not available. Also made clear is the existence of an "optimal" feeding strategy under any set of assumptions, and the dependence of the optimal strategy upon the costs and output prices.

7.2.5. Appraisal of Feedlot Viability.

The full modelling procedure is shown to disclose the nature of the feedlot which is profitable at lowest expected beef price for feedlot output. This information in turn permits a simple model to be constructed to investigate the viability of that feedlot. Hence the use of the complicated and involved modelling procedures is justified by their ability to identify the most appropriate sub-section of the feedlot technology for any set of assumptions. The sensitivity to changes in the major assumptions is not tested, although the effect of changes in the levels of particular inputs is analysed.

In this instance, applying the modelling procedures to a production activity which is not in common use permits decisions to be made about the potential viability of that activity. It is possible that a similar approach when applied to commonly used livestock production activities might reveal possible management options which have been discarded during the refinement of the activity over time, but which sudden changes in resource costs and product prices may make desirable. Thus an extension of the modelling techniques into investigation of fields of activity for which wide experience and knowledge in fact exists may permit better decisions to be made than is usual. This is an example of the usefulness of modelling in forcing a full consideration of all the relevant options.

It is evident from the use made of the full feedlot model to develop a simple model to evaluate the viability of the feedlot technology, that a major problem faced in feasibility studies lies in the design of the strategy to be evaluated. The use of the modelling technique within a framework which permits optimal strategies to be identified offers some prospects of improving decision-making in many fields of livestock production.

7.3. Future Prospects for Feedlot.

Under the assumptions upon which this study is based feedlots are shown to be non-competitive in New Zealand. Alteration of this conclusion requires a reconsideration and relaxation of these assumptions. Some of the assumptions are now examined more closely.

7.3.1. The Schedule of Ration Costs.

Since the formulation of least cost rations by linear programming effectively minimizes the ration cost under each set of constraints, and attempts to employ other formulations can only increase unit ration cost, the only means of reducing feedcosts below the level of the proxy schedule involves access to cheaper nutrients. Within the list of feedstuffs candidate for inclusion in the rations only a few are not completely objectively costed. Winter cereal silage is costed on the basis of the opportunity cost of a beef grazing activity, the profitability of which may not withstand close scrutiny. Protected tallow supplement and rapeseed are not freely available on the market, and should an effective demand bring supplies forward, prices for these materials may in fact differ significantly from those which are assumed.

These three materials consistently appear in the least cost rations, and a reduction in their cost will be reflected in an improvement in the computed value of candidate feedlot steers.

Nutrient cost is sensitive to feedstuff quality, and the assumptions of energy density and crude protein content of each candidate feedstuff may be challenged. The energy values attributed the hays and silages are rather lower than is often represented. As has been repetitively stated, a prospective operator will incorporate his own expectations, so that there can be no doubt that other quality schedules could be applied to the same problem.

Whether there exist potential cost savings and quality advantages which could significantly influence the outcome of the study is doubtful. Some light is thrown on the question by the simplified model (5.3.) where the sensitivity of the breakeven feedlot beef price to changes in C_2 is 0.374. Under circumstances where a revised schedule leads to a reduction of one cent per kilogram dry matter in the unit costs of least cost rations, and the optimal feeding strategies remain unchanged, the resultant reduction in the breakeven beef price is 2.24 cents (daily consumption is 6 kg dry matter). Scope for improvement by this means is evidently limited.

The consistent selection of the protected tallow supplement in the rations of optimal strategies implies that the costs of the more traditional feeds for ruminants are rising to a level where they may be relatively uneconomic sources of nutrients. The possibility of other industrial products or byproducts becoming important as sources of animal feed must not be discounted. The various wastes from the meat processing industry have some apparent potential in this respect.

7.3.2. The Product.

Throughout the study, beef has been considered a homogeneous product. This implies that feedlot beef is indistinguishable from grass-fed beef. The possibility of a higher product price being received by feedlots is clearly remote under these circumstances.

Feedlots are often considered to confer special qualities upon the resultant beef. Consumer demand in the United States has evidently been of a nature which pays a substantial premium for feedlot beef as compared with range beef. The demand for Kobe beef in Japan is another manifestation of this phenomenon, and the short term success of some feedlots in New Zealand up to 1974 was due to access to this market. Even the United States consumer has shown himself to be responsive to high prices in recent years, and the magnitude of the price differential needed by feedlot operators in New Zealand is such that very real quality differences, sufficient to preclude substitution by other products, would be required to sustain this differential in the medium or long term.

Possibilities do exist for special feeding to create such quality differences. The feeding of polyunsaturated oils to produce a meat without the health hazards attributed to excessive consumption of animal fats is a case in point. Other widely known health hazards might be met by similar procedures yet to be discovered.

Special advantages often supposed to accrue to feedlot operation lie in the matters of product grading and ability to meet forward contracts. While these advantages can be seen to exist vis a vis the individual grassland beef produce in New Zealand, the organization of the meat industry is such that grassland beef does not in general suffer problems of price depression from these causes. Only one characteristic of the grassland beef production system can be seen to incur inefficiencies in processing and possibly in disposal, and that is the seasonality . The feedlot technology is well suited to overcoming this deficiency, but the gain to the industry as a whole cannot be supposed adequate to meet the high level of beef prices needed to support feedlot operation.

Hence the only promise of a beef price advantage of the magnitude required for economic viability of feedlot appears to lie in the development of feed supplements which can be employed in feedlots to create a non-substitutable product for which a high priced market can be developed.

7.3.3. Strategies of Store Cattle Purchase.

The buying operations of a feedlot operator must necessarily attract the attention of his fellow bidders. Under the required conditions for feedlot viability such an operator will be able to bid marginally higher than farmers using a grassland technology. It has been noted that the feedlot operator will cause confusion in the normal processes of price formation and discovery unless his fellow bidders realize that he possesses a beef price advantage and can afford thereby to outbid them at their normal limit bid. Whether farmers bidding at auction are in fact able to distinguish between bids from a feedlotter and bids from users of their own technology must be questioned. It is possible that only very gross differences in the limit bid could in fact be detected and if this is the case the feedlot operator must depend for his main supply of cattle upon sources other than the physical auction markets.

With the advantage over operators of the traditional system that he can accurately compute the value of candidate steers, it is probable that the feedlot operator will advertise his offer for cattle of given liveweight on a per kilogram basis. If indeed the necessary conditions (ie. the required level of feedlot beef price) exist, the advertised offer will exceed the price available from other sources, and provided the problems of liveweight estimation are overcome, the feedlot operator will be supplied with cattle and the normal processes of price formation in the auction markets will be undisturbed. Cattle not otherwise available may then be offered.

The prospects of an operational feedlot finding itself able to take advantage of downward price variation at auction appears small, despite the degree of variation found at the Feilding market during the data period. Seasonal variation must be considered, however, in a different light since feedlot viability must be evaluated before commencement of the enterprise on the basis of expected prices relating to a season when greater than minimum prices are paid. Consequently the operational feedlot, in months when the store cattle market is seasonally depressed, might expect to be able to reduce its offer below that used to evaluate feasibility.

An effect of the existence of a premium price for feedlot beef has been assumed to be a mood of optimism affecting the bidders in the store cattle market. This is asserted to be inevitable when the premium price is found in export markets, and when the market demand satisfied is for higher qualities of beef. Under these circumstances there is considerable justification for the assumption.

However, should feedlot beef become a product which satisfies a specific demand which grass-fed beef cannot meet (eg. for health-oriented meat), the emergence of high prices for this product need no longer have repercussions on the store cattle market at large. Hence an operational feedlot producing such specialist output and receiving a sufficient price margin overthe grass-fed beef will find itself able to buy on store cattle markets where the mood may vary from price confidence to price pessimism. Under these circumstances the breakeven beef price for the feedlot, using model (5.3.) will be reduced according to the mood of the market with the coefficient of P_1 falling as low as 0.978 on occasion. Quite clearly such a feedlot, when estimating the future economic viability of its process, would not be well advised to assume the permanence of a pessimistic mood in the beef industry as a whole.

While this study has been designed to isolate the technical aspects of feedlot management and to investigate its interaction with the store cattle market, it is clear that the overall strategy of an operational feedlot must be planned to integrate both aspects. Feedlot operation requires to coordinate flows of cattle in order to optimize the use of its resources, and the analysis of prices for store cattle has made it clear that for any liveweight level, the market price will fluctuate over the year.

One of the essential pre-conditions for entry of an entrepreneur into the risky business of feedlot operation is asserted to be access to contracted prices and delivery dated for the output. Hence planning for replacement strategies initially will be based upon an assumption of fixed output prices and dates. Under these circumstances profit-maximizing marketing strategies will consist of offering a price for candidate cattle which calls forth exactly the rate of supply which is required at each season, and combining this with forward contracts for sale which permit adequate profit levels to be maintained.

The full feedlot model which has been developed has potential as a tool for use in maintaining knowledge of the required input/output cattle price relationship once the existence of the necessary output prices has been demonstrated.

7.3.4. Specific Technical Assumptions.

Underlying the results from the full feedlot model are specific assumptions concerning the relationship of liveweight with expected beef price, of liveweight with carcase yield, and an assumption that optimal feeding strategies including feeding to appetite dominate all strategies which involve rationed feeding. The homogeneity of feedlot output is implicitly assumed, and this is only one of the many sectors of the full model which are treated deterministically but which are better defined as probability distributions.

The reasons supporting the deterministic choice of approach include its relative simplicity, and ignorance as to the details of the probability distributions. Whether this approach leads to incorrect conclusions depends upon the degree of accuracy with which the averaging assumptions capture the essence of each process.

The same considerations apply to carcase yield and price/liveweight expectations. With the former, the linear relationship employed is selected as demonstrably close to the real situation, even though predicting carcase yield from liveweight is in practice fraught with complication. The use of a beef price schedule which is invariable with liveweight is not so obviously sound, and at the root of this difficulty is the problem of modelling a completely unknown schedule. This arises because it is supposed that individual producers will be faced by individual schedules the details of which will be dictated by trade contacts and negotiating ability. These schedules may be no more than single weight/price pairs, and in such cases the full feedlot model will be constrained by Rule 2 (slaughter at fixed weight).

That optimal feeding strategies with appetite feeding dominate all strategies with rationed feeding is an assumption based upon a conclusion reached by Kennedy (43). When output price is independent of time, the assumption is intuitively satisfying. When the output price is expected to increase with time, or when Rule 3 (slaughter at fixed time) is invoked, rationing strategies may in fact become dominant. The slope of the least cost ration curve (Figure 12) is likely to be important in this question.

The sensitivity of the results to modifications in these assumptions is not tested, but the importance of personalized expectations in the construction of the feedlot is again emphasized. However, the results obtained suggest that modification of any of the specific technical assumptions taken in the study is unlikely to show feedlot technology significantly more competitive.

7.4. The Future of the Feedlot Technology - Conclusions.

The study has revealed that the method of pricing candidate cattle in the store cattle market closely approximates an investment value method for both users of the traditional grassland system and potential operators of feedlots. The expected level of daily costs in feedlots which use the optimal feeding strategy is found to be markedly higher than that assumed by grassland farmers. Thus feedlots can compete in the store cattle market only under circumstances where the product price for feedlots is much higher than that for beef from other sources. This gives confirmation of the conclusions of other studies (eg. (32)).

Only one possibility is foreseen that could lead to the establishment of a viable feedlot industry under the store cattle price relationships which prevailed during the period of the study. This lies in the development of, for instance, health-oriented beef as a product unique to feedlots and the existence of an effective demand for this product at very high prices.

Except on a minor scale, supply to a sector of the export market paying high prices for feedlot output is not seen as contributing to long term viability of feedlots, owing to the interaction of store cattle prices with knowledge of high price activity on the export market.

The nature of the feeding activity which offers the prospect of feedlot viability at lowest beef price levels is the finishing of cattle from high weights. Feeding of cattle purchased at light weights, either for slaughter at high weights, or for resale on to the store cattle market, is found to suffer from a severe cost disadvantage which does not permit a feedlot to compete except on the basis of certain knowledge of future favourable movements of beef prices.

The prices expectation model fitted to the data from the Feilding market has parameter values which give grounds for an assertion that the buyers expect a very low level of profit. It is possible that bidders in store cattle markets in other regions assume a higher level of costs and demand a higher profit, and that a continued cost-price squeeze may alter bidder behaviour to reflect these changes at all centres. Changes of this nature would be reflected in lower prices for store cattle, and provided that the actual increase in all the costs of feedlot operation proceeds at a slower rate than the change in expectations on the part of bidders in the store cattle market, it is possible that the feedlot technology may be found more competitive in future. The magnitude of the beef price advantage necessary under the assumptions of this thesis is such that at no time can feedlots be expected to become fully competitive without a beef price advantage.

APPENDIX A.

A.1. Data Collection.

A.1.1. Characteristics of the Feilding Market for Store Cattle.

The market is held weekly on Fridays throughout the year. When a public holiday supervenes the sale is usually moved forward to Thursday. Occasionally an extra special sale is added, such as the annual sale of weaner cattle in April. Normally at the same sale but in adjacent pens and at differing start times there are auctions of fat sheep, store sheep, and fat and boner cattle, as well as of the store cattle now of interest. The saleyards are operated by a saleyard company and the auction of each line of cattle is under the control of the employees of the stock firm of which the vendor is a client.

The procedure is as follows: prior to the start of selling at 11 a.m. the cattle are sorted into pens and are there available for inspection and evaluation by prospective buyers. These pens are numbered and each carries a label identifying the names of the vendor and the stock firm, the number of cattle in the pen and their description by sex, breed and age. The sale starts at a fixed time and takes place in a ring - a covered pen over which seated bidders face the auctioneers' rostrum - into which each pen of animals is brought in turn and offered for sale. The order in which the pens are brought into the ring is more or less standard, being dictated by the flow patterns of the pen complex, but the stock firm whose client's cattle occupy the first pen for sale is chosen each sale by some kind of lottery.

The only objective information given the prospective bidder for any line of cattle is carried on the pen label. His evaluation of the line must be on the basis of this information, his observation of the animals, and his judgement.

Cattle are drawn from a wide area into the weekly Feilding market and there are reputed to be many dealers and traders operating in this market. This, if it were so, would be a factor tending to minimize irrational price fluctuations and to maintain pressure on bidders to reveal their limits. Even in normal seasonal conditions cattle are brought from distances of perhaps 100 miles, and buyers are known to come from similar distances. On occasion, when feed shortages are pressing in rural areas even more distant, cattle are brought for sale at Feilding from yet further afield.

In most respects the conduct of the Feilding sale parallels that of any organized auction of store cattle in New Zealand. Less important markets operate without benefit of a selling ring and an auctioneer's rostrum, the bidders being mobile rather than the cattle. No price advantage can be attributed either method.

The regularity of sales at Feilding, however, and at other centres with weekly markets, is likely to lead to some distinctions between these markets and those with irregular or intermittent selling. These distinctions probably relate to the development of a local coterie of experienced traders whose arbitrage operations reinforce the tendencies of the auction which lead to discovery of limit bids. Irregular sales might by contrast be expected to reveal a less persistent trend to maximum prices.

Feilding market is at the centre of a large area of fertile farmland, where breeders of cattle and buyers of store cattle for feeding are equally represented. Transport costs will therefore be close to a minimum. A different situation might be expected to prevail at centres in predominantly breeding areas. Most purchases will be transported large distances from such sales (80) and prices will undoubtedly be discounted to the extent of the costs of the transport.

Analysis of sale data might confirm the higher mean price levels and the lower variance which these factors can be hypothesized to cause at Feilding by comparison with irregular sales and breeders' sales.

A.1.2. <u>Data Collection Methods</u>.

Sales records were collected for the period starting on 16 February 1974 and ending 17 February 1976. Records are almost complete in that observations were made of 90% of the weekly sales and of all the additional sales. Within each sale, however, some doubt exists as to the completeness of the cover as no separate record exists of the number of steers offered or sold. The observer was not always able to remain to the end of the sale, and these instances have not been identified. While all lines of cattle offered were recorded, within these limitations, the data processed related to only the steers. Of these some lines were eliminated owing to illegibility or incompleteness of the record.

The data recorded and processed for each pen of steers offered for sale included:

Estimated mean liveweight
Condition grading
Age
Breed
Order in sale
Number in pen
Final bid
Sold/passed

(a) Weighing does not form part of normal presentation of lines for sale at Feilding nor at most sales in New Zealand. Some investigations have been undertaken (20) into the relationship of prices with liveweights at sales of beef and dairy-beef weaners where weighing was carried out, with the conclusion that behaviour of buyers does not differ with or without the measured liveweights. As discussed above explicit estimation of liveweight does not appear to be part of the evaluation process of prospective buyers.

The liveweights were estimated, using the method described above (applying a factor to the estimated carcase weight), by an accepted expert. These were recorded before the commencement of the sale. Spot checks confirmed that the estimates did not diverge notably from those made by such habitues as could be persuaded to give an opinion.

(b) The condition grading of a live steer cannot be measured objectively without closer contact than visual inspection. Some animals quite obviously have a better fat cover than others. Some show evidence of recent feed shortage and some of early deprivation. The sum total of these effects, aggregated into a single score, is "condition". If measured on a scale the end points might be agreed by all graders, but the position of animals on the scale would not necessarily be consistent as between graders. There is a concept of "what an animal should look like" in the idea of condition grading, and this is strongly subjective and influenced by the season of the year, the presence or absence of abnormal weather (and feed) circumstances, and by the personal attitudes to cattle feeding practices and even the financial state of the judge.

The fundamental idea uderlying condition grading, as with breed society standards, is that there is a correlation between such grading and the subsequent performance. This idea is not well supported by evidence. A series of trials reported (24) in 1953 showed that a good calf grade was negatively (but not significantly at the 5% level) correlated with total gain both as yearlings and subsequently, although positively correlated with visual gradings at later ages.

The concept of compensatory growth is well enough documented (e.g. (67)), to be a probable influence in the formation of growth rate expectations. While Joblin (38) brings forward experimental results to show that under the grazing management common in New Zealand the loss of potential gain caused by deprivation in the winter is not fully made up by ad lib feeding during seasonal flushes of feed, these results do in fact confirm that growth rates do increase subsequent to a period of deprivation. Therefore, if by means of a superficial condition grading a prospective buyer can identify cattle which will respond to good feeding by better growth rates than others, his ideas of values will be influenced. A contrary effect might be derived from an association of low condition with disease. In any event the grounds for supposing that condition of animals might be a determinant of price are reasonably well based.

Condition scores were allocated to lines of steers on the basis:

fat = 1
good store = 2
thin = 3

These records, condition and liveweight estimates, are obviously strongly subjective in nature. They are viewed as estimates of the estimates of buyers rather than estimates of a measurable statistic. The remaining records are objective, being verifiable attributes or happenings.

(c) The age of each line was read from the pen label, where age is invariably expressed as e.g. 2 year, weaner, $1\frac{1}{2}$ year, etc. The seasonality of New Zealand grassland farming is such that very few calves are born at times other than spring and early summer. Each successive sale therefore showed each of these age classes growing older by one week, and only on very rare occasions were more than 4 classes represented at a sale. In order to formalize this situation an arbitrary birth date, 1 October, was applied to all lines, and the age in weeks calculated on this basis from the information recorded on the pen labels.

(d) The breed desciption was also read from the pen label. With the breeds found in New Zealand little ambiguity is possible and coat colour provided an explicit check on the vendor's description. The breeds and crosses which were represented were allocated one of the following breed classes:

Aberdeen Angus	=	1
Hereford	=	2
Shorthorn	=	3
Hereford x Angus	=	4
Shorthorn x Angus or x Hereford	=	5
Other beef breeds and crosses	=	6
Friesian and Friesian crosses	=	7
Other dairy breeds and crosses	=	8
Mixed beef breeds (usually Angus with Hereford)	=	9

(e) The order in sale, the number in each lot, the final bid made on each line, and the passing or sale of the line at that price, were each recorded on the spot. The size of the total entry at each sale was recorded from the sale summary prepared by the clerk of the saleyards. The total entry at each sale over the data period is illustrated in Figure A.1.

A.1.3. The climatic and economic data included:

Rainfall in the week preceding a sale;
Rainfall on the day preceding a sale;
Soil moisture deficit;
Soil temperature;
Index of the sharemarket;

(a) The rainfall figures were extracted from the records maintained at Massey University, distant 20 miles from the Feilding saleyards. In view of the area from which vendors and bidders at Feilding are drawn this climatic data offers as representative a summary of the district weather as that from any other site within the area. This assumption has not been tested.

(b) The soil temperature was extracted from the same records and makes use of the monthly mean temperatures at a depth of 5 cms. A smoothed curve was drawn from this data and the temperature attributed each sale read from this curve.

(c) The sharemarket index employed is the New Zealand United Index, extracted from the issue of the "Dominion" of the sale date.

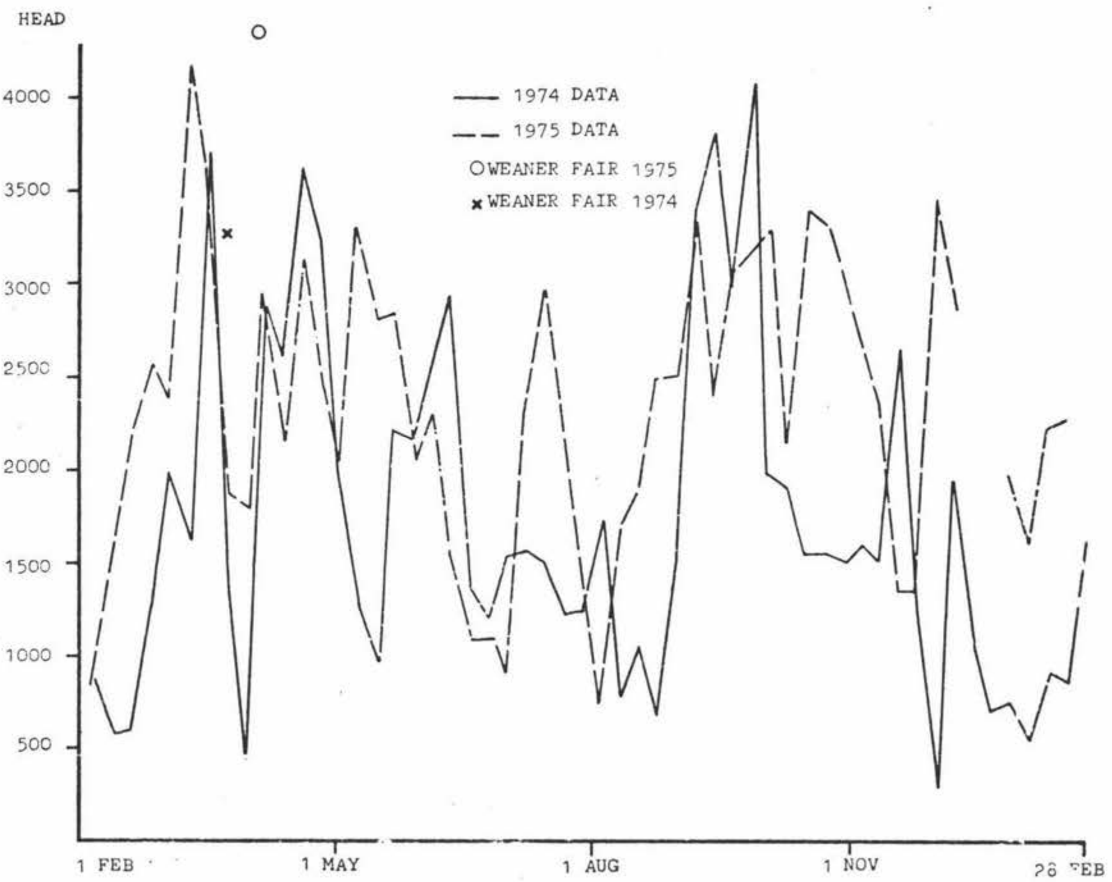
(d) A measure of the soil moisture deficit was computed from the Massey University data for each sale day. The method used involved the calculation of the potential evapotranspiration from the raised pan evaporation record using the adjustment factors described in Finkelstein (47) and then accumulating the nett daily soil moisture loss or gain from a starting point in 1973 where soil moisture level is assumed to be at field capacity.

FIGURE A.1.

Feilding Market

Total Cattle Entered at each Weekly Sale.

1974 - 1975



A.2. Parameter Estimation for the Investment Value Model.

A.2.1. Model Structure.

The model developed on theoretical grounds is:

$$V_k = ((aLP + C/r)e^{-rt} - C/r)/W - F \quad \text{.........} \quad (2)$$

where the symbols are indentical with those described in Chapter Two.

As a result of an examination of the predictions from this model in comparison with the actual prices from selected test data, some changes were made in this structure with the aim of improving the fit of the model. The form of the fully developed model is:

$$V_k = ((aLP(1 - e^{-ks}) + C/r)e^{-rt} - C/r)/W - FP(1 + AT) \quad \text{........}(2a)$$

where the additional symbols are:

k, an index of animal age;
s, a parameter;
T, a variable measuring time from the start of the series;
A, a parameter.

The expected time of holding, t, retains the same form as presented in Chapter Two:

$$t = (L - W)/g + Z_i$$

These changes represent an attempt to moderate the errors given by use of the unmodified model with test data from the 1974 period. These errors indicated that younger animals tended to fetch lower prices than older animals of the same weight, and that an unexplained trend effect was being reflected in the values found for the Z_i. It is assumed that this trend was a result of the high rate of cost inflation prevailing during the data period.

Inspection of the model (2a) indicates that parameter estimation will meet with difficulties caused by the dependencies between values for pairs of parameters:

(a) C and r;

(b) r and t;

(c) g and the Z_i;

(d) A and F;

(e) L and g.

Initial attempts to estimate optimal parameter values confirmed that this was so, and as a result two parameters, L and r, were made constant and given values consistent with the production process and with the assumed levels of interest charges. Hence it was probable that the estimation of the values for the remaining parameters could lead to many sets of "optimal" parameter values as there are pairs of values for L and r.

A.2.2. <u>The Estimation Procedure</u>.

Step 1. <u>The Value of the Parameter g</u>; Under the assumption that $V_k - V_a = 0$, where V_a is the actual unit price recorded, this equation can be rearranged into the form $t_j^* = h(W)$, t_j^* being the value for t which the model is a perfect predictor for lot j.
A regression of t_j^* on W_j, for the observations of sale day i, yields the coefficients of the equation $t^* = a - bW$ for sale day i.
Since $t = (L-W)/g + Z_i$, $dt/dW = -1/g$ and an estimate for $1/g$ is given by the regression coefficient b. Thus an estimate g_i can be found for the value of the parameter g which best fits the data from sale i, given the initial values chosen for the other parameters and constants in the model.

An estimate for the value of g is found as the mean of the g_i.

Step 2. <u>The Values for the Sale Weights</u> (Z_i) Since $t = (L-W)/g + Z_i$, for each observation in sale i, an estimate for Z_i is found as the mean of $t^* - (L-W)/g$

for the observations from sale i. These first estimates for the Z_i values can be improved, in the sense that the "best" set gives the minimum sum of squares of the deviations of the predicted prices from the actual prices. Without estimates for the Z_i, the model is incomplete, and this criterion cannot be invoked. For finding better values for the Z_i, the iterative Newton-Raphson algorithm is used, in the form:

$$(Z_i)_{n+1} = (Z_i)_n - f'(Z_i)/f''(Z_i)$$

where n is the iteration number;
$f(Z_i)$ is the sum of squares for sale i;
f' and f" are the first and second derivatives of $f(Z_i)$ respectively.

This algorithm converges upon the value for Z_i for which $f(Z_i)$ is zero, provided that the first estimate $(Z_i)_n$ is a close approximation to the value sought.

At the completion of Step 2 the parameter values include those which were initially assumed, an estimate for the value of g which approximates that needed for the model to fit the data, and a set of Z_i values which is "best" given all the other parameter values. Since t is a function of g and Z_i, an "optimal" set of Z_i can be found for any value for g (and the initial values for the other parameters), and since the value found for g above is a mean value, and thus an approximation, it is reasonable to determine whether other approximations for the value of g, in the vicinity of that used above, together with the new "optimal" set of Z_i, result in a smaller sum of squares. It was found in practice that no change occurred in the sum of squares when other values for g were tested in this manner using test data, so that for use with the full data this attempt to improve the estimate for g was discarded.

While the parameter g is a theoretical rate of liveweight gain, it is to be noted that the model formulation is such that the real expected rate of liveweight gain for each line of steers is given by (L-W)/t, with t being a function of liveweight and of sale date. Some confusion occurs if this is forgotten.

Step 3. Estimation of the Parameters C, s, F, A; To this stage these four parameters are set at the initial values, and the estimates for g and the Z_i are dependent upon these initial values. In turn, these four parameters can be re-estimated using the same criterion of minimizing the total sum of squares, and the "optimal" values thus found are conditional upon the values given g and the Z_i.
The four parameters are re-estimated using the subroutine MODFIT (71), a minimizing routine using a search procedure for each parameter in turn.

Step 4. Reiteration; Steps 1, 2 , and 3 can be repeated in sequence until the rate of reduction of the sums of squares falls to a predetermined limit. Considerations of computing time led to a decision to restrict reiterations to one repetition of Step 2.

At this point in the process, a set of values has been found for five parameters g, C, s, A, F, and for the sale weights, Z_i. These values are dependent upon the initial values for the four parameters for which initial values were given, and upon the values given the parameters set constant, r and L.

It is clear that with other values for r and L the estimation process would lead to other "optimal" sets of parameter values. The coexistence of a number of sets of parameter values, all of which give a good fit to the data, is thus indicated. This was confirmed, using test data.

It is not so obvious that the "optimal" set of values is dependent upon the initial values for the four parameters, although this again was confirmed with test data. Under these circumstances the criterion for selecting the initial values is important; in practice initial values were set which, in the runs with test data, resulted in the set of Z_i giving a mean value of approximately zero. These initial values were:

$$
\begin{aligned}
C &= 13.0 \\
s &= 0.18 \\
F &= 0.037 \\
A &= 0.004 \\
\text{(constant) } r^* &= 0.0003288 \text{ p.d. (ie. 12\% p.a.)} \\
\text{(constant) } L^* &= 550
\end{aligned}
$$

The resulting set of "optimal" parameter values is thus conditional upon a number of prior decisions.

The determination of the global optimum set of parameter values is seen to require the treatment of each of the Z_i as a parameter. A simultaneous method, for instance using the Newton-Raphson algorithm, would thus require manipulation of a 55 x 55 Matrix, with considerable computational difficulty. The method used is thus a simple first approach.

A.2.3. Influence of Breed and Animal Condition.

The model structure described in para. A.2.1. incorporates no variables to represent breed and condition of the lots. The estimation process of para. A.2.2. thus is carried out to give results independently of the breed and condition of animals. In the execution of the procedure, the 1974 data was first selected to meet the needs for fitting to data from animals of a standard description. Lines excluded were firstly, those with liveweights below 150kgs, or above 500 kgs; and secondly, those which were not sold at auction (ie. passed). Of the remainder, the "standard animal" was selected after consideration of the breed and condition distribution which is shown in Table A.I.

Table A.I.

Breed and Condition Distribution (1974)

(selected data)

Breed	Lines	Condition	Lines
Angus	712		
Hereford	79		
Shorthorn	10		
Hereford x Angus	183	Fat	564
Shorthorn Cross	94	Store	467
Exotic Breeds	14	Thin	111
Friesian	24		
Dairy Breeds	5		
Mixed Beef Breeds	21		
Total	1142		1142

The "standard animal" is described as Angus, of either fat or store condition, and only observations of lines of cattle of this description are included in the parameter estimation process.

Further inspection of Table A.I. reveals the relatively small number of some breeds. Examination of the data sale by sale also discloses the uneven occurrence over time, of these breeds and of the lines of condition grading "thin". Little confidence is thus gained in the possibility of elucidating the effects of these variables upon price.

As a preliminary test, the full data for 1974 was employed in conjunction with the parameter values determined for the "standard animal" and a two-way analysis of variance performed to examine the effect of breed and of condition upon the prediction errors. The BASIS package on the Burroughs B6700 computer was utilized for this purpose, and the results indicated that while breed and condition effects were both highly significant, the interaction between them was equally important. Thus these attributes must be concluded to affect prices in a complicated manner, and the effects of each are not independent of the effects from the other. These conclusions from the 1974 data are limited, and call into question the quality of the data, but the distribution shown by Table A.I. shows also that bidders' experience of these "non-standard" lines is limited by comparison with that of Angus cattle of condition grading store or fat.

However, the conclusion that breed and condition effects are not independent of each other was not reached until after two methods of expressing the influences of breed and condition by means of the model had been completed. The first of these, using a regression equation with dummy variables (53), and resulting in adjustments to the predicted price, was found to give results which were no improvement to the unadjusted predictions from the model. The second method, using adjustment factors to the parameter g for first the breed and then the condition, yielded a significant improvement in the sums of squares. The adjustment factors were found by employing the Newton-Raphson algorithm, with the data first segregated by breed and then by condition. The adjustment factors thus found are shown in Table A.II.

Table A.II.

Apparent Values for the Parameter g, adjusted by breed and condition.

Condition Grading		1 (fat)	2 (store)	3 (thin)
Adjustment Factor for Condition		1.033	0.978	0.935
Breed	Adjustment for Breed	Final Value for g, for each combination of breed and condition		
Angus	0.983	1.015	0.961	0.919
Hereford	0.972	1.004	0.950	0.908
Shorthorn	0.926	0.957	0.906	0.866
Hereford x Angus	1.004	1.037	0.982	0.938
Shorthorn Cross	0.978	1.010	0.956	0.914
Exotic Breeds	0.998	1.031	0.975	0.933
Friesian	0.678	0.700	0.663	0.634
Dairy Breeds	0.807	0.834	0.790	0.755
Mixed Beef Breeds	0.983	1.016	0.962	0.919

The failure of these adjustment factors to reduce the model error for non-standard lines in the 1975 data is described in the text.

APPENDIX B.

B.1. The Growthmodel - representative output.

The following printouts result from the operation of the Growthmodel program on a daily basis but with the 30-day changes only shown.

Column headings are:

ME	Concentration of metabolizable energy in the ration (mcals/kg dry matter)
VI	Dry matter daily intake as a percentage of liveweight
DG	The marginal rate of daily gain (kgs/day)
ADG	The mean rate of daily gain from start (kgs/day)
LW	The level of liveweight reached (kgs)
DAYS	The cumulative duration of the feeding period (days)
FEED	The cumulative total feed consumption (kgs dry matter)
GAIN	The cumulative total gain (kgs)
CR	The conversion rate of feed dry matter to gain

BOUGHT AT200 KG--FAT

ME	VI	DG	ADG	LW	DAYS	FEED	GAIN	CR
2.5	2.42	0.778	0.500	215.0	30	130.2	15.0	8.7
2.5	2.45	0.889	0.668	240.1	60	296.1	40.1	7.4
2.5	2.47	0.984	0.759	268.3	90	483.5	68.3	7.1
2.5	2.46	1.059	0.825	299.0	120	692.7	99.0	7.0
2.5	2.36	1.071	0.874	331.0	150	919.7	131.0	7.0
2.5	2.24	1.059	0.906	363.0	180	1158.3	163.0	7.1
2.5	2.11	1.026	0.925	394.4	210	1404.5	194.4	7.2
2.5	1.96	0.972	0.935	424.3	240	1653.9	224.3	7.4
2.5	1.82	0.900	0.935	452.4	270	1902.1	252.4	7.5
2.5	1.68	0.814	0.927	478.1	300	2145.5	278.1	7.7
2.5	1.55	0.720	0.912	501.1	330	2381.5	301.1	7.9
2.5	1.43	0.625	0.892	521.2	360	2608.9	321.2	8.1
2.5	1.33	0.535	0.868	538.5	390	2827.6	338.5	8.4
2.5	1.25	0.455	0.841	553.3	420	3038.2	353.3	8.6
2.5	1.18	0.385	0.813	565.8	450	3241.9	365.8	8.9
2.5	1.13	0.330	0.784	576.5	480	3440.1	376.5	9.1
2.5	1.09	0.285	0.756	585.7	510	3633.8	385.7	9.4
2.5	1.06	0.249	0.729	593.7	540	3824.0	393.7	9.7
2.5	1.04	0.221	0.703	600.7	570	4011.7	400.7	10.0
2.5	1.02	0.198	0.678	607.0	600	4197.3	407.0	10.3
2.5	1.00	0.179	0.655	612.6	630	4381.4	412.6	10.6
2.5	0.98	0.164	0.633	617.7	660	4564.1	417.7	10.9
2.5	0.97	0.151	0.612	622.4	690	4745.9	422.4	11.2
2.5	0.96	0.140	0.593	626.8	720	4926.8	426.8	11.5
2.5	0.95	0.130	0.574	630.8	750	5107.0	430.8	11.9
2.5	0.94	0.121	0.557	634.6	780	5286.5	434.6	12.2
2.5	0.93	0.113	0.541	638.1	810	5465.4	438.1	12.5
2.5	0.93	0.105	0.525	641.3	840	5643.9	441.3	12.8

BOUGHT AT200 KG--THIN

ME	VI	DG	ADG	LW	DAYS	FEED	GAIN	CR
2.5	2.89	1.094	0.827	224.8	30	161.4	24.8	6.5
2.5	2.88	1.197	0.988	259.3	60	370.3	59.3	6.2
2.5	2.83	1.268	1.071	296.4	90	607.6	96.4	6.3
2.5	2.66	1.265	1.121	334.5	120	867.0	134.5	6.4
2.5	2.47	1.229	1.146	372.0	150	1138.3	172.0	6.6
2.5	2.27	1.165	1.155	407.9	180	1414.7	207.9	6.8
2.5	2.06	1.075	1.150	441.5	210	1689.6	241.5	7.0
2.5	1.86	0.965	1.134	472.1	240	1956.9	272.1	7.2
2.5	1.67	0.841	1.108	499.2	270	2212.7	299.2	7.4
2.5	1.51	0.715	1.075	522.4	300	2455.1	322.4	7.6
2.5	1.37	0.595	1.036	542.0	330	2684.2	342.0	7.8
2.5	1.27	0.490	0.995	558.2	360	2901.6	358.2	8.1
2.5	1.19	0.403	0.953	571.5	390	3109.2	371.5	8.4
2.5	1.13	0.334	0.911	582.5	420	3309.2	382.5	8.7
2.5	1.08	0.281	0.870	591.7	450	3503.6	391.7	8.9
2.5	1.05	0.241	0.832	599.4	480	3693.9	399.4	9.2
2.5	1.02	0.210	0.796	606.2	510	3881.1	406.2	9.6
2.5	1.00	0.187	0.763	612.1	540	4066.1	412.1	9.9
2.5	0.99	0.168	0.732	617.4	570	4249.5	417.4	10.2
2.5	0.97	0.154	0.704	622.2	600	4431.6	422.2	10.5
2.5	0.96	0.141	0.677	626.6	630	4612.7	426.6	10.8
2.5	0.95	0.131	0.653	630.7	660	4793.0	430.7	11.1
2.5	0.94	0.121	0.630	634.5	690	4972.6	434.5	11.4
2.5	0.93	0.113	0.608	638.0	720	5151.6	438.0	11.8
2.5	0.93	0.106	0.588	641.3	750	5330.0	441.3	12.1

BOUGHT AT200 KG--FAT

ME	VI	DG	ADG	LW	DAYS	FEED	GAIN	CR
2.9	2.24	1.078	0.649	219.5	30	116.5	19.5	6.0
2.9	2.16	1.135	0.879	252.8	60	271.7	52.8	5.2
2.9	2.07	1.167	0.971	287.4	90	442.4	87.4	5.1
2.9	1.97	1.175	1.021	322.6	120	626.4	122.6	5.1
2.9	1.85	1.155	1.050	357.6	150	820.6	157.6	5.2
2.9	1.73	1.109	1.064	391.6	180	1021.0	191.6	5.3
2.9	1.59	1.039	1.066	423.8	210	1223.5	223.3	5.5
2.9	1.46	0.945	1.056	453.5	240	1424.0	253.5	5.6
2.9	1.34	0.838	1.038	480.3	270	1617.6	280.3	5.8
2.9	1.23	0.726	1.012	503.7	300	1808.4	303.7	6.0
2.9	1.13	0.616	0.981	523.7	330	1989.6	323.7	6.1
2.9	1.06	0.515	0.946	540.7	360	2163.8	340.7	6.4
2.9	0.99	0.434	0.910	554.8	390	2331.8	354.8	6.6
2.9	0.95	0.365	0.873	566.8	420	2494.9	366.8	6.8
2.9	0.91	0.312	0.837	576.8	450	2654.1	376.8	7.0
2.9	0.88	0.270	0.803	585.5	480	2810.5	385.5	7.3
2.9	0.86	0.238	0.771	593.1	510	2964.7	393.1	7.5
2.9	0.85	0.213	0.740	599.9	540	3117.4	399.9	7.8
2.9	0.83	0.193	0.712	605.9	570	3268.9	405.9	8.1
2.9	0.82	0.175	0.686	611.4	600	3419.5	411.4	8.3
2.9	0.81	0.162	0.661	616.5	630	3569.3	416.5	8.6
2.9	0.80	0.150	0.638	621.2	660	3718.5	421.2	8.8
2.9	0.79	0.140	0.617	625.5	690	3867.2	425.5	9.1
2.9	0.78	0.130	0.597	629.6	720	4015.4	429.6	9.3
2.9	0.78	0.121	0.578	633.3	750	4163.2	433.3	9.6
2.9	0.77	0.114	0.560	636.8	780	4310.6	436.8	9.9
2.9	0.77	0.105	0.543	640.1	810	4457.7	440.1	10.1

BOUGHT AT200 KG--THIN

ME	VI	DG	ADG	LW	DAYS	FEED	GAIN	CR
2.9	2.64	1.393	0.994	229.8	30	143.7	29.8	4.8
2.9	2.48	1.425	1.203	272.2	60	335.8	72.2	4.7
2.9	2.31	1.420	1.277	315.0	90	545.7	115.0	4.7
2.9	2.12	1.379	1.309	357.0	120	768.0	157.0	4.9
2.9	1.92	1.302	1.315	397.3	150	995.9	197.3	5.0
2.9	1.72	1.191	1.304	434.7	180	1222.6	234.7	5.2
2.9	1.53	1.054	1.278	468.4	210	1442.2	268.4	5.4
2.9	1.36	0.901	1.240	497.6	240	1650.9	297.6	5.5
2.9	1.22	0.747	1.194	522.3	270	1847.3	322.3	5.7
2.9	1.10	0.605	1.141	542.4	300	2031.8	342.4	5.9
2.9	1.02	0.486	1.087	558.7	330	2206.5	358.7	6.2
2.9	0.96	0.392	1.033	571.7	360	2373.3	371.7	6.4
2.9	0.91	0.321	0.980	582.4	390	2534.6	382.4	6.6
2.9	0.88	0.269	0.931	591.1	420	2691.8	391.1	6.9
2.9	0.85	0.232	0.886	598.6	450	2846.2	398.6	7.1
2.9	0.84	0.204	0.844	605.1	480	2998.7	405.1	7.4
2.9	0.82	0.183	0.806	610.9	510	3149.9	410.9	7.7
2.9	0.81	0.166	0.771	616.1	540	3300.0	416.1	7.9
2.9	0.80	0.152	0.738	620.8	570	3449.4	420.8	8.2
2.9	0.79	0.141	0.709	625.2	600	3598.2	425.2	8.5
2.9	0.78	0.131	0.681	629.3	630	3746.5	429.3	8.7
2.9	0.78	0.122	0.656	633.1	660	3894.3	433.1	9.0
2.9	0.77	0.114	0.633	636.6	690	4041.8	436.6	9.3
2.9	0.77	0.107	0.611	639.9	720	4188.9	439.9	9.5
2.9	0.76	0.100	0.591	643.0	750	4335.7	443.0	9.8

B.2. Least-cost Rations - Representative Computer Output.

(a) With 2.5 mcals M.E./kg dry matter.

B6700/7700 TEMPO
VERSION: 26.400.000

MASSEY UNIVERSITY
FEEDCOST

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COLUMNS SECTION

NUMBER	NAME	STATUS	ACTIVITY	INPUT COST	LOWER LIMIT	UPPER LIMIT	REDUCED COST
49	GSHQA	BS	23.44792	3.60000	.	NONE	.
50	GSLQB	LL	.	3.60000	.	NONE	0.93020
51	WCESC	BS	41.55208	3.46000	.	NONE	.
52	LSILD	LL	.	4.86000	.	NONE	2.25706
53	MSILE	LL	.	4.78000	.	NONE	0.99784
54	LHAYF	BS	1.77833	5.90000	.	NONE	.
55	LHAYG	LL	.	5.40000	.	NONE	0.10646
56	GHAYH	LL	.	6.40000	.	NONE	0.52551
57	GHAYI	LL	.	6.[illegible]0000	.	NONE	[illegible].04132
58	MOLAJ	LL	.	20.00000	.	NONE	13.04666
59	OLUCK	LL	.	15.50000	.	NONE	9.68378
60	BSTRL	BS	23.29451	3.60000	.	NONE	.
61	BSTRM	LL	.	3.50000	.	NONE	0.72831
62	WSTRN	LL	.	3.50000	.	NONE	0.97148
63	RSTRO	LL	.	4.70000	.	NONE	1.50260
64	BARLP	LL	.	10.80000	.	NONE	1.94933
65	MAIZQ	LL	.	11.10000	.	NONE	1.67258
66	WHEAR	LL	.	12.60000	.	NONE	3.18117
67	LUPIS	LL	.	18.00000	.	NONE	6.54705
68	MEATT	LL	.	20.20000	.	NONE	9.68077
69	MZTSU	LL	.	4.41000	.	NONE	0.88928
70	HIENV	LL	.	20.00000	.	NONE	0.38141
71	UREAW	LL	.	24.40000	.	NONE	9.48397
72	RAPEX	BS	8.92716	16.70000	.	NONE	.
73	SOYMY	LL	.	20.00000	.	NONE	7.60875
74	SUPPZ	BS	1.00000	6.00000	.	NONE	.

(b) With 2.9 mcals M.E./kg dry matter.

COLUMNS SECTION

NUMBER	NAME	STATUS	ACTIVITY	INPUT COST	LOWER LIMIT	UPPER LIMIT	REDUCED COST
49	GSHQA	BS	48.97337	3.80000	.	NONE	.
50	GSLQB	LL	.	3.60000	.	NONE	1.02657
51	WCESC	BS	3.39497	3.48000	.	NONE	.
52	LSILD	LL	.	4.56000	.	NONE	3.05648
53	MSILE	BS	12.63166	4.78000	.	NONE	.
54	LHAYF	LL	.	5.90000	.	NONE	0.58982
55	LHAYG	LL	.	5.40000	.	NONE	0.37768
56	GHAYH	LL	.	6.40000	.	NONE	0.60544
57	GHAYI	LL	.	6.00000	.	NONE	2.24380
58	MOLAJ	LL	.	20.00000	.	NONE	12.82702
59	DLUCK	LL	.	15.50000	.	NONE	10.51890
60	BSTRL	BS	2.68639	3.60000	.	NONE	.
61	BSTRM	LL	.	3.50000	.	NONE	0.53911
62	WSTRN	LL	.	3.50000	.	NONE	0.78210
63	RSTRO	LL	.	4.70000	.	NONE	1.19181
64	BARLP	LL	.	10.80000	.	NONE	0.46954
65	MAIZQ	BS	16.31361	11.10000	.	NONE	.
66	WHEAR	LL	.	12.60000	.	NONE	1.45645
67	LUPIS	LL	.	18.00000	.	NONE	7.27562
68	MEATT	LL	.	20.20000	.	NONE	13.03881
69	MZTSU	LL	.	4.41000	.	NONE	0.37087
70	HIENV	LL	.	20.00000	.	NONE	0.40993
71	UREAW	LL	.	24.40000	.	NONE	33.78176
72	RAPEX	BS	15.00000	16.70000	.	NONE	.
73	SOYMY	LL	.	20.00000	.	NONE	8.88708
74	SUPPZ	BS	1.00000	6.00000	.	NONE	.

APPENDIX C.

The Search for Optimal Feeding Strategies

Where choice of feeding duration is unconstrained by prior decisions relating to slaughter weight or to feeding duration itself, the indentification of optimal strategies which maximize the objective function (Z = discounted nett present value) requires information on the shape of the response surface Z. For convenience this surface can be considered in each of its dimensions (t, duration; E, ration energy density) separately.

1. The shape of Z(t) given E.

$Z(t)=W(v+kW)Pe^{-rt} - RX$ where: $W = W(t)$, the liveweight at time t days;

$X = X(t)$, the total feed consumed to the tth day;

P = the expected beef price

R = the unit cost of feed;

r = the daily interest rate;

v, k constants which relate carcase yield to liveweight.

Now, X, W, and t are physically interdependent so that for a given value for one, the values for the other two are uniquely determined. Hence stationary points on the curve Z(t) are characterized by

$$0 = dZ/dt = dZ/dX = dZ/dW$$

In each case this condition reduces to:

$$W^* = (A/r - v/2k) \pm (A^2/r^2 + v^2/4k^2 - BG/rk)^{\frac{1}{2}}$$

where $A = dW/dt$

$B = dX/dt$

$G = Re^{rt}/P$

In order for both roots to be real, the value of the expression inside the second pair of brackets must be positive. This condition is met when the value of A, (ie. dW/dt), exceeds a minimum which depends upon the values taken by the other parameters. With feasible values for these it can be shown that this minimum is at the lower end of the range of expected rates of gain. Given this condition, Z = f(t) has two stationary points, a minimum and a maximum, and the curve is sigmoid. Now as t increases, W approaches a maximum (the mature weight), e^{-rt} approaches zero, and X increases continuously. Hence when t is very large, Z(t) is very small, and the curve Z = f(t) falls to the right. The "effective" segment of the curve depends upon the state at t = 0.

In any specific case relating to a prospective entry for feeding the position of each axis is unknown. For the Z axis (t = 0), three possible positions can be envisaged, and these represent the alternative possibilities: (see Figure C.1)

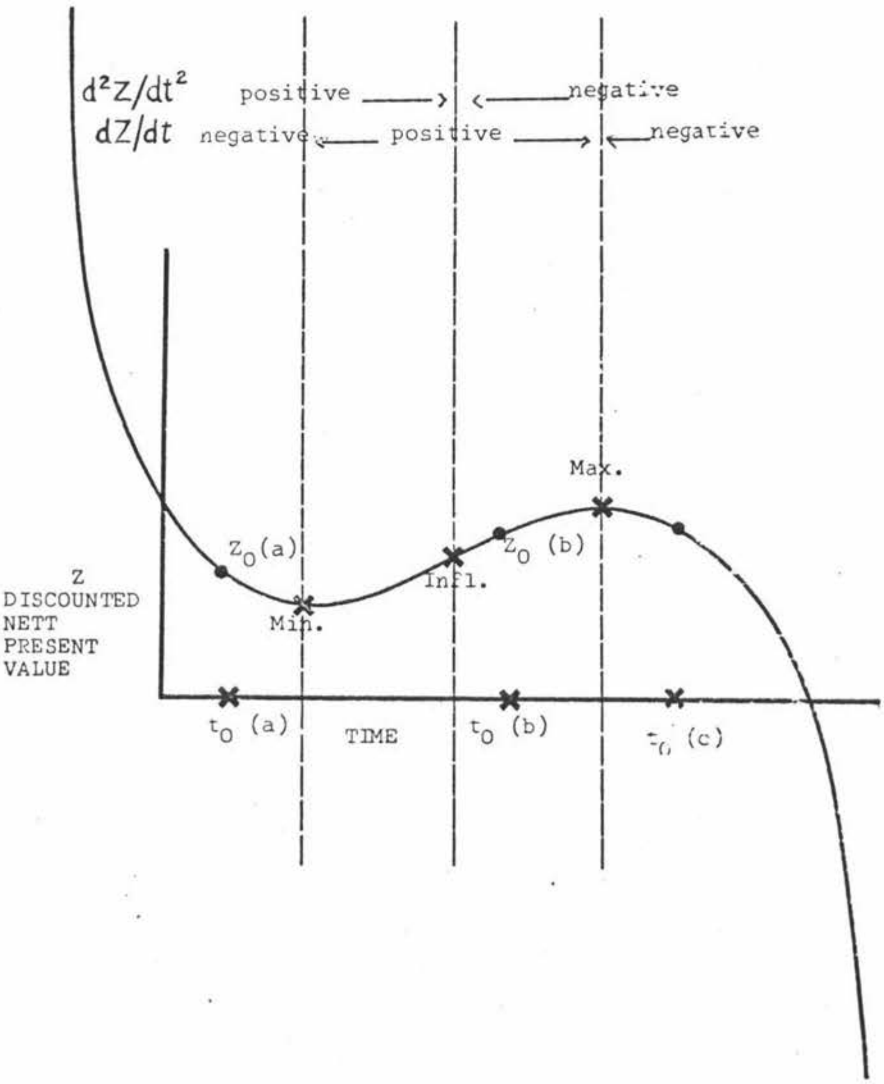
(a) t_0 lies to the left of the local minimum, (min.); Since dZ/dt is negative, $Z(t_0)$ represents a local maximum, but since d^2Z/dt^2 is positive the existence of the subsequent maximum (max.) is known. Computation will therefore continue until this maximum is reached (identified by dZ/dt = 0 and d^2Z/dt^2 negative). The global maximum will be the greater of $Z(t_0)$ and Z (max.).

FIGURE C.1.

The Feedlot Response Surface - Diagramatic

A Section through the surface at a constant Ration energy concentration showing the alternative positions of t_o

(see text)



(b) t_0 lies between min. and max. Since as t increases, Z(t) will increase, the maximum will be reached at max. (identified as above) and will be the global maximum.

(c) t_0 lies to the right of max. Since as t increases dZ/dt is negative and d^2Z/dt^2 is also negative, the value for $Z(t_0)$ is the global maximum.

Consequently, for each level of ration energy concentration, the duration of feeding can be found which yields a maximum value for the objective function and which is unique for the steer in question.

2. The shape of $Z(E_{max})$, the locus of maxima from the successive ration energy concentration levels.

From the foregoing it is evident that $Z(E_{max})$ need not be a smooth continuous locus, since case a. may rule at one energy level, case b. at the next, and case c. at a third. This situation would give large steps between t* and W* at successive energy concentration levels, although not necessarily large steps in the value for Z(max). Hence, while there are no grounds to suppose that the response surface is other than continuous, there are no grounds also to expect simple analytical methods successfully to enumerate or locate the global maximum or a series of local maxima, even were the functional form of Z(E) completely known for each candidate steer.

So, although at each energy density level the optimal feeding duration can be identified with certainty for a given steer, a simple search procedure to identify the energy density which gives the maximum maximum cannot be found. There is one exception - if only one maximum exists with no local maxima - a numerical procedure will identify the maximum as that point which is succeeded by a lower maximum on the next energy density. That such a point is indeed the global maximum can be proved only by a repetition of the search with the starting point at the other end of the energy range. Complete enumeration of $Z(E_{max})$ is hence required even in the simple case where an unambiguous global maximum is thought to exist.

Note: Operation of the programme invariably revealed the uniqueness of the solution and the absence of discontinuities in the shape of $Z(E_{max})$, and search from one end of the energy range proved sufficient to identify the global maximum. This does not, of course, prove that the global maximum is always unambiguous.

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