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THE UNIVERSITY OF ALBERTA

An Evaluation of Beef Production Alternatives in Atlantic Canada

by

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Rollin George Andrew

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled An Evaluation of Beef Production Alternatives in Atlantic Canada submitted by Rollin George Andrew in partial fulfilment of the requirements for the degree of Master of Science in Agricultural Economics.

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Supervisor

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Date 28.04.87

Dedication

I would like to dedicate this thesis to my wife, Joan and daughters, Katie and Kristy.

Abstract

This thesis is directed towards two related research objectives: to develop a decision-making framework for evaluation of the economic returns from alternative beef finishing systems in Atlantic Canada; and to develop a price forecasting mechanism for slaughter and feeder cattle that can be used in the beef finishing decision model.

A multi-period decision model is used to provide estimates of returns from beef finishing alternatives based on beef feeding trials conducted in the region by Agriculture Canada. Beef feedlot marketing and replacement decisions based on forecasted prices, using futures market estimates, are compared to returns from predetemined fixed marketing and replacement strategies.

The analysis revealed a significant difference among the estimated gross margins of the several beef finishing alternatives. Economic analysis also revealed the potential benefits to beef producers from basing marketing and replacement decisions on a decision model with an appropriately defined price forecasting procedure. Multi-period decisions models of this type can serve as a useful management decision aid to beef producers.

Several recommendations for future research and extension activities arise from this research. First, multi-period decision model could be used more extensively to model livestock production processes. This expansion in use will require close cooperation between physical scientists and economists in model development and in the interpretation of livestock data. Second, price forecasting techniques based on futures market information for beef cattle, appear to provide a practical and relatively inexpensive method to forecast subsequent cash prices for beef cattle. Finally, agricultural decision models of this type should describe the production system under consideration in realistic and accurate terms, if livestock producers and agriculture extension workers are to benefit from research of this type.

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I. Introduction

A. Background

The beef industry is a small but important part of agriculture in Atlantic Canada. In the ten year period 1974 to 1983, the beef industry accounted for 11 percent to 14 percent of the annual total farm cash receipts in the provinces of New Brunswick[1], Nova Scotia [2] and Prince Edward Island[3]. In recent years, beef production has been viewed as an area in agriculture that could expanded in the region. Traditionally beef production systems in the region have relied primarily on the use of forages with some limited grain feeding. This reliance has been due mainly to the high cost of feed grains in the region relative to other areas in Canada. These extensive types of beef production lead to many cattle not being marketed till 24 to 30 months of age. During the late 1970's and early 1980's, these types of production systems were at a disadvantage due to high interest rates and low market returns.

Few full-time producers in the region are primarily engaged in beef production and within the industry, the cow-calf sector remains relatively small. The majority of beef production is from dairy or dairy-cross animals. This factor in combination with extensive production systems, has had a major impact in producing carcass grades that are well below the national average.[4] The level of price differentiation between A, B and C carcass grades has drastically lowered the returns of the region's beef producers.

The Atlantic region currently produces about 60 percent of its livestock feed grain requirements. The major cereal crop is mixed grain (oats and barley), with a recent expansion in barley production for use in hog rations. Virtually all the locally produced feed grain for sale is a product of Prince Edward Island and New Brunswick potato rotations and is generally of lower quality than western feed grains. Farm prices for locally produced feed

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[1] *New Brunswick Agricultural Statistics*(1985)
[2] *Nova Scotia Agricultural Statistics*(1984)
[3] *Prince Edward Island Agricultural Statistics*(1984)
[4] *P.E.I. Agricultural Statistics*(1984) indicate that in 1983, 46 percent of cattle slaughtered in the region graded A1 or A2; as compared to the national average of 74 percent in the same carcass grades.

grains usually reflect the western feed grain price plus feed freight assistance. In the past this pricing mechanism has been detrimental to the expansion of regional grain production because of higher regional production costs.

The majority of larger feedlots in the region (200 or more head per year) use cull potatoes and potato processing waste as a major feed source. Recently the use of potato by-products has been viewed as a means to expand beef production in the region due to their relatively low costs in relation to other feeds. Nicholson(1983) estimated that feedlot beef production utilizing potato by-products could be tripled to 50,000 head per year from present levels, even though there are several possible disadvantages from feeding potato by-products.[5]

The Atlantic Region has a definite potential for expanded forage production. The region is very similar climatically to many of the intensive forage production areas of Europe. A number of European forage production systems are currently being evaluated in the region.[6] Hickey(1982), an Irish researcher, has estimated that dairy steers can be marketed at 14 to 16 months of age in a weight range of 900 to 1100 pounds on a ration consisting primarily of forages.

Marketing of locally produced beef has historically been a problem within the region. In the past, local processors have been faced with the problems of low carcass quality, instability of supply, and high processing costs caused by inefficient and antiquated plants. This market void has traditionally been filled by imported beef from western and central Canada. In recent years, major processing plant expansions in the region have improved the competitiveness of the local processing industy and expanded the market potential for local beef production.[7]

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[5] These include variability in cullage rates per year, seasonal variation in supply, storage requirements, the threat of disease transmission between farms, and unavailability of culls in many areas.

[6] These systems offer advantages in terms of reduced time required for conservation, reduced weather losses, increased labour efficiency, and reduced costs per unit of energy conserved; when compared to many conventional North American systems.

[7] These plants will handle locally produced beef on the condition that it is comparable in terms of quality with imported carcasses.

Nicholson(1984) has recently evaluated, through livestock research trials, some of the more common beef production systems followed in the region. The results of these trials have provided valuable information on weight gains and feed efficiency for a range of intensive and extensive management systems. Since the early 1970's there have also been several economic studies of beef production in the region, including the development of an extensive simulation model by Lovering and Treat(1979). However, in the past it has been very difficult to disseminate this type of information to the beef industry. Beef producers and extension workers find the results of computer simulation models more acceptable if they are based on actual livestock research trials conducted in the region.

In the Atlantic Region there has been little research devoted to the development of decision models that incorporate technical, physical, and economic data on beef production systems with multi-period input and output price forecasting.[8]

B. Problem Definition

A major problem facing beef producers in Atlantic Canada is that they have a wide range of beef production systems to chose from, but a scarcity of reliable economic information on which to evaluate these beef production alternatives. Producers are reluctant to make the necessary investment decisions to improve the efficiency of their operations, without adequate information on which to base these decisions. This has severly restricted the growth of the beef industry in the region; and caused a serious misallocation of resources to occur when producers have invested in a particular production system that did not fit their management level and resource base.

Producers lack information on the economic implications of alternative production systems and their performance under local conditions. In addition, producers lack decision aids that can be used to determine when to market slaughter cattle and purchase replacement feeder cattle. Presently, many producers make these decisions based on rigid criteria such as

[8] The previous economic evaluations of beef production systems have been based on only one production period (one year or less) and the resulting conclusions have been very dependent on narrowly defined ranges of input and output prices.

predetermined slaughter weight levels and seasonality of production. The timing of marketing and replacement decisions has a major effect on the cash flow and viability of the feedlot enterprise because current production decisions affect decisions in subsequent production periods. This is similar to many of the classical asset replacement problems of production and resource economics.

The problem can be defined as a misallocation of resources caused by a lack of research on the economic implications of alternative beef production systems when evaluated within a multi-period decision-making framework to determine optimal marketing and replacement patterns. The solution to this problem would benefit the following groups:

1. Beef producers who want to increase their net farm incomes; and
2. Producers in other agricultural commodities, particularly potato and dairy producers, who are seeking production alternatives.

The two research hypotheses that will be evaluated in this thesis are:

There is a significant difference in the gross margins of alternative beef finishing systems in Atlantic Canada.

and

Atlantic Canada beef producers who follow a fixed marketing and replacement strategy could increase their returns by following a marketing and replacement decision strategy based on forecasted prices.

C. Objectives

The primary objective of this research is to determine the economic benefits which might accrue to Atlantic Canada beef producers through improved feeding, marketing and replacement strategies. The two stated research hypotheses will be tested through the following procedure:

1. The evaluation of recent research data that are available on beef production systems in Atlantic Canada within an appropriate multi-period economic decision-making framework.

2. The development of a multi-period decision model of a typical feedlot operation in the region that incorporates price forecasting techniques for feeder cattle and slaughter cattle. This would more accurately simulate the actual decision process of feedlot operators in the region. Beef producers would benefit from increased market returns as a result of following the most profitable production strategy, while optimizing subsequent marketing and replacement decisions.

D. Outline of the Thesis

The remainder of the thesis will proceed in the following stages:

Chapter II. - The infuence of time in the production process will be examined. This will include a discussion of general theoretical considerations, the influence of time in livestock production, and asset replacement principles in relation to agriculture.

Chapter III. - The optimal decision process through time will be examined. This will include a discussion of theoretical considerations, dynamic and linear programming models, and the modelling of beef production systems.

Chapter IV. - The formation of price expectations will be evaluated. This will include a discussion of theoretical considerations, rational price expectations theory, price forecasting techniques, and the futures market for agricultural commodities.

Chapter V. - This chapter will outline the research methodology that was used in this study. This will include a discription of the beef finishing model used in the study, the price forecasting procedure followed, and the method of evaluation to be used.

Chapter VI. - In this chapter the data base that is used in this study will be outlined. This will include the sources of physical and economic data, and the discount rate rate chosen.

Chapter VII. - This chapter will include the analysis and discussion of the results of study.

Chapter VIII. - This chapter will include a summary of the study, conclusions, recommendations and needs for further research.

II. The Influence of Time in the Production Process

A. General Theory

Time is an important component of many production processes. A production process can be viewed as a flow through time, either within a production period or over a series of production periods. Dillon(1977) states that time can influence livestock and crop response functions in the following ways:

1. The contribution of fixed inputs may vary with the time length of the response process so that time directly influences response;
2. The capacity of the set of fixed inputs to accomodate variable inputs may be a function of time and of the mix of variable inputs made available;
3. The time sequence of input injection or output harvesting may influence yields and returns; and
4. There may be input carry-over effects from one production period to another, if the injection of variable inputs within one production period is not completely utilized.

Time effects are particularly important in agriculture due to the volatile nature of input and output prices for many commodities. The time preference or time value of money is also important, when one views present versus future consumption preferences.[9]

Many livestock and crop production systems can be considered as on-going or continuous production processes, rather than as a single production period. The basic principle of profit maximization over a series of production processes becomes one of attempting to maximize profit per unit of time, rather than in any one particular production period. Maximization of total profit from an enterprise does not yield the same solution as the criterion requiring maximization of profit per unit of time. Dillon(1977) states that if profit maximization is to be acheived in the absense of time preference, then the marginal profit per unit of time must equal the average profit per unit of time over the series of production

[9] Doll and Orazam(1984) state that these time influences consist of: the timliness of input application, the optimal length of the production period, cost and revenue flows over time, the time preference of money, and the flow of profit over time.

processes. The maximization of profit in a sequence of response periods requires that each response period should be shorter than if the response period was only carried through once. This principle is illustrated graphically in Figure II.I. If one analyses a single response period, the profit maximizing input level would occur on day 131 (Figure II.I.), where total profit is a maximum. If, however, the production process consists of a sequence of response processes; profit maximization over time would occur on day 112. The logic of this is that as inputs are used beyond day 112, the marginal profit per unit of time is less than the maximun average profit per unit of time that could be obtained by using the input in the next response period.

The net effect of including time in the production function is to increase the level of marginal costs by the opportunity cost of the input over time. This example indicates the effect that the length of a particular production period has on profit maximization in subsequent production periods.

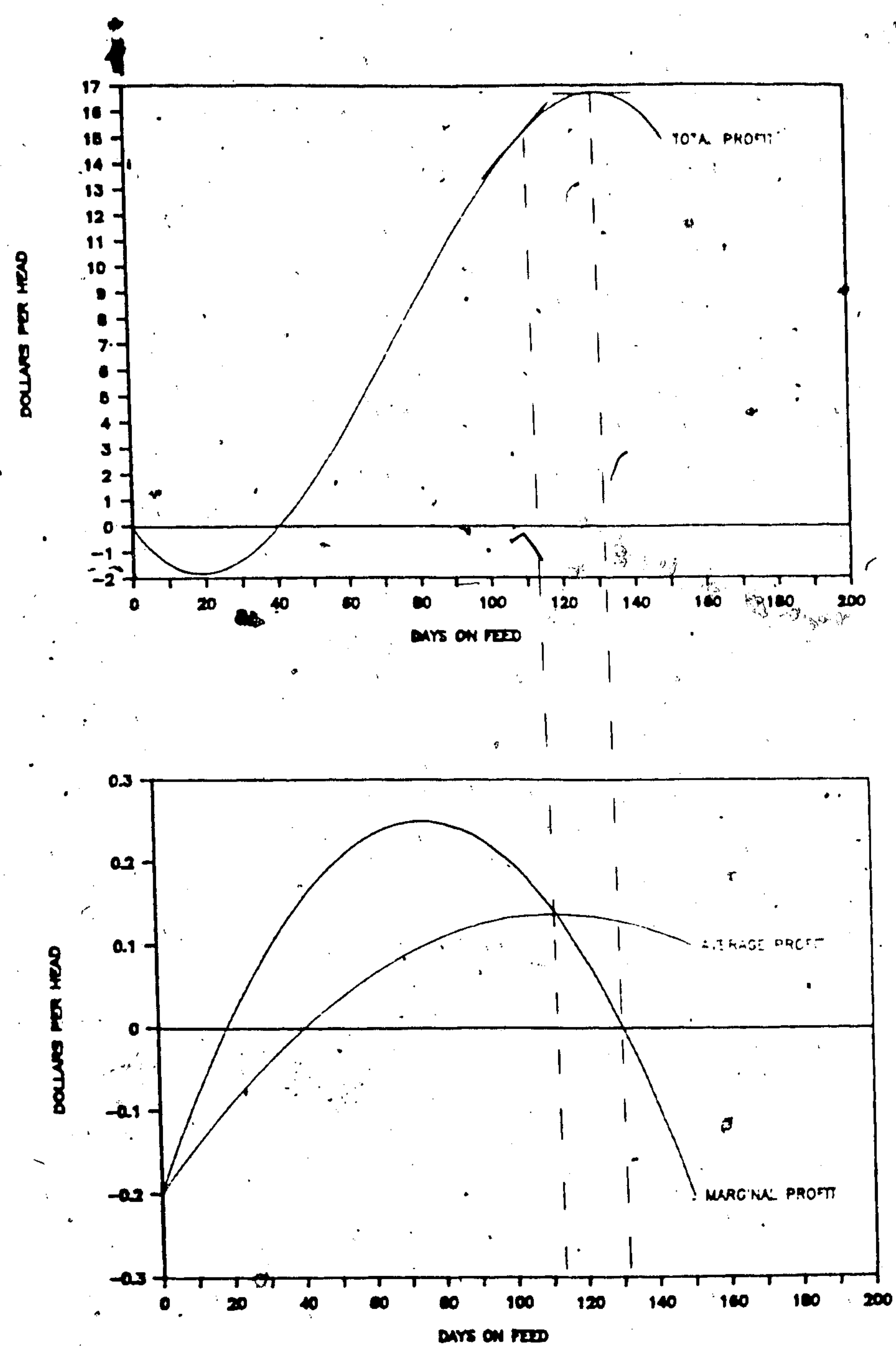
The opportunity costs associated with time are often ignored in the analysis of time dependent livestock response processes. Analysis is often based on a one lot or one cycle basis, with no reference to the effect on subsequent response periods. Livestock production typically involves a continuous sequence of response periods. Optimal operating conditions in livestock production require a choice of the length of each response period, as well as a choice of optimum input allocation.

In beef production, under feedlot conditions, time influences the production process through:

1. The type of feedlot system chosen, whether it is intensive or extensive;[10]
2. The multi-stage nature of the overall production process in terms of animal growth stages and ration formulation; and
3. The interdependence of production stages, since the growth in and length of a particular stage affects response in the following production periods.

[10] An extensive system is defined as one based on a low energy ration and aimed at acheiving a relatively low rate of average daily gain. An intensive system, on the other hand, is based on a high energy ration and is aimed at acheiving a relatively high rate of average daily gain.

Figure II.1: Total, Marginal, and Average Profit of Time Resulting from the Feeder Enterprise.



Heady(1983) mathematically expressed the effect of time on livestock production systems as:

$$Y = f(Fc, T, A)$$

- where:
  Y = rate of gain per animal per unit of time
  Fc = rate of feed consumption per unit of time
  T = the length of the production period
  A = variable inputs in the production process.

The relationship specified in this formula is equivalent to attempting to maximize output by applying animal units, feed and other productive inputs to a fixed period of time.

The type of optimizing procedure that the the livestock producer choses will be determined by his individual goals or objectives. These usually involve such criteria as minimization of feeding cost per head per day, maximization of return per head per day, minimization of feeding cost per head over time, and maximization of return per head over time. If producers wish to maximize revenue over a specific time horizon, then production functions can be used to determine the optimal feeding time and rations. Returns would then be maximized over the specified time period, rather than on a one lot basis.[11] On the other hand, producers may wish to minimize feeding time to take advantage of improved cattle prices or lower feed prices in future time periods. The choice of a particular production system is very dependent on future expectations of input and output market conditions. The volatile nature of livestock input and output markets complicates these marketing and replacement decisions over time.

The timing of current marketing and replacement decisions has a critical effect on the subsequent decisions that will be made in future time periods. This is due to the continuous nature of the decision process of many livestock enterprises that operate on an on-going basis. The solution to a replacement problem of this type is generally referred to under the heading of "asset replacement theory".

[11] The length of the time period chosen will depend on the reliability and availability of information on input and output market conditions.

B. Asset Replacement Principles

Relation to Agriculture

The analysis of the influence of time on a particular agricultural productive process, can be viewed as an asset replacement problem. The basis of the asset replacement decision process is that a decision has to be made as to when some element of a particular productive process should be replaced. The basic profit maximization principle requires that response in the present period of the production process should be harvested when per unit of time its marginal net revenue is equal to the maximun net revenue expected in the next response period. Perrin(1972) states the asset replacement principle as:

> To compare gains from keeping the current asset for another time interval with the opportunity gains which could be realized from a replacement asset during the next period. (p.69)

Traditionally, literature on asset replacement in agriculture and forestry has dealt with relatively durable assets such as farm machinery and forest stands.[12] A classic example of asset replacement occurs in forest stand management. In this example a forest should be left to grow another year, if the additional net returns are greater than the average annual returns from a new stand. The basic principles of asset replacement can however, be applied to less durable assets such as livestock. Two early studies of this type were Trant and Winder(1961) - broiler production and Smith(1973) - dairy herd replacement. The number of production cycles under consideration has a major impact on the timing of replacement decisions of this type due to the interrelationships between production cycles.[13] A beef feedlot system can be viewed as a continuous time replacement model of on-going beef production. The feedlot manager would wish to maximize the present value of the entire stream of future benefits (residual earnings) from the production process associated with the asset (feedlot) over time.

[12] Early studies in this field include Faris(1960), Burt(1963,1965), Chisholm(1966), and Perrin(1972).

[13] Perrin(1972) states that the consideration of earnings from the second and subsequent asset levels leads to an earlier replacement age, than if only one cycle were considered.

This is equivalent to the maximization of returns on a per head of feedlot capacity basis over time. In order to accomplish this goal, the feedlot manager must be able to form expectations of future levels of returns and be able to compare these returns on an equitable basis.

Choice of a Discount Rate

The relative value of future versus present earnings is reflected in the choice of a discount rate. The asset replacement decision will thus depend on: the stream of expected future earnings, changes in asset value over time,[14] and the discount rate chosen. The choice of a discount rate is critically important in the formulation of any asset replacement problem, since the market value of an asset of any age will equal the discounted value of its remaining net earnings. The higher the discount rate, the less valuable are expected earnings in future time periods in relation to present time periods. Normally, the choice of a discount rate will be based on one or more of the following criteria:

A. The Cost Of Capital Approach

The cost of capital approach is based on the cost of investment capital to the firm. In it's simplest interpretation this refers to established interest rates for short, medium and long term loans.[15] This method, while being easy to calculate, distorts the reality of investment opportunities available to the firm.[16] Perrin(1972) rejected the cost of capital approach because he felt that it was only valid if an individual faces perfect capital markets with no time preference for earnings. In reality this type of scenario rarely exists.

B. Preferences in the Timing of Personal Consumption

The individual's time preference for money has a large affect on the choice of a discount rate, since it equates present versus future consumption preferences. The time preference effect for money is usually determined by one of the following methods:

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[14] In the beef feedlot replacement problem, since beef cattle are the replacement asset, this can be viewed as changes in feeder cattle prices.

[15] Gray and Furtan(1983) used a discount rate based on the current savings interest rate.

[16] Dillon(1977) states that in a world of certainty, the interest rate used should be the maximun rate of return obtainable from using the input (ie. capital).

1. Compounding present costs or discounting future returns to make them comparable in terms of time. In many cases the discount factor that is used is based on the historical inflation rate over the time period under consideration. This type of approach does not account for the riskiness of enterprise.
2. Discounting future profits by a predetermined risk factor. In this case an estimate is established of the expected risk of an enterprise as well as the individual's attitude toward risk.[17] An appropriate discount rate is then selected based on these two criteria.
3. The use of an accrual formula to convert lump sum earnings over time.

The use of these types of approaches results in the selection of a particular production system or strategy with the highest internal rate of return over time. This selection criteria however, is highly biased by personal preferences with minimal reference to actual capital market conditions. Perrin(1972) rejected this approach on the basis that if the internal rate of return were above the market rate for ventures of similar risk, then market forces would react on the market price until the rate fell to approximate the market rate. This is similar to changes in the market value of tradeable shares on a stock market in reaction to changing market conditions. The value of a particular company's shares will be determined by the company's expected rate of return and risk, in relation to the expected level of return in the market as a whole.[18]

C. Market Rate of Return on Investments of Similar Risk

This approach is based on analyzing the rates of return of other investment opportunities of similar risk. The appropriate rate of return (discount rate) for an individual firm is equal to a base or riskless rate, and a risk premium based on the preceived degree of risk of the firm in relation to the market.[19] While discount rates can be calculated for individual enterprises, the value that is most often used is the rate of return on a particular

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[17] The individual may be either risk averse, risk neutral or a risk preferrer.
[18] A more indepth explanation of this approach termed the "capital asset pricing model" theory can be found in Brigham and Grapenski(1985).
[19] The base rate that is normally used is based on market securities with low preceived levels of risk (ie. government bonds).

stock market portfolio.[20] The major benefit of using the market rate of return approach is that it reflects actual investment opportunities that are available, while also accounting for the riskiness of future returns. Historically, in much of the agricultural economics literature, risk has been treated as some function of market price; while virtually ignoring actual rates of return in the marketplace.

The majority of recent literature on asset replacement in agriculture and forestry have been based on the market rate of return approach.[21] Most authors in the field agree that:

1. Direct calculation of present values are a more appropriate and accurate evaluation technique than previous marginal criteria;
2. The time dimension and its specification is important in the optimal replacement solution; and
3. The choice of discount rate has a major effect on the actual replacement decision.

Recent studies have refined existing asset replacement literature to include such considerations as tax policies and investment incentives.[22]

The actual choice of a discount rate is very dependent on the type of analysis being performed. If the analysis is based on historical data, then the discount rate can be easily determined by analyzing financial markets during the period. If the analysis is based on determining expected returns in some future periods, then the discount rate should account for the level of risk and uncertainty associated with these returns. In studies of this type, the market rate of return on alternative investments or a similar risk discount scalar is usually used. The discount rate that is chosen when analyzing beef production alternatives over a specific future time horizon, should accurately reflect the high level of risk inherent in these systems. The two most appropriate methods of accurately accounting for this risk are:

1. A risk discount scalar that accounts for the individual risk of the enterprise based on the

[20] In Canada, the rate of return of the Toronto Stock Exchange(T.S.E.) composite index is commonly used in this type of analysis.

[21] These studies include Perrin(1972), Chisholm(1974), Samuelson(1976), and Dillon(1977).

[22] These include: Chiang(1982), tax policies; Melichar(1979), assets as growth stocks; McConnell(1982), imperfect capital markets, and Nautiyal(1984), inflation effects.

standard deviation of expected returns.[23]

2. The market rate of return on alternative investments of similar risk.

The choice of an appropriate discount rate for beef finishing (feedlot) operations will be based on one of these two methods. The actual method that is chosen however, will depend on whether or not accurate data is available on the historical levels of return and risk of the beef finishing operation.

[23] In a Canadian study of this type, Driver and Stackhouse(1976) used a risk discount scalar based on the standard deviation of expected gross margins.

III. The Optimal Decision Process Through Time

A. General Theory

Mathematically the problem of determining the optimal or best operating decisions over a period of time can be approached through:

1. Differential Calculus - whereby the overall problem is considered as a continuous problem of several variables, and
2. Dynamic Programming - whereby the overall problem is considered as a series of recursively related problems with each involving the same variables.

While these two approaches yield basically the same results, dynamic programming better approximates the actual decision process that an individual is faced with over time. Johnston(1964) states:

> There seems to be a natural correspondence between the dynamic programming framework and the context in which real decisions are made. We normally think of the decision maker as making decisions at various points of time, where the present position is known and estimates are made on a continuing basis of crucial parameters governing their future positions.(p.540)

The main advantage of dynamic programming is that it offers a computer oriented approach to maximization over a time horizon, while offering more flexibility than linear programming approaches.[24] The calculus approach, on the other hand, rests on the existence of mathematical functional relationships between variables with the possibility of continuous substitution. This technique, while mathematically powerful, has difficulties with multi-stage maximization problems and often breaks down if functional relationships are linear. This procedure also requires the specification of exact functional forms, while neglecting the topic of uncertainty in future outcomes.

[24] An indepth comparison of the difference between dynamic and linear programming can be found in Kislev(1968).

B. Dynamic Programming

Theory

Dynamic programming is a basic mathematical technique that is useful in making a sequence of interrelated decisions over time. Richard Bellman is generally considered to have been the pioneer of dynamic programming techniques.[25] Originally, dynamic programming techniques were applied to inventory control problems and used in determining least cost transportation routes. The techniques were later applied to production processes to maximize returns over a specified time frame. Bellman felt that the basic purpose of dynamic programming in formulating many of the mathematical models of the universe was not so much to calculate numbers as to determine the structure of the actual decision process. Dynamic programming thus allows one to not only formulate optimal decision policies, but also to examine how these decisions are made.

The term "dynamic" indicates that one is interested in processes in which time plays a significant role and in which the order of decisions may be crucial. Multi-stage decision processes of this type are characterized by the task of finding a sequence of decisions which maximizes or minimizes an appropriately defined objective function. These processes involve dynamic systems where the inputs are a sequence of decisions. These decisions are made at various stages in the evolution of the process. The decision process can be divided into a series of time periods or stages, thus attempting to match the reality of the actual decision process facing the individual. The decision of the individual at each stage is influenced by the existing state of the system, the options or alternative choices available; and the consequences, to the individual, of the resulting state from each decision taken. The basic characteristics of the dynamic programming techniques are:

1. A physical system characterized at any stage by a small number of parameters termed the state variables;

[25] Descriptions of the dynamic programming procedure and its applications can be found in Bellman(1957), Bellman and Dreyfus(1962), Johnston(1964), Beckman(1968) and Glauss(1972).

2. At each stage, a choice of a number of decisions is available;
3. The effect of a decision is to transform the state variable;
4. The past history of the system is not important in determining future actions; and
5. The purpose of the process is to maximize some function of the state variables.

The dynamic programming process is illustrated in Figure III.I. Each stage **(T)** of the process corresponds to the state **(St)** of the system in a different time interval. The system is in a different state at each stage of the process. Each decision **(Dt)** taken, results in a change in the state of the system and a specific return **(Rt)**. The dynamic programming process is based on determining a sequence of optimal decisions, which maximize the expected returns over a specified time period given the present state of the system.

The most important feature of dynamic programming is that an optimal policy at any stage is independent of the policy adopted in any previous stage. This criterion is referred to as the "Principle of Optimality". Bellman(1957) states this principle as:

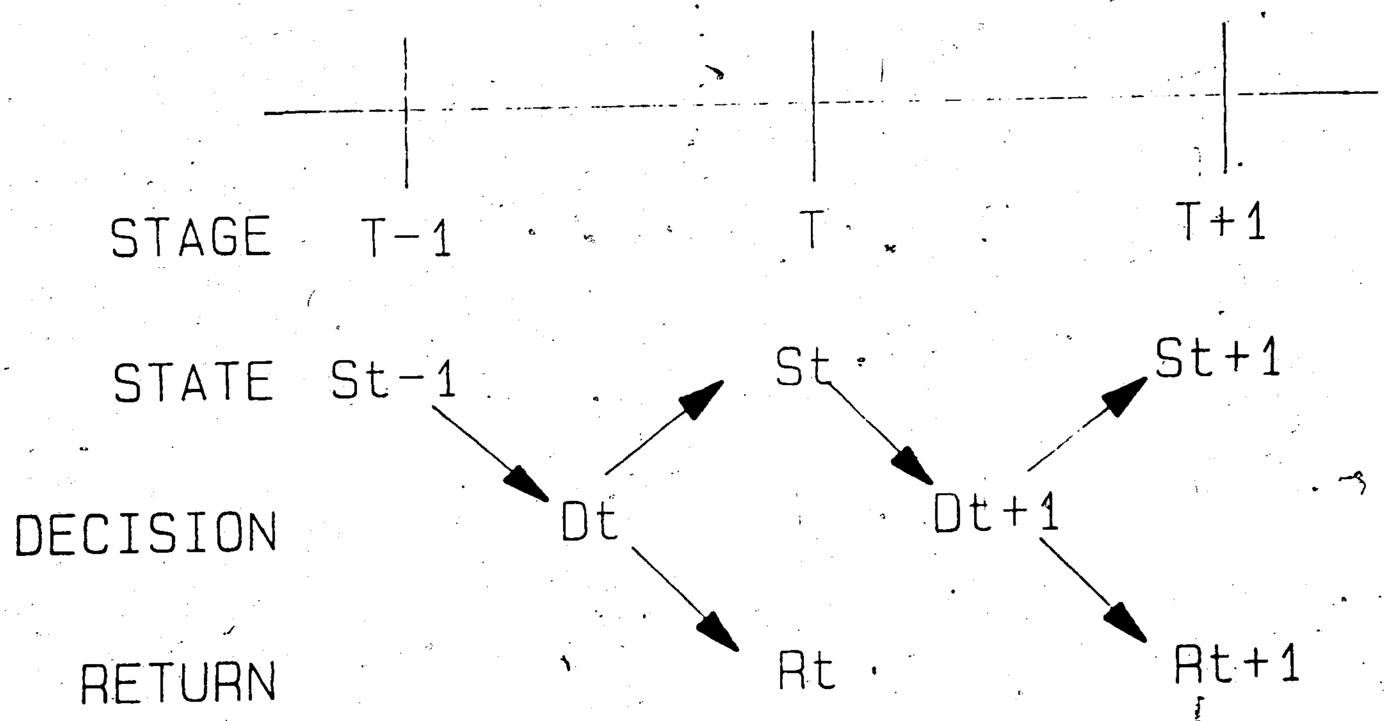
> An optimal policy has the property that whatever the initial state and initial decisions are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision. (p.83)

Based on this principle, a sequence of optimal decisions is defined as one which maximizes the expected returns over T time periods given the present state of the system.[26]

The concept of a dynamic system does not only involve a description of the various parts of the process. It also involves a description of how these parts are related to one another, and what rules apply to the way they vary together over time. Dynamic programming attempts to imbed the original problem within a family of similar problems. The single N dimensional problem is thus reduced to a sequence of N one-dimensional problems. The problem can then be redefined as a sequence of one-dimensional problems requiring a decision at each stage. In this way, dynamic programming techniques start with a small portion of the problem and determine the optimal solution for this small problem. The problem is then gradually enlarged by finding the optimal solution from the previous one,

[26] Johnston(1964) describes the essential elements of dynamic programming as: a set of functional equations, the principle of optimality, and a sequential decision process.

Figure III.I: The Dynamic Programming Decision Process



Source: Johnston(1964). p.535

until the original problem is solved in its entirety. This approach is commonly referred to as a "backward stage by stage" or "backward-pass approach". Hillier and Lieberman(1974) accurately summarize the dynamic programming procedure as:

1. The problem is divided into stages with a policy decision at each stage;
2. Each stage has a number of states associated with it that define possible alternative conditions;
3. The effect of the policy decision at each stage is to transform the present state into a state associated with the next stage (network of decisions);
4. Given the current state, an optimal policy for the remaining stages is independent of policies adopted in previous stages (Principle of Optimality);
5. The solution procedure begins by finding the optimal policy of each stage of the last stage;
6. A recursive relationship that identifies the optimal policy for each state at stage N, gives the optimal policy for each stage (n + 1); and
7. The solut[illegible]rocedure moves backward stage by stage, each time finding the optimal policy state of each stage until the optimal policy is found when starting at the initial stage.

In this research deterministic dynamic programming is used. Consequently it is assumed that the next state of the system is known based on the decision taken at that stage. The state of the next stage is completely determined by the state and policy decisions of the current stage. In deterministic dynamic programming the state variable changes from stage to stage as an exact function; as opposed to probabilistic dynamic programming where changes in the state variables have a random component. Deterministic dynamic programming is generally used when analyzing established physical and biological relationships. In systems of this type, there is a well established correspondense between causal factors and their results based on historical data. This can be represented mathematically as:

$$X(t+1) = h[U(t), X(t), T(t)]$$

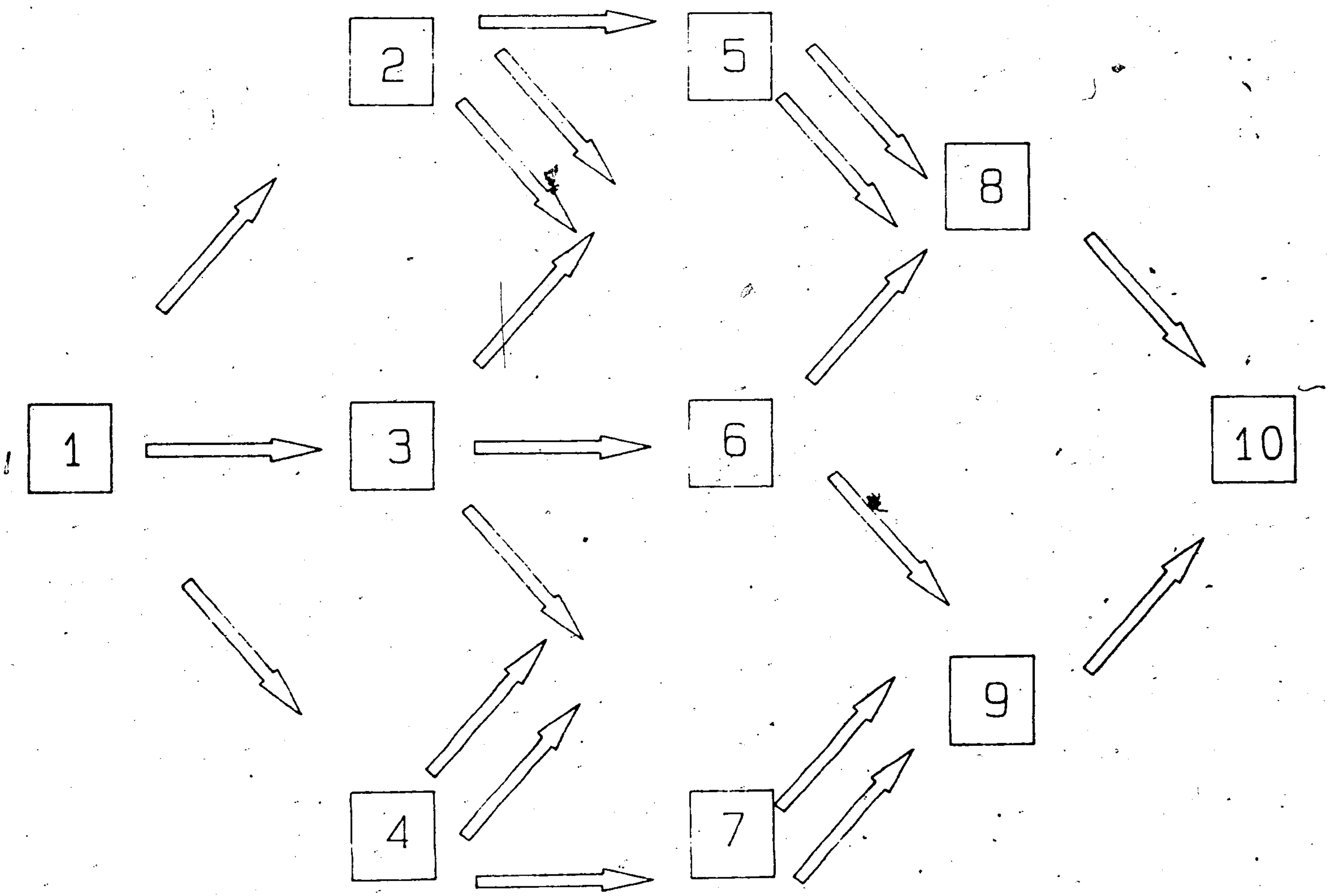
The state of the system **X(t+1)** is determined by the decision **U(t)** in the previous stage, the previous state of the system **X(t)** and the random element **T(t)**. The random element is equivalent to any events that were unforseen, when the decision **U(t)** was taken. The deterministic case is illustrated by the stagecoach problem in Figure III.II. In the stagecoach problem, one attempts to move from one destination **(stage 1)** to another destination **(stage 10)** by travelling through different stages representing stagecoach routes. The individual (driver) knows the relevant costs of travelling between each stage by the alternative routes and can thus determine the least cost route to follow.

Agricultural Applications

In the modelling of agricultural livestock production processes, the term "stage" refers to the production time period that the animal is in and the term "state" refers to the characteristics of the animal in the time period. Thus a particular beef animal in any stage of the production process can be described in terms of its current state (ie. physical and economic attributes). The state of the animal is determined by such factors as: the genetic potential of the animal, its age and condition, the type of ration that is being fed, environmental influences, prices and costs, and the level of management. Dynamic programming procedures, while appearing to be fairly simple and straightforward, are not without computational difficulties. The major problem in formulating any problem through a dynamic programming framework, is in attempting to adequately and accurately define the entire process within the state variables.[27] This specification becomes increasingly difficult, when there are a relatively large number of parameters that affect individual states. The inclusion of these parameters in the model, greatly increase computational difficulty and costs. In addition, it is difficult to segment many production processes into distinct individual stages. These problems have severely inhibited the application of dynamic programming concepts to many real world decision processes. The reality which the dynamic programming framework attempts to simulate is lost, if the individual decision states and stages are not

[27] Burt(1982) states that the primary consideration in formulating dynamic programming models is the choice of the state variables, which must jointly describe the entire history of the process.

Figure III.II: Deterministic Dynamic Programming: Stagecoach Problem



Source: Hillier and Lieberman, p.249

accurately identified. This is particularly true of many agricultural applications due to the interrelationships and indivisibilities of production processes over time.

There has been a gradual shift in the application of dynamic programming techniques to agricultural problems over the last 15 years. The term "dynamic programming" in many recent studies has been applied simply to production systems in which parameters that affect the decision process change over time. These studies, while often maintaining some of the components of classical dynamic programming techniques[28] have been broadly defined to encompass models that analyze anticipated changes in input and output prices and the level of returns over time. The term "dynamic programming" or "dynamic system" has gradually come to be broadly applied to studies that attempt to accurately model the agriculture decision process over time.[29]

C. Modelling Beef Production Systems

Background

There have been several major developments in the modelling of beef production systems, since the early 1950,s. The earliest studies, such as Heady(1963), were based on determining the beef gain surfaces (isoquants) and feed substitution rates for beef cattle. The derived isoquants were then used to determine optimun ration formulations, utilizing relatively naive input and output cost assumptions. These early studies depended on the correct estimation of animal performance on alternative rations based on available animal science data. The estimation of [illegible] gain response isoquants was refined in studies such as: Townsley(1968), Br[illegible] Brokken et al(1976), Burt(1981), and Heady and Bhide(1980, 1983 [illegible] programming models were based on net-energy systems of beef cattle nutritio[illegible] estimated gain response and feed requirements for various classes of

[28] This would include an application such as least cost ration formulation to a specified liveweight level.

[29] Harle(1974) provides an excellent argument in favor of a more dynamic approach to farm planning.

beef cattle, were based on the average daily net energy requirements for maintenance and growth.[30]

This research provided valuable information on the feed requirements for beef cattle over various production growth stages and rates of gain. These standardized coefficients were incorporated into linear and dynamic programming models that examined the economic implications of beef production alternatives. In Canada, these formed the basis of regional linear programming models of beef production alternatives. These studies include Lovering and Treat(1979), who developed a forage-beef simulation model for Atlantic Canada; and Sontag and Hironaka(1974), who evaluated beef production alternatives for Western Canada.

Studies of this type, while addressing some of the concerns of the livestock feeder, did not sufficiently answer all of their questions and concerns. These questions include:

1. **What type of ration and feeding system should be used in each feeding period?** The choice of ration will effect the rate of gain and length of feeding time till marketing,
2. **When should the animal be marketed to obtain the best possible return?** This includes methods to estimate future trends in input and output prices, and their effect on optimal market weights,
3. **How long should the production period be to maximize profit per unit of time, given the available rations and expected future prices?** This involves an analysis of the effect of the length of the production cycle, on the level of profit in future production periods, and
4. **When should replacement animals be purchased?** This involves a decision as to when to purchase replacement feeders and at what weight.

The livestock feeder must determine the optimal initial weight, final weight, length of total feeding time, number and length of each production period, and the type and quantity of ration to feed in each period. In order to answer these questions, researchers required more "dynamic" models of the beef production systems. These models had to accurately represent the actual decision process of the beef producer.

[30] In North America, the standard reference text for these coefficients is: *Nutrient Requirements of Beef Cattle;* National Academy of Science; Washington, D.C.; 1984.

Dynamic Beef Production Models

The early applications of dynamic programming to agricultural production were aimed at modelling the various stages of production processes. These studies included: Heady et al(1959), Burt and Allison(1963), and Johnston(1964). Many of the early models of beef production systems used linear programming techniques to determine the least cost ration at each stage of the production process. In studies such as Meyer and Newett(1970), dynamic programming techniques were used to determine the optimal sequence of rations to feed to produce liveweight gains at minimal cost levels. In a few studies, such as Halter and Dean(1965), the dynamic programming framework was used to determine optimal purchase and selling weights. The general optimization criterion used in these studies was to maximize the return per animal per feeding period over a specified time frame.

Dynamic programming techniques provided a means of more accurately representing the biological production process and its relation to marketing and replacement decisions. The first step of the dynamic programming procedure is to specify the various states of the beef animal at each stage of production in suitable and realistic terms. This requires a detailed knowledge of the physiological and nutritional coefficients of growth at each stage in the production process. This is one of the major disadvantages of dynamic programming approach, since the model becomes more complicated and computationally expensive as additional growth stages are specified. However, dynamic programming techniques seemed to provide a method of answering the two major questions concerning the economic evaluation of alternative beef production systems:

1. How to realistically model the growth rate of animals utilizing alternative ration choices?
2. How to derive the economic implications of these alternative production systems?

This required the introduction of price forecasting techniques within the decision models to facilitate decision-making over a future time horizon. Initially, these input and output price forecasts were based on historical data on market and production trends. Later, more advanced statistical and subjective probability techniques were intoduced.

The procedure used in these beef production models was similar, in many ways, to classical dynamic programming techniques. This optimal "backward pass" procedure consists of:

1. The determination of the first optimal profit level, along with the optimal initial length, first period length and total completion time; and
2. The optimal ration composition, weight gain, and period length are then computed for each production period.

There are many examples of studies which, while using the term dynamic programming, consist mainly of evaluating production options and returns over a future time frame. These studies usually have several base rations and analyze optimal marketing and replacement decisions over time. They differ from classical dynamic programming model in that they do not require optimal ration formulation at each stage. Models of this type can be termed "dynamic" in that they attempt to simulate the producer decision process, when there are changing input and output costs over time. Many of the production and marketing decisions facing beef producers are clouded in uncertainty about future cattle feedlot performance and input and output prices.

Beef Feedlot - Literature Review

The following is a brief review of beef production studies that are relevant to this particular research. It should be noted that livestock production studies in other agicultural commodities use similar "dynamic" programming techniques.[31]

Bullock and Logan(1970) used statistical decision theory to combine apriori information about the historical pattern of month to month price changes, with information provided by a price forecasting model to develop feed and sell decision criteria for feedlot cattle. The imporatnt aspects of their dynamic programming model consisted of:

1. The optimization criteria was to predict the minimun predicted price to feed cattle an

[31] These include: Brookhouse(1967), broilers; Smith(1973), dairy herd replacement; Blackie and Dent(1976), hogs; Yager et al(1980), cull beef cows; and Chavas et al(1985), hogs.

additional 30 days;

2. The sell decision was based on a liveweight range of between 360 to a 450 kilograms; and
3. A forecasting model was developed to predict average monthly slaughter prices one month ahead of the decision date.

The price forecasting model for feeder and slaughter cattle consisted of the following independent variables: historical monthly cattle marketings, historical monthly prices, predicted monthly marketings, the average price in the previous month, the average price in the same month in the previous year, and quarterly dummy variables. The mathematical concepts which the authors followed are similar to many of the subsequent dynamic programming models of beef production systems. Mathematically they expressed the monthly change in the value of a steer as:

$$Xs = [\ Pt + P^{*}\ ] \times [\ W + G\ ] - [\ Pt\ ] \times [\ W\ ] - C$$

where:
Xs = change in the steer's value in 30 days
Pt = current price
P^{*} = price change in next period
W = current weight of steer
G = expected weight gain over the next period
C = expected cost per head of feeding in the next period

Kennedy (1972, 1973)[32] developed several dynamic programming models for determining optimal marketing and feeding strategies for feedlot cattle. Kennedy, who is a leading exponent of dynamic programming techniques, states:

> The decisions entailed in optimally sequencing cattle liveweight are complex dynamic ones. Dynamic programming is shown to be a suitable framework for dealing with some of the non-linear and discontinuous functions involved.(p.147)

The important features of these models were:

1. The objective was to optimize liveweight gain and ration composition;
2. The time period interval chosen was 28 days;
3. The weight interval chosen was seven kilograms over a range of 100 to 500 kilograms;
4. There was a choice of nine possible feeds to formulate optimal rations;
5. The metabolizible energy system of ration formulation was used; and

[32] These studies are based on similar research methodology and yield similar results.

6. The discount rate used was based on comparable market investment opportunities.

The feedlot operator could then base his decision criteria on three available options:

1. to keep the animal for fattening in the next period,
2. to sell the animal and invest the proceeds, and
3. to sell the animal and buy a replacement at the initial weight.

The optimization procedure, which is similar to most dynamic programming models, starts by considering each liveweight state at the beginning of the final period and then selects for all decision options that are open, the one which maximizes returns in the last period.

Ryan(1974) used dynamic programming techniques to evaluate alternative selling criteria, culling criteria, and management levels of beef feedlots. The basic assumptions which were used in the study were that growth rates are independent of purchase weights and are normally distributed, and that purchase weights are normally distributed. Ryan concluded, not surprisingly, that gross margins are sensitive to cattle prices, ration costs and management expertise. The most important conclusion of the study was in pointing out the errors that can occur in using group averaged data in the analysis of livestock systems. Ryan found that, in the validation of the model, only 50 per cent of the cattle reached the specified market weight on the date predicted using average gain criteria. He stated that decision model results that utilize average data, should only be applied to an all-in and all-out marketing system.

Clark and Kumar(1978) applied dynamic programming techniques to pasture based beef production systems. Their decision model was based on a quarterly year time frame, current and anticipated future prices of feeder and slaughter cattle, feed availability, and expected costs and expected rates of growth. This study is particularly interesting because of the relatively long length (quarterly) of the decision process.

Glen(1980) used linear and dynamic programming to evaluate beef feedlot optimization techniques. The study is somewhat unique in that the time period interval of four days is considerably less than that used in most other studies.[33]

[33] The nutritional data used in the study were based on metabolizable energy coefficients.

Van Poolen and Leung(1986) developed a dynamic programming approach to analyze beef feedlot management strategies. The basic producer decision framework of determining when to breed or cull beef cows was based on the resulting value of their offspring in the feedlot. The major features of this study are: cash flow is dependent on the age and state of the cow, monthly time intervals, historical feed and cattle prices were used as forecasted prices, and linear programming was used to formulate least cost rations.

These studies provide a brief overview of recent developments in beef feedlot optimization techniques. The studies stress that there are four major considerations in formulating any beef feedlot optimization problem:

1. Length of the Decision Period

This involves determining the optimal length of the decision period based on the livestock growth stages and the marketing system followed. While most studies use a monthly time period, this can range from quarterly to less than one week. The decision period chosen will depend on the actual decision framework of the farm operator and the reliability of nutritional and price data. Generally the shorter the time period used, the greater are the data and computational requirements.

2. Type of Nutritional Data

The majority of studies use standardized nutritional coefficients such as published by the National Research Council (United States) or the Agricultural Research Council (Britain). Possible other sources of data are from research feeding trials and on-farm studies. The accuracy and source of data used will largely determine the length and number of stages in the model.

3. Type of Price Data

The majority of studies utilize either historical price data or forecasted prices based on historical prices. In many cases, elaborate statistical procedures have been used to forecast future prices. The use of historical data and statistical forecasting techniques seem inadequate however, to accurately represent the procedures that beef producers use to forecast future prices. A forecasting procedure of this type should be based on information that is readily available to beef producers.

4. Validation Of Results

The validation of results is perhaps, the most important and most often overlooked step in the development of any simulation model. Validation techniques employed in most studies, consisted of a continuous comparison between the projected (target) results and the present state of the system (actual). Ideally, the model should be developed to exactly mimic the beef producer's production and decision process. These results can then be evaluated against those generated by the decision model. This implies that the accuracy of model predictions must be accessed, rather than the data to be used in comparison. This forms the basic problem of attempting to validate any model results, namely that of obtaining realistic and representative data with which to test model predictions.

These four considerations namely the length of the decision period, type of nutritional data, type of price data, and the validation of results; must be effectively dealt with to insure that accurate and realistic results are acheived.

IV. The Formation of Price Expectations

A. General Theory

In order to accurately model the effect of time in the beef production process, one must be able to simulate the feedlot manager's formation of future price expectations. This futuristic view of prices and returns can be viewed as "gazing into a crystal ball", and often yields similar results. The rational feedlot manager will base his future projections of prices on the current information tha[illegible] has available. This information set will include:

1. information on beef prices,
2. seasonal trends in production,
3. projections of feed availability,
4. personal experience,
5. information gained from the media, neighbours, and market forecasts and
6. the individual's views of market risk and uncertainty.

The rational feedlot manager will then weigh these sources of information in order to form an opinion on what the future holds. Price expectations that are formed by this method are termed "rational" price expectations. The feedlot operator's managerial decision will then be based on current prices and his projection of future prices.

Rational Price Expectations

Price expectations are said to be rational whenever the public's expectations of the relevant price variable equals the objective mathematical expectations of that variable, conditional on the data set available when the expectation was formed.[34] In mathematical terms this can be expressed as:

$$P(t) = E(t-1)\,[P(t) / I(t-1)]$$

[34] Begg(1982) states that the hypothesis of rational expectations asserts that the unobservable subjective expectations of individuals are exactly the true mathematical expectations implied by the model itself.

The left hand side of the equation **P(t)** is the expectation of price in time t, and the right hand side is the expectation **E(t-1)** in the previous time period of the price in the next period **P(t)** based on the available information set **I(t-1)**. If there are no errors in forecasting, then the individual is assumed to have "perfect foresight" or perfect knowledge of future market conditions. Forecasting errors that do occur are assumed to be the result of information that was unknown to the individual when the forecast was made.[35] Sheffrin(1983) states:

> Expectations are rational if, given the economic model, they will, on average equal the expectation. Expectations will diverge from the actual values only because of some unpredictable uncertainty in the system. (p.9)

The basis of the rational expectations approach assumes that individulas know the entire structure of the model and previous values of all relevant variables. The rational expectations approach incorporates new information as it becomes available and is thus very sensitive to structural change in the economy. Sheffrin(1983) states:

> If the economic system changes we would expect economic actors, at least after a suitable amount of time, to change the way they form expectations.(p.3)

This is a major advantage when compared to relatively fixed parameter econometric models. The rational expectations approach, due to the dynamic nature of the economy, often provides more accurate predictions than when just historical values of the individual variables are used to form expectations.

B. Price Forecasting Techniques

Relation to Agriculture

In agriculture, a price forecasting mechanism should provide information that is:

1. Representative of a particular commodity;

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[35] Begg(1982) states:
it is not attractive to assume that individuals make systematic errors in forming expectations, for such errors would eventually be discovered. (p.61)

2. Readily available to the general public; and
3. Realistic in terms of how producer price expectations are formed.

The most common types of price forecasting mechanisms for agricultural commodities are:

1. Econometric models which attempt to identify significant variables that affect price movements; and[36]
2. Futures markets where price expectations are formed by market interaction based on the information that is available.

It is difficult to aggregate the individual price forecasts of all participants in the futures market. However, the process of price formation in the futures market context would seem to most closely simulate the individual producer decision process. In addition, producers have more confidence in price forecasts that are determined by a decision process similar to their own.[37]

The Theory of Futures Markets

Most analysts view futures markets prices as rationally based price expectations, that play an important part in the producer price expectation process. Giles and Goss(1981), among others, believe that current futures prices are unbiased estimates of subsequent spot prices and state:

> Commodity markets themselves especially those with forward trading facilities anticipate future prices in the process of current price formation. Commodity markets perform this function because they incorporate current information, including the expectations of economic agents, in the determination of current prices. (p.1)

This view of the futures market is based on the assumptions that:

1. The market is competitive;

[36] Bullock and Logan(1970) and Kulshrestha and Rosaasen(1980) contain relevant econometric models of price forecasting for beef cattle.

[37] Blackie and Dent(1976) state that managers have more confidence in their own expectations of future prices and costs than those based on a econometric forecasting mechanism.

2. Information is available and used rationally; and
3. Economic agents are risk neutral.

Price expectations are formed, through a human decision-making process based on the analysis of important endogenous variables that affect the price of the commodity.[38] The futures market price formation process is similar to the rational expectations approach. The formation of a futures price at any point in time is a result of the expert appraisal of past conditions, available information, and expectations of supply and demand. Rational price formation thus becomes a principle economic role of the futures market in providing guidance in decision making and resource allocation.

The difference between the futures market price and spot price for agricultural commodities was originally viewed as the price of storage.[39] The price of storage was defined as the difference between the price of a futures contract and the current cash price. This relative "price spread" then provides information on either the incentive or the disincentive to store a particular commodity. This view of the "price spread" was due to the fact that many of the original agricultural commodities that were traded on a futures market, such as cotton, were very storeable commodities. In the past 30 years, this view of the role of the futures market has changed as less storeable commodities have been traded and the market has become more sophisticated.[40]

Giles and Gray(1981) state the essential functions of present day futures markets as:

1. To facilitate producer and processor risk management by providing facilities for hedging;
2. To facilitate stockholding because of the price spread between futures and spot prices which serves as a guide to inventory control (price of storage);
3. To serve as centers for the collection and dissemination of information; and
4. To perform a forward pricing function through the market's anticipation of subsequent

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[38] In the live cattle market these would include such variables as: breeding intentions, slaughter weights, per capita consumption of beef, feed availability, export demand, and pork and poultry prices.

[39] Working(1949) contains an excellent discussion of this viewpoint.

[40] Tomek and Gray(1970) look at the history and changing role of agricultural futures markets.

cash prices.

Futures markets are termed "efficient" if futures prices reflect available information. Unanticipated price changes, as in the rational expectations approach, are assumed to be due to new information or shocks to the economy. These errors in forecasting can usually be attributed to one of the following factors:

1. Random noise or unforseen economic shocks;
2. Exogenous variables to the system; and
3. Errors in the transmission of information due to:
   a. uninformed market participants,
   b. risk aversion,
   c. irrational market participants,
   d. imperfect capital markets, and
   e. transmission costs of market information.

There are however, many questions concerning the accuracy of futures market information. These include:

1. Do market prices reflect the expectations of non-farm speculators, as well as crop producers?
2. Which future contract is the most appropriate to use for forecasting?
3. At which date should a futures price be observed?
4. Does a futures contract price represent the rational expectations of all producers of a particular commodity?

The basic question concerning the use of futures market prices is whether or not they are accurate indicators of subsequent cash prices, when compared to other estimation techniques.

Reliability of Futures Market Price Estimates

In defense of the role of futures markets in price determination, Kofi(1977) states:

> It has been shown that well-established and properly regulated futures markets are superior to cash markets in price determination because they provide central market prices in open competitive bargaining.(p. 584)

This quote summarizes the most often used argument in defense of the use of futures market prices for future cash price estimation. This argument is that futures market prices provide readily availible price information that is determined by open market interaction. The futures market prices for many agricultural commodities have been shown to reflect the use of available market information in rational price determination.[41] Gardner(1976), among others, states that it was a theoretically well-grounded hypothesis that the futures price of the next year's crop contract reflects the market's current estimate of next year's cash price.

The usual criticism of the future's market price expectations approach is that it is not as efficient as some econometric forecasting techniques. Just and Rausser(1981) compared commodity price forecasting using futures prices with several commercially available econometric forecasts.[42] They concluded that futures markets performed relatively better on average than the econometric forecasts, particularly for the more storeable commodities. In addition, they concluded that futures markets were much more efficient in including new information in their forecasts.[43]

The other major criticism of the use of futures market's prices in subsequent price estimation is that as the prediction time frame is expanded, the estimate becomes less accurate. There appears to be little doubt that this is true, however it is also true of most econometric forecasts. This becomes much less of a problem with futures markets however, since new information is constantly being incorporated into the estimation of a particular futures market price.

In analyzing the available research on the validity of futures market estimation of subsequent cash prices of agricultural commodities, there appears to be sufficient evidence to support their valid use as a forecasting technique.

[41] These studies include: Leuthold and Hartman(1979), Tomek and Gray(1979), and Gardner(1976).

[42] These included seven, readily available, private and governmental forecasts for U. S. agricultural commodities.

[43] A possible reason postulated for the advantage of the futures market is that they (ie. futures traders) can take advantage of the information provided by econometric forecasts, that occur earlier in a particular month.

The Futures Market for Live Beef Cattle

Futures market prices for live beef cattle are some of the most complex to estimate. This is due to the difficulty in estimating such factors as: the cyclical nature of beef production, female slaughter, birthrate, slaughter weights, breeding intentions, feed availability and prices, and seasonal variations in supply and demand. It has also been shown that the futures markets for live beef cattle appears to provide much more accurate estimates of subsequent prices during periods of increasing prices rather than decreasing prices.[44]

While some authors doubt the usefullness of beef cattle futures prices in the estimation of future cash prices,[45] the majority agree that they provide accurate estimates between 1 to 4 months prior to the contract delivery date. These finding are substanciated in Erhlich(1969), Leuthold(1974), Gardner(1976), Gils and Goss(1981), and Martin and Garcia(1985). In the majority of cases, futures prices perform better than lagged cash prices in explaining subsequent spot prices in this range. This is mainly due to the reliability of market information on beef supply and demand factors in the short term (one to four months). The actual prices for live cattle change less frequently than the futures market anticipates over time. This volatility in futures market prices however, is somewhat compensated by daily market restrictions on the price movement of contracts.

The major drawback to the accurate estimation of longer term forecasts is the relative lack of storeability (absence of inventories) of beef. This increases the probability of expectational errors in price formation due to the absence of arbitrage between spot and future prices. This is the major reason that the futures markets of more storeable commodities perform better in the longer term. This problem can be overcome, to some extent, in beef markets by the constant updating of futures market information. This could be accomplished by updating estimates on a monthly or quarterly basis, which would be consistent with a beef producer's process of revision of future price expectations.

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[44] Martin and Garcia(1985) attribute this to high levels of market instability during periods of low returns.

[45] These include Caldwell et al(1982) and Martin and Garcia(1985).

In summary, the futures market for live beef cattle appear to provide reasonably accurate estimates of future beef prices, particalarly in the shorter term (1 to 4 months). While these estimates may not be perfectly accuarate they are at least equal to other price forecastings techniques. They have the additional advantages that the information is readily available and follows a procedure similar to the formation of rational producer price expectations.

V. Research Methodology

A. Description of the Beef Finishing Model

Background

The success of any beef production decision model is based on its ability to simulate the actual conditions under which decisions are made. The beef production model that was used in this research was intended to simulate the beef producer's decision making strategies based on the beef production systems under consideration. The short-term economic returns from beef finishing operations depend on the optimal use of the firm's resources. When determining how best to use these resources, the feedlot manager must consider:

1. Expected changes in slaughter cattle prices over time;
2. Expected changes in feeder cattle prices, feed, and other input prices over time; and
3. The phsysiological (growth) characteristics of the beef cattle in the feedlot.

These considerations are important when deciding what marketing and replacement decisions will maximize present and future returns to the feedlot.

Origin and Purpose of the Model

Origin:

The beef finishing decision model that was used in this research was adapted from a hog fattening model developed under the direction of Prof. Dr. K. Riebe at the University of Kiel, West Germany. The original decision model was developed to evaluate hog production, marketing and replacement strategies based on the use of available on-farm feedstocks within a farm planning framework.[46] Adaptation of the model required translation and reprogramming into Fortran IV compatible with the University of Alberta computer system. The model was originally tested and the results verified using Canadian swine data. The model was then adapted to simulate beef finishing activities and the beef feedlot decision process.

[46] A description of the hog fattening model is contained in Hartjen(1984).

Purpose:

The main purpose of the model is to maximize the gross discounted level of net returns from the beef finishing operation over a specified time horizon. This is accomplished through the use of a recursive algorithm that is used to determine an optimal sequence of replacement and marketing decisions. The optimal decision is defined as one which maximizes the expected returns over a specified number of time periods (planning horizon), given the initial state of the system.

Description of the Model

In this dynamic programming modeling technique, it was assumed that the decision maker (feedlot operator) knows at each decision stage:

1. the current state of the system;
2. the payoffs (returns) that result from each action taken; and
3. the new state that is generated from a particular action.

It is also assumed that the feedlot manager has a choice of alternative actions (decisions) at each stage of the the decision process. The term "stage" is used to describe the current production or time period under consideration. The term "state" refers to the present physical characteristics of the beef animal and the expected value of these characteristics. Thus, within each stage of the system, the beef animal can be viewed as being in a specific physical condition or state. This programming technique requires that one is able to seperate the states of the system into their component parts. This means that each stage of the growth process of the animal must be accurately described if one wishes to accurately model the beef finishing systems.[47]

The number of time periods or decision stages under consideration are referred to as the planning horizon. The planning horizon is usually determined in advance of any decisions. The length of the planning horizon is based on the physical, technical and economic coefficients of the particular system under consideration. In the evaluation of beef production

[47] In dynamic programming terms, this criterion is commonly referred to as the "State Seperation Property".

systems, the planning horizon must be of a sufficient length to encompass several production cycles.

In this beef finishing model, the feedlot manager has three basic decision options within each production period. These options are:

1. To keep an animal in the present period and feed it into the next period;
2. To sell an animal in the feedlot and immediately replace it with a feeder animal; and
3. To sell an animal in the feedlot and not replace it with a feeder animal.

In cattle finishing, as in many agricultural processes, the timing of marketing and replacement decisions is critical because of the cyclical nature of the production process. It is important that the effect of current production decisions on subsequent production decisions be taken into consideration. The problem thus becomes one of attempting to maximize returns over a number of production cycles rather than in a particular production period. Due to the sequential nature of this decision process, the problem of determining the optimal marketing and replacement strategies must be considered over several production periods.

In this beef finishing model, the optimal decision process is determined by the "backward pass approach". This involves the calculation of optimal decisions through the inductive or recursive calculation of the value function. In this method, the optimal marketing and replacement decision is first calculated for the last production period under consideration (time T). Once this optimal decision is made, the optimal decisions are then calculated recursively (time T-1) for each production period under consideration. At each stage in the process, this procedure is repeated until all stages are considered. The model is thus developed on the basis of a "terminal criteria function" where optimization is based on the final state of the system and the last decision process. At each stage in the decision process the discounted value of the gross margin is recalculated. Any additions to gross margins are additive, while any losses are negative.[41]

The decision process of the beef feedlot centres around the following marketing and replacement decision strategies. The marketing decision is based on the assumption that

[41] This is referred to as the property of "additivity".

animals must reach a specified minimal weight and condition before they can be marketed. Once this stage is reached then the feedlot manager has the option to sell the animal or fatten him for another time period. The choice to sell or fatten depends on the anticipated future price for slaughter cattle, the costs of additional feeding and the opportunity costs (foregone revenue) of keeping the animal another period. In this particular model, the feedlot manager has a choice of 5 marketing options based on weekly feeding periods.

The replacement decision is based on the relative estimation of future returns from the replacement decision in relation to expected returns in another replacement period. This means that when determining whether or not to replace in the current week, the feedlot manager must consider the opportunity costs of replacing in the next week. The expected profitability of the replacement decision will be based on current feeder cattle prices, feed and variable costs, and the expected slaughter price when the animal is marketed. In addition, the potential gains from delaying the replacement decision till a later time period must also be considered. The replacement decision is based on the following assumptions concerning the initial state of the feedlot:

Assumption I. Initially there are no animals in the feedlot.

Assumption II.- There is limited capacity in the feedlot.

These two assumptions ensure that replacement decisions are only made that increase the gross margin of the feedlot over time.

The beef finishing model is based on the marketing and replacement activities or decision processes. In this research, the description of these decision processes will be illustrated throught the use of sample model input and output data from a particular animal. The following is a description and mathematical derivation of each process:

A. Optimal Marketing and Feeding Activities:

The feedlot manager has the choice of several weight options at which to market cattle.[49] These marketing options are based on expected weight gains, feeding costs and expected beef prices in subsequent marketing periods. The following are the mathematical

[49] The number of marketing options is variable depending on individual decision criteria.

stages of this decision process:

1. The expected gross margin GM(t) is calculated based on the minimal slaughter weight and slaughter price in the current period;
2. The expected gross margin GM(t+1) in the next marketing period is then calculated based on the expected weight gain and beef price;
3. This future gross margin GM(t+1) is then discounted by the weekly discount factor.[50];
4. The additional feed and other variable costs are then subtracted from the discounted gross margin GM(t+1). This is equal to the net gross margin after additional costs are accounted for;
5. The gross margin in the current period GM(t) is then compared to the gross margin from keeping the animal an additional feeding period GM(t+1). If the future gross margin GM(t+1) is greater than the current gross margin GM(t), then the animal is fattened for another period. If there is no net benefit to be gained from feeding, then the animal is sold; and
6. This procedure is then repeated for each of the marketing periods under consideration, until the maximun market weight is reached (final option).

Mathematically the decision process can be written as:

$$GM(t) = Ps(t) \times W(t)$$

$$GM(t+1) = [Ps(t+1) \times W(t+1) \times I(t+1)] - V(t+1) - [Q(t+1) \times Fp(t+1)]$$

where:

GM(t) = gross margin in current period
Ps(t) = slaughter price in current period
W(t) = weight of animal in current period
GM(t+1) = gross margin in the next period
Ps(t+1) = slaughter price in the next period
W(t+1) = weight in the next period
I(t+1) = the weekly discount factor
V(t+1) = variable costs in the next period
Q(t+1) = feed quantity in the next period
Fp(t+1) = feed price in the next period

[50] In this particular model all revenues and costs and the discount rate are expressed in nominal terms.

The decision process can now be written in the following form:

IF GM(t) > GM(t+1) THEN <u>SELL</u>

IF GM(t) < GM(t+1) THEN <u>FEED</u>

The stages of this decision process are illustrated in Figure V.I. In this example, the feedlot manager has a choice of 5 possible marketing options to chose from. These options range from a minimal market weight of 496 kilograms to a final market weight of 524 kilograms. The first marketing option occurs at time t. At this point in the decision process, a decision can be made to feed or sell an animal in the feedlot. This decision process is continued until the final marketing option is reached (t+4) and the animal must be sold.

B. Optimal Replacement Activities:

The feedlot manager has a choice of when to purchase replacement feeder cattle. The basic assumption of feeder replacement is that the feedlot manager will replace in the earliest possible time period provided that:

1. space is available in the feedlot;
2. the value of the discounted gross margin from the replacement decision is positive; and
3. the value of the discounted gross margin of replacement in the current period (t) is higher than the value from replacement in a subsequent time period (t+1).[51]

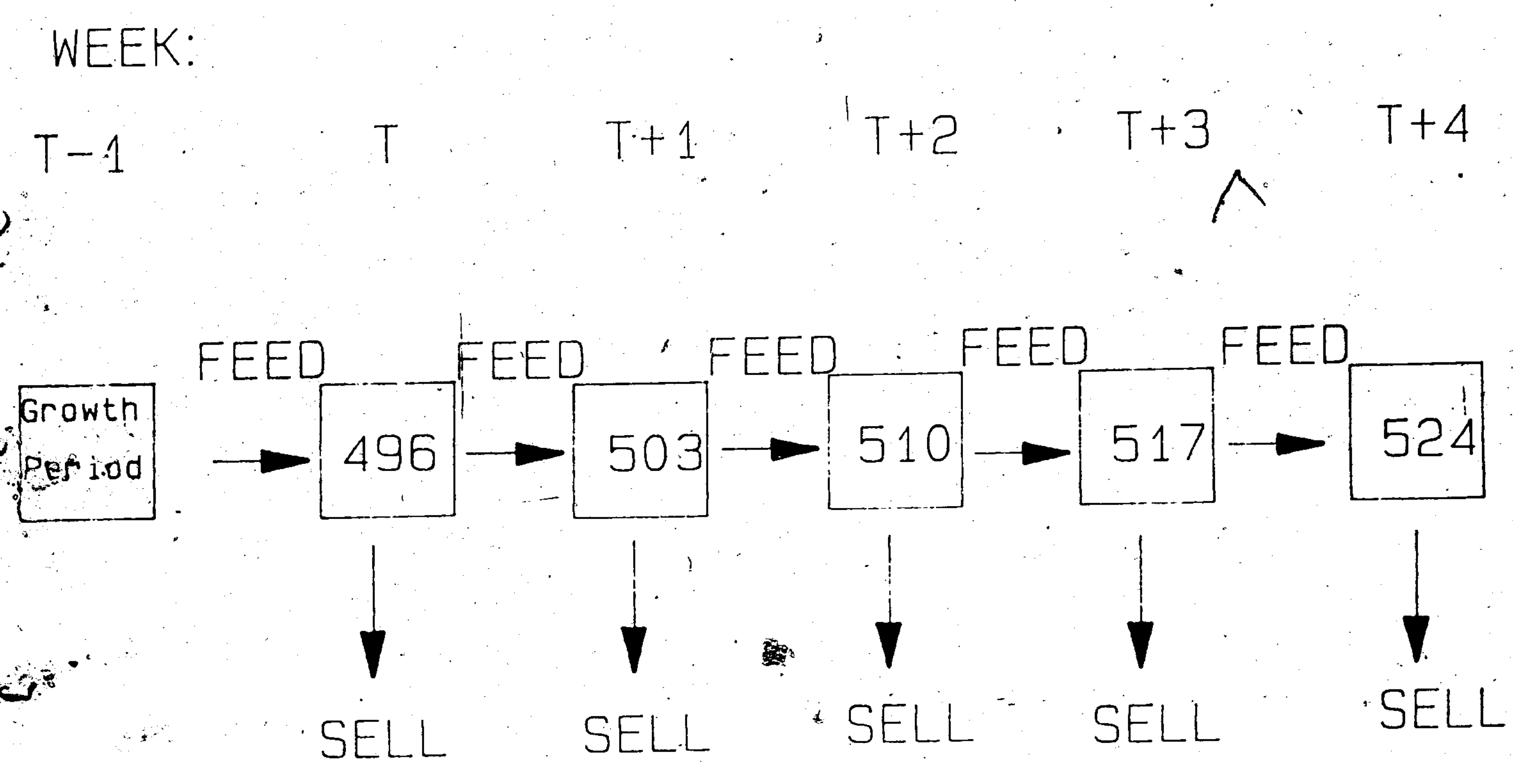
The replacement decisions are evaluated on a cyclical basis. The length of each cycle is based on the total number of weeks required to reach the minimal market weight. The mathematical calculation of the feeder replacement decision proceeds in the following manner:

1. The optimal replacement decision and gross margin GM(t) is first calculated for the last possible replacement date. The final replacement date is determined by the time span required to grow cattle to the minimal slaughter weight. This ensures that no feeders are put on feed that cannot be marketed;[52]
2. The same calculation is then performed recursively for the next week (week t-1). The

[51] The replacement decision is based on replacement with an identical weight and type feeder in each period.

[52] If the total lenght of the planning horizon was 184 weeks and it required 41 weeks to reach a minimal slaughter weight, then the last possible replacement date would occur at week 143 (184 - 41 weeks).

Figure V.I: An Example of Cattle Marketing Options



resultant value of the gross margin GM(t-1) from replacement in this week (week t-1), is then compared to the discounted value of the gross margin GM(t) in the previous week (week t);

3. If the value from replacement in the current week GM(t-1) is greater then the value in the previous week GM(t), then a decision is made to replace in the current week; and

4. The replacement decision is then repeated recursively for all remaining (t-1) time periods, until the final time period is reached (t=0).

The optimal replacement decision process can now be written in the following form:

IF GM(t-1) > GM(t)

and GM(t-1) > 0 THEN <u>REPLACE</u>

In this way, the algorithm calculates the highest attainable gross margin that can be obtained from the optimal replacement decisions.

The marketing and replacement decision processes of the beef finishing model have thus far been presented as distinct and seperate decision processes. [illegible] ect of current marketing decisions on subsequent replacement decision must, however, [illegible] accounted for if the beef feedlot production process is to be realistically represented [illegible] me. The decision model accounts for any net benefits to be acheived from a replacement animal when compared with the expected returns from keeping an animal currently in the feedlot. This is accomplished in the beef finishing model through the following decision criterion:

> If the expected discounted return from the replacement decision is greater than the discounted value of the net returns from all extended marketing options, then sell the animal that is currently in the feedlot and purchase a replacement.

This model decision rule ensures that replacement and marketing decisions account for the effect of current marketing decisions on the level of returns in future production periods.

The following is a mathematical illustration of the replacement procedure:

A. COST CALCULATION - feeding and variable costs are calculated for each of the growth phases of the animal.

The costs in each phase are:

$$C1 = - [(Fj \times Qj)+Vj] / (1-L1-L2-L3)$$

$$C2 = C1 - [(Fj \times Qj)+Vj] / (1-L2-L3$$

$$C3 = C2 - [(Fj \times Qj)+Vj] / (1-L3)$$

$$Ct = C3 - (Pf) / (1-L1-L2-L3)$$

where:
C1,C2,C3 = accumulated costs in each growth period.
Ct = total cost over the three growth periods.
Fj = feed price in period j.
Qj = feed quantity period j.
Vj = variable costs period j.
Lj = percentage death loss in period j.
Pf = purchase price of feeder animal.
j = growth period(ie.1,2,3).

B. REVENUE CALCULATION - The revenue calculation is based on the final weight times the expected slaughter price at the end of the feeding period.[53] This value is then discounted by the appropriate discount rate over the time period. Mathematically, the procedure can be written as:

$$GM(T+w) = Ct + [(Ps(T+w) \times W(w)) \times I(w)]$$

where:
GM = expected discounted gross margin
Ct = accumulated costs over the feeding period
Ps = anticipated slaughter price
W = weight at the end of the feeding period
I = discount rate over the feeding period
T = initial time period
w = number of weeks in the feeding period

If the total gross margin of the beef feedlot can be increased by the replacement decision, then the replacement decision is made in the period. This increase in gross margin is then added to the total discounted value of the gross margin for the feedlot. If there is no replacement decision, then the total gross margin value of the feedlot remains unchanged.

Model Output

The following is a description and explanation of the output generated by the model:

I. Data Requirements:

[53] If the total number of weeks in the growth periods was 41, then the slaughter price would be based on the projected price in T + 41 weeks.

An individual data file is required for each type of finishing system under consideration. An example of a data file is illustrated in Figure V.II. The following is an explanation of data requirements that are illustrated in Figure V.II:

1. Beef Feed Trial - number of the feeding system.
2. ID - animal identification.
3. Start of Plan - day and month of initial start of the planning horizon (in this case the 1 st day of the 11 th month (Nov. 1)).
4. Planning Horizon - the number of production cycles in the model.
5. Feeder Initial Weight - initial weight of feeder cattle.
6. Discount Rate - the percentage discount rate.
7. Growing - the feeding (growth) periods till minimal slaughter weight.
8. Marketing - the marketing period options.
9. Duration - the length of each feeding and marketing period in weeks.
10. Feed - feed consumption in each period (dry matter basis).
11. Variable - other variable costs in each feeding period.
12. Death Loss - percentage death loss in each feeding period.
13. Weight - weight of the animal at the end of each period.
14. Average Feed Value - feed conversion ratio over the feeding and marketing period.

FIGURE V.II: An Example of Model Data Requirements.

PROCESSING DATE : APR 1987

PLANNING HORIZON : 4

BEEF FEED TRIAL # 3 ID = 9k

START OF PLAN : 1.11.

FARM SPECIFIC INPUT DATA
==================================

FEEDER INITIAL WGHT : 256.0 KG
DISCOUNT RATE : 11.0 %

A. FEEDING PERIODS TO 496.0 KG LIVEWEIGHT

PERIOD	DURATION	FEED	VARIABLE	DEATH LOSS	WEIGHT
1	20	568.00	100.00	0.0	337.00
2	12	523.00	60.00	0.0	430.00
3	9	449.00	45.00	0.0	496.00

B. MARKETING PERIODS FROM 496.0 KG LIVEWEIGHT

PERIOD	FEED	VARIABLE	WEIGHT
1	50.00	5.00	503.00
2	50.00	5.00	510.00
3	50.00	5.00	517.00
4	50.00	5.00	524.00

AVERAGE FEED VALUE 524.0 KG AND 45 WEEKS = 6.49

II. Output of Calculated Results:

An example of the output generated by the model is illustrated in Figure V.III. The following is an explanation of these results:

1. Weeks - the current week and month in the planning horizon.
2. Meat - slaughter price in dollars per kilogram.
3. Feeder - value of feeder in dollars per animal[54].
4. Fp1, Fp2, Fp3 - feed prices per kilogram of dry matter in each of the three feeding periods.[55]
5. Fp4 - feed price in the marketing periods.
6. G.M. - value of the accumulated discounted gross margin over the planning horizon.
7. M.V. - marginal value of replacement decision in each time period. This is stated in terms of a increase or decrease in the total discounted gross margin.
8. " R' " - indicates the replacement decision in each period; where "0" means do not replace, and "R" means replace. An example of this decision procedure is illustrated in Figure V.IV.
9. Slaughter Wt. - The slaughter weight at the end of each period and the decision to sell or feed in each period, where "+" means to Feed, and "-" means to Sell. An example of this decision process is illustrated in Figure V.IV.
10. Gross Margin / Place / Year - this indicates the value of the discounted gross margin of the feedlot in the first year. This value is based on the feedlot space requirement per animal per year.[56]

[54] Slaughter and feeder cattle prices are entered on a weekly or monthly basis in the data file

[55] In this example, feed prices are assumed to be fixed over the term of the planning horizon.

[56] This is equivalent to gross returns expressed on the basis of the per animal capacity of the feedlot.

FIGURE V.III: An Example of the Output of Model Results.

BEEF FEED TRIAL # 3 ID = 9k GROSS MARGIN / PLACE / YEAR = 24.19

WEEKS	MEAT	FEEDER	FP 1	FP 2	FP 3	FP 4	G.M.	M.V.	R	496.	503.	510.	517.	524.
0 NOV	1.58	424.96	0.10	0.10	0.08	0.08	139.69	-50.61	O	+	+	+	+	
1 NOV	1.59	427.52	0.10	0.10	0.08	0.08	139.97	-58.90	O	+	+	+	+	
2 NOV	1.59	430.08	0.10	0.10	0.08	0.08	140.25	-67.19	O	+	+	+	+	
3 NOV	1.60	432.64	0.10	0.10	0.08	0.08	140.53	-83.50	O	+	+	+	+	
4 NOV	1.61	435.20	0.10	0.10	0.08	0.08	140.81	-94.11	O	-	-	-	-	
5 DEC	1.60	433.28	0.10	0.10	0.08	0.08	141.10	-86.56	O	-	-	-	-	
6 DEC	1.60	431.36	0.10	0.10	0.08	0.08	141.38	-77.53	O	+	+	-	-	
7 DEC	1.59	429.44	0.10	0.10	0.08	0.08	141.67	-68.50	O	+	+	+	-	
8 DEC	1.59	427.52	0.10	0.10	0.08	0.08	141.95	-49.90	O	+	+	+	+	
9 JAN	1.60	435.84	0.10	0.10	0.08	0.08	142.24	-41.54	O	+	+	+	+	
10 JAN	1.61	444.16	0.10	0.10	0.08	0.08	142.52	-33.18	O	+	+	+	+	
11 JAN	1.62	452.48	0.10	0.10	0.08	0.08	142.81	-24.81	O	+	+	+	+	
12 JAN	1.63	460.80	0.10	0.10	0.08	0.08	143.09	-27.22	O	+	+	+	+	
13 JAN	1.64	457.60	0.10	0.10	0.08	0.08	143.38	-18.11	O	+	+	+	+	
14 FEB	1.64	454.40	0.10	0.10	0.08	0.08	143.67	-9.78	O	+	+	+	+	
15 FEB	1.65	451.20	0.10	0.10	0.08	0.08	143.96	-1.45	O	+	+	-	-	
16 FEB	1.66	448.00	0.10	0.10	0.08	0.08	144.25	8.16	R	+	+	+	+	
17 FEB	1.67	454.40	0.10	0.10	0.08	0.08	136.36	2.14	R	+	+	+	+	
18 MAR	1.67	460.80	0.10	0.10	0.08	0.08	134.49	-6.04	O	+	+	+	+	
19 MAR	1.68	467.20	0.10	0.10	0.08	0.08	134.76	-14.25	O	+	+	+	+	
20 MAR	1.69	473.60	0.10	0.10	0.08	0.08	135.03	-28.35	O	+	+	+	+	
21 MAR	1.72	472.96	0.10	0.10	0.08	0.08	135.30	-35.40	O	+	+	+	+	
22 APR	1.74	472.32	0.10	0.10	0.08	0.08	135.57	-41.71	O	+	+	+	+	
23 APR	1.77	471.68	0.10	0.10	0.08	0.08	135.85	-40.59	O	+	+	+	+	
24 APR	1.80	471.04	0.10	0.10	0.08	0.08	136.12	-39.48	O	-	-	-	-	
25 APR	1.79	469.76	0.10	0.10	0.08	0.08	136.39	-37.72	O	-	-	-	-	
26 MAY	1.78	468.48	0.10	0.10	0.08	0.08	136.67	-33.88	O	-	-	-	-	
27 MAY	1.78	467.20	0.10	0.10	0.08	0.08	136.94	-27.13	O	-	-	-	-	
28 MAY	1.77	465.92	0.10	0.10	0.08	0.08	137.22	-27.56	O	+	+	+	+	
29 MAY	1.77	465.92	0.10	0.10	0.08	0.08	137.49	-29.26	O	+	+	+	+	
30 MAY	1.77	465.92	0.10	0.10	0.08	0.08	137.77	-31.27	O	+	+	+	+	
31 JUN	1.76	465.92	0.10	0.10	0.08	0.08	138.05	-33.29	O	+	+	+	+	
32 JUN	1.76	465.92	0.10	0.10	0.08	0.08	138.32	-35.35	O	-	-	-	-	
33 JUN	1.73	456.32	0.10	0.10	0.08	0.08	138.60	-27.84	O	-	-	-	-	
34 JUN	1.71	446.72	0.10	0.10	0.08	0.08	138.88	-24.09	O	-	-	-	-	
35 JUL	1.68	437.12	0.10	0.10	0.08	0.08	139.16	-23.88	O	-	-	-	-	
36 JUL	1.66	427.52	0.10	0.10	0.08	0.08	139.44	-28.23	O	-	-	-	-	
37 JUL	1.65	426.88	0.10	0.10	0.08	0.08	139.72	-24.33	O	-	-	-	-	
38 JUL	1.64	426.24	0.10	0.10	0.08	0.08	140.00	-16.69	O	-	-	-	-	
39 AUG	1.63	425.60	0.10	0.10	0.08	0.08	140.28	-9.05	O	-	-	-	-	
40 AUG	1.62	424.96	0.10	0.10	0.08	0.08	140.56	-10.48	O	-	-	-	-	

FIGURE V.IV: Explanation of the Model Decision Process

A. REPLACEMENT DECISION - assume that the initial state of the planning horizon is in week 16 as illustrated in Figure V.III. At this point a replacement decision should be made denoted by the symbol " F " in the replacement column. This replacement decision would generate an increase in gross margin of $ 8.16. This is higher than the gross margin generated by the replacement decision in the subsequent week (week 17, $ 2.14). If however, a replacement decision was made in week 15, this would lead to a decrease in gross margin of $ 1.45. Therefore in week 15, the decision is made not to replace (ie. R=0).

B. MARKETING DECISION - assume that one is again at week 16 in the planning horizon, and the animal has reached the minimal market weight of 496 kilograms. A decision must now be made to sell the aniaml or feed the animal an additional week. This decision requires that a comparison be made of the current value of the animal compared to his value after feeding another week.

*CURRENT GROSS MARGIN:

GM(t) = Ps(t) x W(t)

GM(t) = $ 1.66 x 496 = $823.36

*FUTURE GROSS MARGIN:

GM(t) = [Ps(t+1) x W(t+1) x I(t+1)] - V(t+1) [Q(t+1) x Fp(t+1)]

GM(t+1) = [($1.67 x 503) x .998] -$5.00 -[($.08 x 50)] = $829.32

SINCE GM(t+1) > GM(t) THEN FEED ANOTHER WEEK

* The explanation of these variables has been previously mentioned.

III. Additional Output:

The model also prints a graph of the optimal marketing and replacement decisions either in the first year or over the entire planning horizon. An example of this graph is illustrated in Figure V.V, and outlines the optimal marketing and replacement decisions in the first year. The "+" indicates that an animal of that weight should be kept for another period, and the "-" indicates that the animal should be sold.

B. Price Forecasting Procedure

Background

In order to realize the potential benefits of a beef finishing model of this type, one must be able to accurately forecast future beef prices. Producer price expectations have a major impact on the anticipated level of future profits or losses in cattle feeding. These expectations have a significant effect on current feeder cattle prices and placements. There is little doubt that there is a strong relationship between current and expected slaughter and feeder cattle prices. Gracey(1982) states that current losses in cattle feeding tend to produce future profits by the downward adjustment of current feeder cattle prices. Cattle feeders respond to low market prices by attempting to recover these losses in future periods. They attempt to do this by lowering the prices they pay for feeder cattle in terms of current slaughter cattle prices.

This approach however requires that producers can accurately forecast future trends in beef cattle prices. In this research, the future beef price forecasting procedure was based on the assumption that:

> Beef futures market price estimates are a reasonable and rational estimation of beef producers' future price expectations.

FIGURE V.V: Graph of the Optimal Marketing and Replacement Decisions.

```
BEEF FEED TRIAL # 3      ID = 9k

524.   -----------------------------------------------------
517.   ++++----+++++++-++++++++----++++---------------++++++
510.   ++++---++++++++-++++++++----++++---------------++++++
503.   ++++-+++++++++++++++++++----++++--------------+++++++
496.   ++++--++++++++++++++++++----++++--------------+++++++
BARN   OOOOOOOOOOOOOOOORROOOOOOOOOOOOOOOOOOOOOOOOOOORRROOOOO
        NOV DEC JAN  FEB MAR APR MAY  JUN JUL AUG  SEP OCT
```

The Futures Market for Beef Cattle

The Chicago Mercantile Exchange currently conducts the only North American futures market for beef cattle. This exchange, which started in 1964, offers two futures markets for beef cattle. One market for live slaughter cattle and the other for feeder cattle. A futures contract is a contractual agreement, enforceable by law, to buy or sell a specified quantity and quality of a particular commodity. Contracts are identical, in general terms, for each commodity, and only differ in terms of the delivery month and contractual price. The months for which contracts are offered are set by the exchange and contract prices are determined by market interaction.[57] The general contractual specifications for cattle futures are illustrated in Table V.I.

Relationship Between U.S. and Canadian Beef Prices

In order to use the U.S. futures market to forecast Canadian beef prices, it was first necessary to establish the relationship between U.S. and Canadian beef prices. Canadian and U.S. beef prices are strongly related based solely on the size of the U.S. beef market in relation to the Canadian market. Tryfos(1973) states:

> For the most part, the price of Canadian beef is determined by United states beef prices because of the dominant role it plays over the Canadian market. (p.26)

This relationship is based on the assumption that, in the absence of transfer costs and tariffs, the Canadian price should be equivalent to the U.S. price expressed in Canadian dollars. These results were generally supported by Caldwell(1981). This implies that Canadian beef prices will automatically adjust to changes in U.S. beef prices. This explanation may appear to be rather naive, since in the short-term transfer costs and tariffs will affect this price relationship. However, if these factors are relatively constant over time then the market will adjust to compensate for these factors.

In this research, it was assumed that there is a direct functional relationship between Canadian and U.S. beef prices based on the exchange rate. In order to test this relationship,

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[57] In this research, the topic of hedging was not addressed.

TABLE V.1: Futures Market Contract Specifications for Beef Cattle.

A. SLAUGHTER CATTLE:

- 40,000 pound liveweight contract
- U.S. grade 1, 2, 3, 4 choice steers
- average weight between 1050 to 1200 pounds
- weight range from 950 to 1300 pounds
- delivery months (1982/1983): Jan., Feb., Apr., June, July, Aug., Oct., and Dec.

B. FEEDER CATTLE:

- 42,00 pound liveweight contract
- U.S. grade choice and good feeder steers
- average weight between 575 to 700 pounds
- weight range from 525 to 750 pounds
- delivery months (1982/1983): Jan., Mar., Apr., May., Aug., Sept., Oct., and Nov.

Source: *Chicago Mercantile Exchange (1984).*

Canadian and U.S. slaughter and feeder cattle prices were compared on a monthly basis between the time period 1980 untill 1984. This comparison was based on the monthly weighted average slaughter prices for A1/A2 steers in Toronto and choice grade slaughter steers at Omaha. Feeder cattle prices were based on 275 to 320 kilogram good feeder steers at Toronto and 275 to 320 lb. choice grade feeder steers at Omaha. Canadian prices were adjusted to U.S. prices by the average monthly exchange rate.[51] The means, standard deviations (S.D) and cofficient of determination (R^2) of Canadian and U.S. slaughter cattle prices ($ per cwt..) are illustrated in Table V.II:

TABLE V.II: U.S./CANADIAN SLAUGHTER CATTLE PRICES ($ per cwt.).

COUNTRY	MEAN	S.D.	R^2
Canada	$81.05	$4.25	0.77*
U.S.	$79.19	$5.00	

*Significance: $P < .05$

The results of the same statistical tests for feeder cattle prices are illustrated in Table V.III:

TABLE V.III: U.S./CANADIAN FEEDER CATTLE PRICES ($ per cwt.).

COUNTRY	MEAN	S.D.	R^2
Canada	$80.43	$4.35	0.65*
U.S.	$82.02	$5.13	

*Significance: $P < .05$

These results indicate that there is a significant relationship between beef prices at representative Canadian and U.S. markets. The results also indicate that there is a slightly stronger relationship between slaughter cattle than feeder cattle prices.

[51] Data sources: slaughter and feeder cattle prices, *Livestock Market Review*(1980-1985); exchange rate, *Bank of Canada Review*(1981-1985).

Beef Price Forecasting Procedure

It has already been established that prices established on the futures market for beef cattle are based on a rational price expectations approach and that there is a significant relationship between Canadian and U.S. beef prices. There are however, four major concerns that must be dealt with when using futures market price expectations as forecasts of subsequent cash prices. The following is a brief analysis of these concerns:

1. **When to Make Price Forecasts**: This involves the choice of a particular day or week in a month to make a price forecast. The date chosen varies from study to study. Leuthold(1974) chose the 15th day of the forecast month; Martin and Garcia(1985) chose the closing price on the third week of the month; and Just and Rausser(1981) used the last day of the month as a basis to make subsequent price forecasts. In this research, the closing futures price on the last day of the month were used to forecast prices in subsequent contract months. Theoretically,this is the best estimate of future price expectations that encompasses all available information.[59]

2. **When to Update Forecasts**: Beef futures market price information is available for up to 13 months from a particular forecast date. The majority of studies indicate that accurate forecasts of future cattle prices can be observed 1 to 15 weeks prior to the contract delivery date. Generally as the length of the forecast increases, the reliability of a particular forecast decreases.[60] Forecasts should be updated whenever new and relevant information becomes available.

3. **What Beef Price to Forecast**: The futures market price forecasts should be used to forecast, as realistically as possible, subsequent cash prices for the same type, grade and weight classes of animals as specified in the futures contract. In this research, the futures market price forecasts were used to estimate the following future cash prices:

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[59] It should be noted that futures market price information is only available for specified contract months. Prices in nonspecified months were based on a extrapolation of these prices.

[60] Leuthold(1974) estimated the following coefficients of determination (R^2) for futures market prices and subsequent cash prices for U.S. slaughter cattle: 1 month, .85; 2 months, .57; 3 months, .41; 4 months, .28; 5 months, .16; and 8 months, .04.

a. Slaughter Cattle - The average monthly weighted price for 450+ kilogram A1/A2 grade steers on the Toronto Market. The is equivalent to the futures contact specifications of 500 to 600 kilogram U.S. choice grade steers at Omaha.

b. Feeder Cattle - The average monthly weighted price for good 275 to 320 kilogram feeder steers on the Toronto market. This is equivalent to the futures contract specification of 260 to 320 kilogram U.S. choice and good feeder steers at Omaha.

4. **How to Account for Exogenous Price Influences**: Factors such as tariffs, transfer costs, grade differentials, and the exchange rate influence Canadian beef prices in terms of U.S. beef prices. It is very difficult to accurately account for these influences when comparing beef prices in the two countries. In this research, an index of Toronto versus Omaha price was used to partially account for the effect of these influences. This index was recalculated whenever a price forecast was made.[61] The futures price estimates were then adjusted by this price index to determine a forecasted cash price. This index should partially account for the effect of these exogenous influences over the planning horizon, if it is revised frequently.

Evaluation of Price Forecasting Procedure

The actual beef prices for feeder and slaughter cattle over the immediate planning horizon (Oct.,1982 to Jan.,1984), were compared using two estimation procedures. The first procedure **(FORECAST)** was based on futures market price estimates adjusted by the exchange rate in the forecast month. The second procedure **(INDEX)** used the futures price estimate indexed by the Toronto price divided by the Omaha price in the previous month. The first procedue will only account for exchange rate fluctuations. The second procedure, in theory, should account for exchange rate fluctuations and the influence of other exogenous factors. Price forecasts were made: 1 month prior to the contract month, 2 months prior to the contract month, and 1 year prior to the contract month. The mean, standard deviation (S.D.), coefficient of dtermination (R^2) and level of significance (SIG) were calculated for

[61] This index was based on the monthly weighted average Toronto and Omaha prices in the month before the forecast is made. If the forecast is made in October, 1982, then the index is calculated based on September,1982 prices.

each forecasting procedure in relation to actual prices. The results of these tests are illustrated in Table V.IV: Slaughter Cattle, and Table V.V: Feeder Cattle.

The results for both slaughter cattle and feeder cattle indicate that the price forecasts provide a reasonable approximation of subsequent cash prices. The results appear acceptable for both the 1 month and 2 month update procedures.[62] This is consistent with the recommendations of most studies on the use of futures price information for beef cattle. The correlation coefficients of the index procedure for both cattle classes are close to 80 percent and signicant, when a 1 month update is used. In this research the 1 month index procedure was used to forecast subsequent cash prices, even though both procedures provide acceptable results.

The price forecasting procedure that is used in this research has the following advantages:

1. The information needed to impliment the forecasting procedure is readily available to beef producers,
2. The approach followed is similar to the actual process in which producers form price expectations, and
3. The price forecasts can be easily updated.

The possible disadvantages of the procedure are:

1. The price forecasts must be updated frequently to provide reasonable estimates, and
2. The forecasting procedure is based on the performance of U.S. futures markets. This may at times cause some inaccuracies in the estimation of Canadian prices due to exogenous factors.

C. Evaluation

The comparison of the alternative beef finishing systems and the evaluation of the performance of the model was divided into two parts. These are:

[62] It is interesting to note that the yearly forecasts of both procedures provide relatively high, but insignificant coefficients of determination (R).

TABLE V.III: SLAUGHTER CATTLE PRICE FORECASTS ($ per cwt.).

PRICE	1 MONTH	2 MONTH	YEAR
ACTUAL			
Mean	$79.05	$79.51	$78.40
S.D.	$4.25	$4.18	$4.26
FORECAST	$78.06	$76.22	$71.91
S.D.	$4.55	$5.11	$2.17
R^2.	.71	.54	.41
SIG.	*	*	
INDEX			
Mean	$80.03	$78.25	$74.20
S.D.	$3.87	$6.25	$1.29
R^2.	.80	.44	.22
*SIG.	*	*	

TABLE V.IV: FEEDER CATTLE PRICE FORECASTS ($ per cwt.).

PRICE	1 MONTH	2 MONTH	YEAR
ACTUAL			
Mean	$79.83	$80.25	$80.64
S.D	$4.46	$5.54	$4.66
FORECAST			
Mean	$79.21	$79.93	$80.42
S.D.	$6.30	$4.50	$0.32
R^2.	.84	.64	.24
SIG.	*	*	
INDEX			
Mean	$80.19	$81.41	$78.92
S.D.	$4.86	$4.18	$0.32
R^2.	.79	.52	.57
*SIG.	*	*	

*SIGNIFICANCE: $P < .05$

Evaluation of Beef Finishing Systems

This evaluation is intended to test the following hypothesis:

There is a significant difference in the gross margins of alternative beef finishing systems in Atlantic Canada.

In order to test this hypothesis, individual model results were determined for each animal in each finishing system. The mean and standard deviation of the discounted gross margin per year were then calculated for each system. A statistical comparison was then made to determine if there was a significant difference between the systems under consideration. In this evaluation historical slaughter cattle and feeder cattle prices were used. The evaluation of this hypothesis was based on the following two decision strategies:

I: Fixed Marketing and Optimal Replacement Strategy - All animals were marketed at the minimal slaughter weight. The only decision made was whether or not to purchase replacement feeders.[63]

II: Optimal Marketing and Replacement Strategy - In this strategy, the extended marketing options of the model was evaluated. The optimal replacement strategies for each animal were also determined.

Evaluation on a Continuous Feedlot Basis

The optimization criterion that was followed by the model (ie. gross margin) does not account for any benefits that might occur if the feedlot were considered to operate on an on-going basis. These benefits occur from following the optimal marketing decisions generated by the model even if there is no replacement decision. The beef finishing model was used to determine optimal marketing and replacement strategies that could be evaluated on an on-going feedlot basis. The decisions of the model were evaluated using a accounting procedure to estimate beef feedlot returns.[64] This evaluation was used to test the following hypotheseis:

[63] The fixed marketing option was "forced" on the model through an increase in variable costs in the other marketing periods.
[64] This was be based on a spreadsheet approach using an IBM PC.

Atlantic Canada beef producers who follow a fixed marketing and replacement strategy could increase their returns by following a marketing and replacement strategy based on forecasted prices.

In order to test this hypothesis, one representative animal was evaluated from each finishing system. This evaluation was conducted based on the following decision strategies:

I: Fixed Marketing and Replacement Strategy with Perfect Knowledge - This encompassed a fixed marketing strategy (minimal slaughter weight), with immediate replacement by a feeder animal. This analysis was based on the assumption of perfect knowledge of future beef prices and costs.

II: Optimal Marketing and Replacement Strategy with Forecasted Prices - This procedure involved the evaluation of the beef finishing systems using forecasted prices. This provided data to evaluate the forecasting ability of the model. Price forecasts were updated on a monthly basis. Marketing and replacement decisions were evaluated at one month intervals based on the model decisions using forecasted prices.

This evaluation of the beef finishing systems was conducted based on the following assumptions:

1. The beef feedlot was considered to operate on an on-going basis. It was assumed that at the beginning of the planning process, there was an inventory of cattle in the feedlot. These cattle were distributed evenly at 20 percent, 40 percent, 60 percent, and 80 percent of the minimal slaughter weight. The beginning inventory value of these animals was based on their weight times the slaughter price at the beginning of the planning period;
2. Cattle were moved through the feedlot on a weekly basis. Each week the animal would enter a new weight category based on its expected gain in the week;
3. Cattle were marketed and replacement feeders purchases made in accordance with the strategy specified in the beef finishing model;
4. Feed and other variable costs were be calculated on a weekly basis for each animal in the feedlot;
5. The time period under consideration was one year;

6. The inventory value of cattle in the feedlot at the end of the year was based on year end slaughter prices and weights;
7. The total undiscounted value of returns was then calculated for each system during the year. This was adjusted by accumulated costs and any change in inventory value to determine total profit for the year. The calculation of gross margins per year are based on the following formula:

   Gross Margin = Sales - Feed - Feeder Purchases - Variable ± Inventory change; and
8. The individual results of each system under the various decision criteria were then evaluated.

Conclusions and recommendations were based on these trial results.

VI. Research Methodology: Data Base

A. Physical Data: Beef Production Systems

Four beef production systems were evaluated utilizing research trial data from the Agriculture Canada Research Station in Fredricton, New Brunswick.[65] The four systems were: potatoes and forage, barley and forage, free choice silage, and backgrounding on silage with barley finishing. These beef production systems were assumed to be representative of beef production alternatives that currently exist in the region. The following is a brief description of these beef production systems. Systems I and II can be considered as being representative of intensive finishing systems. Systems III and IV can be considered as being representative of extensive finishing systems.

SYSTEM I: A high level feeding system based on cull potatoes and silage. The animals received cull potatoes in gradually increasing amounts up to a maximun of 15 kilograms per day of dry matter. The animals also received grass and grass - legume silage for the first 210 days (ad libitum). The animals were fed corn silage from 210 days until slaughter.

SYSTEM II: A feeding system based on rolled barley and silage. The animals were fed in a similar manner to system I, except that dry rolled barley replaced cull potatoes. Barley was fed in gradually increasing amounts up to a maximum intake of 3.5 kilograms of dry matter per day.

SYSTEM III: A feeding system based on free choice (ad libitum) silage. Animals were fed grass and grass-legume silage for the first 210 days. Corn silage was fed from 210 days until slaughter.

SYSTEM IV: A 210 day backgrounding period of grass and grass-legume silage followed by a high level of barley feeding until slaughter. Animals were fed to gain approximately 0.7 kilograms per day in the backgrounding period. The ration was changed to corn silage and barley after 210 days.[66]

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[65] A description of these trials is contained in Nicholson(1984).

[66] Dry rolled barley was gradually increased to a maximun of 3.5 kilograms (dry matter) per day.

Conduct of Trials

The following is a brief description of the specifications of these research trials:

A. Trial Period: The trial was conducted between October 1982 and September 1983.

B. Type of Animals: 64 spring born beef calves were weaned in early October at approximately 6 months of age and 200 kilograms. These calves were then preconditioned for 3 weeks before beginning the trial.[67] The steer calves were distributed among the 4 systems to equalize the mean and standard deviation of initial weights. The trial started the last week of October, 1982.

C. Initial Weights: The means and standard deviations (S.D.) of initial weights is shown in Table VI.I:

TABLE VI.I: MEAN INITIAL WEIGHTS OF ANIMALS

SYSTEM	MEAN	S.D.
I	203.1kg	40.09kg
II	203.4kg	37.43kg
III	203.6kg	37.27kg
IV	203.5kg	40.10kg

D. Implants: All animals were implanted (Ralgro) at the start of the trial and at 120 days.

E. Weight Recording: Live weights were initially recorded at 28 day intervals. As animals approached slaughter, weights were recorded more frequently at 2 week intervals.

F. Slaughter Weights: The targeted slaughter weight was 465 kilograms (liveweight) provided the animals appeared visually to have reached A1/A2 carcass grades. Large framed steers were generally fed to higher slaughter weights and smaller framed steers to lighter weights. The means and standard deviations (S.D.) of slaughter weights are illustratd in Table VI.II

[67]During this preconditioning period, all animals were vaccinated and dewormed.

TABLE VI.II: MEAN SLAUGHTER WEIGHTS OF ANIMALS

SYSTEM	MEAN	S.D.
I	457.1kg	26.48kg
II	451.1kg	37.97kg
III	471.1kg	36.65kg
IV	481.8kg	29.40kg

G. FEEDS: All feeds were weighed and recorded on an individual animal basis. Feeds were analyzed for dry matter content, total nitrogen and metabolizable energy.[68]

H. Supplements: All animals received 1 kilogram per day of a protein, mineral, and vitamin supplement throughout the trial period.[69]

The summary of the individual trial results is illustrated in Table VI.III: All feed weights are expressed on a dry matter basis.

[68] The range of crude protein content on a dry matter basis were: Barley, 10.02-13.68 %; Potatoes, 8.96-12.36 %; Grass silage, 8.4-13.75 %; and Corn silage, 8.31-11.25 %.

[69] This supplement contained 40% barley, 50% soybean meal, 4% molasses, and 6% of a vitamin-mineral mix.

TABLE VI.III: MEAN TRIAL RESULTS FOR EACH SYSTEM

VARIABLE	SYSTEM I	SYSTEM II	SYSTEM III,	SYSTEM IV
In. Wt.	203.1kg	203.4kg	203.6kg	203.5kg
Fin. Wt.	457.7kg	451.5kg	471.1kg	471.8kg
Gain	254.6kg	248.1kg	267.5kg	268.3kg
Days	239.5	229.5	290.6	294.5
Grain	0.0kg	399.1kg	0.0kg	199.4kg
Potatoes	490.8kg	0.0kg	0.0kg	0.0kg
Silage	917.3kg	943.9kg	1586.2kg	1364.2kg
Premix	215.0kg	205.1kg	258.5kg	262.8kg
D.M./Gain	6.4	6.3	6.9	6.9
Gain/Day	1.07kg	1.10kg	0.93kg	0.91kg

The important points of interest in Table VI.III are:

1. The heavier finishing weights, longer days on test, and lower feed conversion ratios in systems III and IV compared to the other systems, and
2. The higher average daily rate of gain in systems I and II compared to the other more extensive systems.

Evaluation of Physical Data

The feeding trial results for each animal were broken down into three growth stages (periods). The growth periods were based on the type of ration being fed and the expected rate of gain in the period. The feed requirements and gain in each period were then calculated and incorporated into the model data base. Individual rather than pooled data was used due to the wide variation in the initial and final weights, feed intake and feed conversion, and the average rate of daily gain. These variations made it very difficult to extrapolate representative data for each system under consideration.

Extended Marketing Periods

In the original research trial, all animals were marketed when they reached the specified target criteria. In order to provide data to evaluate various marketing options, four additional weekly marketing periods were added to individual animal data. The feed consumption and weight gain in these periods are based on animal performance in the previous 28 day growth period. The four weekly periods were chosen to provide sufficient data to evaluate individual systems, without the risk of individual animals acheiving a lower carcass grade.[70]

Representative Animals in Each System:

The evaluation of the alternative beef production systems on an on-going feedlot basis requires the choice of a representative animal from each system. These animals were chosen based on the following criteria:

1. The animal must have acheived an A1 carcass grade,
2. These animals must be of approximately the same initial weight, and
3. These animals must be within a 10 percent range of the mean initial weight, mean average daily gain (A.D.G.) and mean feed conversion ratio (F.C.R.) of the particular system they represent.

The relevant statistics on each representative animal are outlined in Table VI.IV:

Table VI.IV: REPRESENTATIVE ANIMALS IN EACH SYSTEM

SYSTEM	INT. WT.	FINAL Wt.	A.D.G.	F.C.R.
I	191.0kg	455.0kg	1.04kg	6.3
II	204.0kg	468.0kg	1.19kg	6.2
III	192.0kg	451.0kg	0.96kg	7.0
IV	186.0kg	446.0kg	0.97kg	6.7

[70] This approach may slightly undervalue feed intake in these additional periods, since animals require more energy for maintenance at higher weights and ages, as well as having a higher proportion of the weight gain in the form of fat.

B. Economic Data

Beef Price Data

Atlantic Canada does not have a single major livestock marketing centre. The majority of cattle are marketed through local livestock sales and slaughtering plants. This makes it very difficult to obtain accurate data on historical slaughter and feeder cattle prices. Historically, regional beef prices have followed price trends on the Toronto livestock market. Therefore in this research, the assumption was made that Atlantic Canada beef prices will closely follow Toronto price trends. The monthly weighted, average Toronto price for A1/A2 slaughter steers was used as the basis for slaughter cattle prices.[71] The feeder cattle price was based on the monthly weighted, average Toronto price for 275 to 320 kilogram feeder steers. The majority of the feeders in the trials were in the 180 to 275 kilogram range. Therefore, the Toronto price was adjusted to reflect the historical price premium for these 180 to 275 kilogram steers.[72]

Historically, there has been a price differential between Atlantic Canada beef prices and Toronto beef prices. The reasons for this price differential include such factors as transportation costs and proximity to major retail markets. In an attempt to estimate this price differential, a comparison was made between feeder cattle prices in Truro, Nova Scotia and Toronto in October, 1982.[73] The prices of the 1982 Truro sale were compared to the Toronto weighted, weekly, average prices in the same period. The comparison, based on similar feeder classifications, indicated a price differential of approximately $0.06 per kilogram.[74] This price differential was applied to both feeder and slaughter cattle prices. This provided a crude estimate of the actual price differential in the time period covered in the model. The formulas to adjust cattle prices are:

[71] *Livestock Market Review*(1980-1984).
[72] In the time period Sept., 1981 till Sept., 1982; this premiun averaged $0.03 per kilogram.
[73] In early October, the region's major fall feeder sale is held in Truro.
[74] *Livestock Market Review*, Oct.21, 1982.

A. Slaughter Cattle:

ASp = TSp - Pd

<u>where:</u>
ASp = Atlantic Canada slaughter price
TSp = Toronto Slaughter price (A1/A2 steers)
Pd = Price differential (Toronto/Truro)

B. Feeder Cattle:

AFp = TFp + TPp - Pd

<u>where:</u>
AFp = Atlantic Canada feeder price
TFp = Toronto Feeder price (275 to 320 kg. steers)
TPp = Toronto price premium (180 to 275 kg. steers)
Pd = Price differential (Toronto/Truro)

Livestock Production Costs

The derivation of livestock production costs were based on the following assumptions:

Assumption I: Livestock production costs, exclusive of feeder cattle, remain constant over the entire planning horizon. This assumption was made due to the following reason. Beef production input costs remained relativly constant during the period under study. The farm input price index for animal production in Eastern Canada changed very little during this time period. Between the 4th quarter of 1982 and the 4th quarter of 1984, this price index changed by less than 2 percent. [75]

Assumption II: The beef feedlot is already considered to be in existence. This study was not concerned with the feasibility of constructing a feedlot and thus only variable operating expenses were considered.[76]

Assumption III: The rations are assumed to be fixed for each beef finishing system under consideration. In Atlantic Canada there is a limited choice of feeds available and the majority of beef feedlots operate on a relatively fixed ration basis.

[75] *Statistics Canada*(1984).

[76] Fixed costs of production are not considered. These include such items as depreciation on buildings and equipment, long-term debt repayment, and return to owner's equity.

The following is a breakdown of the production costs included in this analysis and their source:

A. Feed: Feed costs were based on a market value approach whenever possible.

1. Barley prices were based on the average producer price for the 1982/1983 crop year;[77]
2. Cull potato prices were based on their average transportation costs to the feedlot. These potatoes have no other market value;[78]
3. There are no documented prices for silage in the region. Therefore silage prices were based on cost estimates derived from a linear programming model using 1982/1983 input prices.[79]

The feed costs that are used in the analysis are illustrated in Table VI.V:[80]

Table VI.V: FEED COSTS PER TONNE OF DRY MATTER.

FEED	COST/TONNE
BARLEY	$150.0
POTATOES	$ 66.0
GRASS SILAGE	$100.0
CORN SILAGE	$480.0
SUPPLEMENT	$370.0

B. Yardage: The term yardage is used to denote all other variable costs of production, exclusive of feed and feeder cattle costs. Yardage charges include the following costs:

1. Hired labour,
2. Tractor and equipment operating expenses,
3. Maintenance of buildings,
4. Utilities,
5. Veterinary and medicine,

[77] *P.E.I. Agricultural Statistics*(1984).
[78] Nicholson(1984)
[79] Lovering and Treat(1979).
[80] Costs are expressed on a per tonne dry matter basis.

6. Bedding, and
7. Waste disposal

These costs were estimated using a linear programming model of a beef feedlot.[81] This model calculates costs on a per head basis based on the capacity of the feedlot. The calculated yardage fee was charged to the feedlot on a weekly basis per head. For the purposes of this analysis, the yardage fee is $0.35 per day. Yardage fees remained constant throughout the finishing period and planning horizon.[82]

C. Death Loss: Death loss will vary depending on the type of ration fed, management practices, climatic conditions, and the condition of feeder cattle. In this research, a 1 percent figure for death loss was used.[83] Death loss was charged equally in the 3 growth stages of each beef finishing system. There was no allowance for death loss in the final four weekly marketing periods (extended data).

D. Length of the Planning Horizon: The length of the planning horizon was set at 4 production cycles for each system. This provided a sufficient time frame over which to evaluate alternative beef production systems.[84]

C. Choice of a Discount Rate

The choice of a particular discount rate has a major impact on the level of future returns from the enterprise. The discount rate is used to compare expected future returns from the enterprise in terms of present levels of returns. The discount rate thus reflects the relative risk of future returns in terms of present returns. In the review of studies on asset replacement, most authors recommend that the discount rate should be based on the level of returns of comparable investments.

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[81] Based on cost estimates prepared by the author and contained in Nicholson(1984).
[82] Yardage and supplement costs are combined when entered as data in the beef finishing model.
[83] This is consistent with estimates contained in Nicholson(1984) and Van Deurzen(1983) for these types of finishing systems.
[84] The length of these beef production cycles varies from 27 to 44 weeks.

The level of anticipated returns in these enterprises is based on a riskless rate plus a risk premium specific to the enterprise. The risk premium is based on the expected risk of the enterprise when compared to other investment alternatives. This risk premium is usually based on the historical evaluation of investment returns and the variation of these returns.[15] As previously mentioned this method of determining a risk adjusted discount rate is generally referred to as "The Capital Asset Pricing Model." This model is based on a riskless rate, usually based on government backed securities, plus a risk premium based on the historical performance of the firm. In many economic studies the expected rate of return on a portfolio of stocks is used as the basis to establish a risk premium. Stocks in general are characterized as having relatively high levels of returns when compared to less risky investments. However, there is also a high degree of variability in yearly stock market returns. Beasley et al(1986) found that common stocks in the United States returned an average annual risk premium of 8.3 percent over government treasury bills.[16]

In Canada, the Toronto Stock Exchange "300" Composite Index is commonly used as a measure of the rate of return on a stock market portfolio. This index is based on the weighted average value of a representative index of 300 Canadian stocks from 14 major groups and 43 sub - groups. This returns index measures changes in the values of these stocks, as well as any dividends which may accrue. Boyle et al(1984) found that the average annual rate of return of these index stocks was 11.7 percent in the period 1949 to 1981. Over the same period, stock market investors received a average annual risk premium of 8.1 percent above the return on Canadian treasury bills.[17]

The coefficient of variation is a standard risk measurement that can be used to compare the relative risk of alternative investment opportunities. Mathematically the coefficient of variation(C.V.) is stated as:

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[15] Brigham and Grapenskl(1985) state that as a general rule investments with higher historical returns have larger standard deviations than investments with lower historical returns.

[16] This was based on the average annual rate of returns on common stocks and U.S. treasury bills from the period 1926 to 1981.

[17] Beasley et al(1986) contains a detailed historical analysis of the relative degree of risk and rate of return for a variety of investment alternatives.

$$C.V. = S.D. / Er.$$

where:
C.V. = coefficient of variation
S.D. = standard deviation of expected returns
Er. = expected average rate of return

The coefficient of variation thus measures the amount of risk per unit of expected return. As an example, let us assume we have two investment opportunities A and B. We know the riskless rate, the risk premium of investment A and the coefficients of variation (C.V.'s) of the two investments. The formula to determine the appropriate risk premium for an investment is:

$$Rd = Rr + [Ra \times (CV(b) / CV(a))]$$

where:
Rd = required rate of return
Rr = riskless rate
Ra = historical risk premium of investment A
CV(a) = coefficient of variation of A
CV(b) = coefficient of variation of B

If one also assumes that:
Rr = .03 percent
Ra = .08 percent
CV(a) = .20
CV(b) = .10.

Then:

$$Rd = .03\% + [.08\% \times (.10 / .20)] = .07\%$$

The risk premium applied to a beef feedlot operation should ideally be based on the coefficient of variation of feedlot returns in relation to the coefficient of variation of stock market returns. This is based on the assumptions that:

1. A normal, stable risk premium exists for the stock market portfolio such that the expected future risk premium can be measured by the average historical risk premium; and
2. A portfolio of stocks that has a similar risk exposure over time as the beef feedlot could be identified.

The determination of a coefficient of variation of the feedlot enterprise requires accurate data on feedlot returns over a extended historical period. Unfortunately, there is little reliable information of this type available.[88] A possible alternative method would be to compare the means and standard deviations of slaughter cattle and feeder cattle prices over a extended time period. This however, would still be inadequate to accurately measure the relative rate of returns and riskiness of cattle feeding. Due to these factors, the risk premium used in this research was based on the historical risk premium of the stock market portfolio.[89] The use of this risk premium was based on the assumption of similar risk exposure between the market portfolio and beef finishing operations.

There are two discount rates that will be used in this research.[90] These are:

1. Riskless Rate: Historical Prices

In this case, future beef prices and input costs are known with certainty over the planning horizon under consideration. This is equivalent to a world of "perfect knowledge" about future returns. The discount rate chosen should reflect the apparent risklessness of this type of investment. The rate of return on 60 day Government of Canada treasury bills was chosen as an appropriate riskless rate after the evaluation of several alternatives. Treasury bills of this type are considered to be a very safe and relatively riskless investment. Their low risk of default and short term to maturity mean that their rates of return are very stable. These types of treasury bills also have a term to maturity that is similar to the length of the production cycles of the beef finishing systems being analysed. The riskless rate was based on the expected rate of return on these treasury bills at the beginning of the planning horizon.[91] This is consistent with the feedlot manager's best estimate of a riskless rate over the planning horizon.

[88] The author tried several possible sources of information. In all cases however, the information was not sufficient to make a valid comparison.
[89] The market portfolio in this case was based on the T.S.E. "300" Composite Index.
[90] As previously mentioned the discount rate is expressed in nominal terms.
[91] This rate was 11.29 percent in October, 1982. Source: *Bank of Canada Review*, October, 1982.

II. Risk Adjusted Rate: Forecasted Prices

In this case, most input costs and livestock coefficients are assumed to be known with certainty. However, slaughter and feeder cattle prices were based on a price forecasting procedure. In any forecasting procedure there is a high level of inherent risk based on the accuracy and reliability of the forecasts. This is particularly true in the feedlot enterprise, since future slaughter and feeder cattle prices have a major impact on cattle feeding margins.[92] In this study, the assumption was made that the riskiness and risk premium of the stock market and beef feedlot are comparable.[93] The discount rate for the beef feedlot was [illegible] based on the riskless rate plus the historical risk premium of the market portfolio. The risk premium was determined by analyzing the risk premium of the T.S.E. "300" Composite Index and government treasury bills over a 20 year period from 1962 to 1981.[94] This data period was chosen since it was of sufficient length to provide a reliable indication of the historical rates of return of investment opportunities.[95] The mean (Rr) and standard deviation (S.D.) of the average annual percentage rates of return of several investment opportunities are illustrated in Table VI.VI. The returns on 1 to 3 year and 10 year Government of Canada Bonds are included for comparative purposes.

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[92] Gracey(1982) states that the most important determinant of cattle feeding profits is the future price of slaughter cattle.

[93] This was based on the assumption of no risk discounting in the determination of the futures market prices for beef cattle.

[94] *Bank of Canada Review* (1962 to 1981), and *Toronto Stock Exchange Fact Book*(1982).

[95] Shorter term evaluation is meaningless due to variations in average annual rates of return in the market portfolio.

TABLE VI.VI: ALTERNATIVE INVESTMENT RATES OF RETURN

INVESTMENT	Rr	S.D.
T.Bills	6.86%	3.61%
Bonds(1-3)	7.27%	2.94%
Bonds(10+)	7.96%	2.53%
T.S.E.	10.70%	17.10%

As illustrated in Table VI.VI, the expected average annual rate of return increases as the risk exposure of the investment increases. Treasury bills are considered a safe, riskless investment. Longer term government bonds have higher rates of return and increased risk exposure due to fluctuations in interest rates. The stock market offers the highest potential for profit and the highest risk exposure. This high level of risk exposure of the stock market is illustrated in the the standard deviation of its returns, when compared to the other investment opportunities. Based on this historical data, the risk premium of the stock market compared to treasury bills was 3.8 percent annually. This risk premium was added to the riskless rate to determine the risk adjusted rate. In this case the risk adjusted rate that was used was 15 percent.[96]

The discount rate that was used in the model could perhaps have been more accurately determined on a individual producer basis. Beef producers may have quite accurate historical returns information on their own operations. This information could more accurately reflect the risk exposure and risk premium required in individual beef finishing operations.

[96] This is based on a risk premium of 3.8 percent and a treasury bill rate (October,1982) of 11.2 percent.

VII. Analysis of Results

A. Evaluation of Beef Finishing Systems

Fixed Marketing and Optimal Replacement Strategy

In this strategy, the individual beef fininishing systems were evaluated on the basis of a fixed marketing strategy and optimal replacement strategy generated by the decision model. The optimal replacement decisions are based on historical beef prices. Since only optimal replacement decisions were determined by the model, this strategy can be viewed as being sub-optimal. The mean and standard deviation (S.D.) of the discounted value of the yearly gross margin per animal place are illustrated in Table VII.I:

TABLE VII.I: ANNUAL GROSS MARGIN-FIXED MARKETING STRATEGY ($ per head of capacity).

SYSTEM	I	II	III	IV
MEAN	$139.89	$127.81	$49.59	[illegible]
S.D.	$63.97	$76.21	$34.54	$[illegible].40

The mean gross margins of Systems I and II are higher than the indicated gross margins of the two more extensive finishing systems (System III and IV). There is a wide variation in the range of returns in each system, as indicated by the standard deviations.

The individual animal results for each system are illustrated in Table VII.II. There is a wide variation in the indicated levels of returns within all four systems. Generally animals with above average feed conversion and daily rates of gain have the higher gross margins in each system. It is interesting to note that in system IV, one animal had a gross margin of zero. The model will not make a decision to put an animal on feed unless a positive discounted level of return can be acheived. In this particular case, there was no expectation of a positive return at any period in the planning horizon.

TABLE VII.II: INDIVIDUAL ANNUAL GROSS MARGINS-FIXED MARKETING STRATEGY ($ per head of capacity).

SYSTEM I	SYSTEM II	SYSTEM III	SYSTEM IV
$280.01	$277.58	$118.94	$101.58
266.36	258.29	107.00	76.49
197.72	231.86	96.48	75.11
196.39	186.23	65.02	73.79
154.86	156.23	64.49	59.39
139.89	127.78	61.53	55.66
123.21	127.16	57.08	55.36
118.78	117.74	50.79	44.80
116.47	109.85	32.39	35.19
110.99	99.10	32.14	32.72
109.46	90.36	29.47	26.22
98.46	74.[illegible]9	24.75	23.27
96.76	57.74	17.31	18.17
89.34	57.40	15.24	15.80
69.84	54.72	14.33	12.03
69.67	18.80	6.62	0.00

* The returns are expressed on a per head of feedlot capacity basis over the first year of the planning horizon and are listed in decending order.

In order to test the hypothesis of no difference between the gross margins of the finishing systems, simultaneous confidence intervals were established for the mean gross margins of each system.[97] The confidence interval is used to determine if the true parameter (ie. differnce in mean gross margins between the beef finishing systems) is significantly different from zero. The confidence interval can be regarded as the set of acceptable hypotheses. Any hypothesis within the confidence interval (95%) is accepted, while any hypothesis outside the confidence interval is rejected. The null hypothesis to be tested is:

$U1 = U2 = U3 = U4 = 0$

where:
U1 = mean gross margin of System I
U2 = mean gross margin of System II
U3 = mean gross margin of System III
U4 = mean gross margin of System IV

This hypothesis implies that there is no significant difference between the mean gross margins of any of the beef finishing systems under this strategy. If the confidence interval is positive (ie. does not include zero), then one can conclude that there is a 95 percent chance that there is a difference between the two means and reject the null hypothesis of no difference. The results of these hypothesis tests for the annual gross margins of each system are illustrated in table VII.III:

[97] A detailed description of this test can be found in Wonnacott and Wonnacott (1984).

TABLE VII.III: TESTS OF SIGNIFICANCE-FIXED MARKETING STRATEGIES ($ per head of capacity).

TEST	SYSTEM II	SYSTEM III	SYSTEM IV
I	$12.08+/-70.22	90.29+/70.22	95.79+/-70.22
Sig.	NO	*YES	*YES
II		78.21+/-70.22	83.71+/-70.22
Sig.		*YES	*YES
III			5.50+/-70.22
Sig.			NO

*Significance: $P < .05$

[illegible] tests of significance indicate that Systems I and II have significantly higher annual gross margins than Systems III and IV. However, there was not a significant difference between either the returns in System I and System II, or in the returns between System III and IV.

Optimal Marketing and Optimal Replacement Strategy

In this strategy, the individual beef finishing systems were evaluated on the basis of the optimal marketing and replacement decisions generated by the decision model based on historical prices. The mean and standard deviations (S.D.) of the gross margins of each system are illustrated in Table VII.IV:

TABLE VII.IV: ANNUAL GROSS MARGIN-OPTIMAL MARKETING STRATEGIES ($ per head of capacity).

SYSTEM	I	II	III	IV
MEAN	$153.40	$128.14	$63.33	$46.57
S.D.	$64.24	$73.44	$55.74	$25.54

Systems I and II have higher yearly, mean gross margins than the other two less intensive beef finishing systems. The individual animal results of each system are illustrated in Table VII.V. As in the previous strategy there is a variation in the indicated gross margins within each system. This is largely a reflection of the individual physical and genetic attributes of each animal.

In order to test the hypothesis of no significant difference between the mean annual gross margins of the systems, simultaneous confidence intervals were calculated for each system. This procedure was the same as that followed in the first strategy. The results of these hypotheses tests are illustrated in Table VII.VI:

TABLE VII.VI: TESTS OF SIGNIFICANCE-OPTIMAL MARKETING STRATEGIES ($ per head of capacity).

TEST	SYSTEM II	SYSTEM III	SYSTEM IV
I	25.26+/-72.70	90.06+/-72.70	106.85+/-72.70
Sig.	NO	*YES	*YES
II		64.60+/-72.70	81.59+/-72.70
Sig.		NO	*YES
III			81.59+/-72.70
Sig.			*YES

*Significance: P < .05

TABLE VII.V: INDIVIDUAL ANNUAL GROSS MARGINS-OPTIMAL MARKETING STRATEGY ($ per head of capacity*).

SYSTEM I	SYSTEM II	SYSTEM III	SYSTEM IV
$293.45	$256.40	$222.09	$84.83
263.08	250.05	118.94	74.91
224.26	237.25	112.35	74.30
212.10	187.98	91.96	71.02
166.06	156.23	90.61	68.79
153.40	139.28	60.05	55.75
144.57	127.16	58.97	54.00
139.42	117.74	57.32	51.20
133.95	117.03	53.05	44.11
130.76	109.85	50.12	41.66
128.77	92.81	30.75	40.52
119.55	82.18	29.61	34.47
100.54	57.40	18.54	32.84
97.63	56.77	10.98	8.86
76.58	43.25	5.49	4.28
70.28	18.80	2.51	3.19

* The returns are expressed on a per head of feedlot capacity basis over the first year of the planning horizon and are listed in decending order.

From the tests of significance in Table VII.VI, one can conclude that System I (potatoes) has a higher annual gross margin than either System III or System IV. One can also conclude that System II (barley) has a higher annual gross margin than System IV. The other tests of significance yield inconclusive results.

Summary

The evaluation of both strategies indicate that system I (potatoes and forage) is superior, in terms of gross margins, to the two extensive forage based systems (III and IV). System II (barley and forage) has significantly higher gross margin than System IV under both decision strategies. System II also has a higher gross margin than System III under the fixed marketing decision strategy. The remaining tests of significance between individual beef finishing systems yield inconclusive results.

It is difficult to make comparisons among the results of the two strategies that were evaluated since the gross margins were only evaluated in the first year of the planning horizon. This method of evaluation underestimates the total benefits of the optimal marketing and replacement decisions over a series of production cycles (ie. planning horizon). However, one can make a comparisonsions of the two strategies, from an analysis of the returns of each system over the entire planning horizon. The length of the individual planning horizon will vary for each animal in each system. [9] The mean, standard deviation (S.D.) and percentage change in gross margin over the entire planning horizon (ie. four production cycles) for each system under the two strategies are illustrated in Table VII.VII:

[9]In this particular research, the length of the individual planning horizon varied from 104 to 192 weeks.

TABLE VII.VII: COMPARISON OF DECISION STRATEGIES OVER THE ENTIRE PLANNING HORIZON ($ per head of capacity).

SYSTEM	I	II	III	IV
FIXED				
Mean	$433.60	$333.03	$196.51	$184.63
S.D.	$173.08	$178.50	$115.99	$128.25
VARIABLE				
Mean	$457.93	$344.22	$260.34	$227.02
S.D.	$179.19	$180.72	$141.73	$136.98
Change	5.61%	3.39%	9.52%	10.20%

The means and standard deviations of the gross margins are from 3% to 10% larger than when returns are only evaluated in the first year (Table. VII.IV.), because of the longer time frame under consideration. There is an increase in the gross margins of all systems when the optimal marketing strategy is followed rather than the fixed marketing strategy. Systems III and IV, the forage based systems, had larger increases in the their gross margins than Systems I and II. This could be due to the higher daily rates of gain in the later marketing periods of these systems (III and IV), when compared to the earlier backgrounding periods. The results also point out that both optimal marketing and replacement decisions must be considered at each stage of the production process, if the full benefits of using a decision model of this type are to be realized.

B. Evaluation on a Continuous Feedlot Basis

A yearly accounting of a beef feedlot was conducted based on the following decision strategies:

1. Fixed Marketing and Replacement Strategy **(Fh)**, and
2. Optimal Marketing and Replacement Strategy **(Op)** based on forecasted prices.

Since this evaluation was based solely on a representative animal from each system, no comparisons were made between alternative finishing systems.[99] The hypothesis to be tested was that the use of a beef finishing decision model would yield increased returns (gross margin) when compared to fixed marketing and replacement strategies. It is unrealistic to think of beef producers as having "perfect knowledge" of future beef prices. The potential benefits to producers of using this model can only be realistically evaluated using forecasted beef prices. The results of thes evaluation for the fixed marketing and replacement strategy **(Fh)** and the optimal decision strategy using forecasted prices **(Of)**, are illustrated in Table VII.VIII:

TABLE VII.VIII: ANNUAL FEEDLOT RETURNS -FORECASTED PRICES ($ per head of capacity).

SYSTEM	I	II	III	IV
Fh	$166.50	$161.64	$124.27	$124.08
Of	$189.20	$174.89	$133.44	$129.38
Change(%)	13.63%	8.19%	7.38%	4.27%
Change($)	$22.70	$13.25	$9.17	$5.30

These results indicate that there is a 4 to 14 percent increase in yearly gross margins if the price forecasting strategy is followed. The yearly increase in dollars per head of feedlot capacity range from $ 5.30 to $ 22.70. These results using forecasted beef prices are quite encouraging particularly for the two intensive finishing systems (I and II). These two systems may perform better than the two extensive systems because of their shorter term production periods.[100] Generally the longer the finishing period in the beef feedlot, the less reliable are the longer term price forecasts. This is particularly true of the replacement decision which is based on long term slaughter cattle price forecasts.

[99] This is due to the variation in returns between animals in individual systems.
[100] Systems I and II require 36 weeks compared to 44 weeks in Systems III and IV.

— A comparison was also made of the kilograms of beef produced per year under the fixed decision (**Fh**) and price forecasting decision (**Op**) strategies. These returns are expressed on a per head of feedlot capacity basis and are illustrated in Table VII.IX:

TABLE VII.IX: KILOGRAMS OF BEEF MARKETED PER YEAR (kg. per head of capacity).

SYSTEM	I	II	III	IV
Fh	555.48kg	788.65kg	543.74kg	549.03kg
Op	578.54kg	711.15kg	493.45kg	482.84kg
Change(kg)	+23.06	-77.50	-50.29	-66.19
Change(%)	+4.15%	-9.82%	-9.25%	-12.06%

These results indicate that the yearly kilograms of beef produced under each system will vary depending on the decision strategy followed. The quantity of beef produced increased for System I under the price forecasting strategy. One can speculate, based on past analysis, that this was due in part to the profitability of this system compared to the other three finishing strategies. The kilograms of beef produced per year decreased in the other three systems with the price forecasting strategy. In these three systems, replacement decisions were made later in the year than in System I. and this resulted in less kilograms of beef produced per year. These three finishing systems had higher gross margins under the price forecasted strategy, even though less beef was produced per year in System II, III and IV. One can conclude from this analysis, that it is not always advantageous to operate a beef feedlot at full capacity in anticipation of positive future returns.

VIII. Summary, Conclusions and Recommendations

A. Summary

This thesis was directed towards two interrelated research objectives. The first objective was to develop an appropriately defined decision making framework to evaluate the economic returns from alternative beef finishing systems in Atlantic Canada. This was accomplished through the development of a multi-period programming model of beef finishing systems. The model was developed to provide a consistent economic evaluation framework that could be used to evaluate beef finishing systems over an extended time horizon. A comparison was then made of alternative beef finishing systems based on research trial data that was collected in the region. The model decision process attempted to simulate, as realistically as possible, the actual decision process of beef producers in the region.

The second objective was to develop a price forecasting mechanism for slaughter and feeder cattle prices that could be used in the decision model. This was accomplished through the use of a price forecasting procedure based on frequently updated futures market price estimates. This price forecasting procedure was then adapted to reflect the actual prices of slaughter and feeder cattle in the region. The decisions generated by the model, using forecasted prices, were then compared to returns generated from fixed marketing and replacement strategies.

The development of the beef finishing model encompassed many factors which affect the producer decision process. These include such factors as: nutritional requirements and growth characteristics of beef cattle, the role of time in the decision process, the determination of variable costs of production, the formation of producer price expectations, and the influence of risk on the decision process. Throughout this study, the author attempted to learn as much about the actual producer decision proces as possible. The approach followed was similar to that advocated by Burt (1982), who states:

> In emperical agricultural economics research, the objective is to learn much more about a dynamic process than merely an optimal solution path starting from some initial state. (p.382)

B. Conclusions

The statistical evaluation of the economic results of the alternative beef finishing systems indicate that in several cases there is a significant difference in their respective gross margins. The intensive finishing systems (Systems I and II) generally had higher gross margins than the more extensive finishing systems (Systems III and IV). This difference can be partially attributed to the higher opportunity costs of time, the lower feed conversion ratio and lower rate of daily gain of these extensive systems. This conclusion is important due to the increased emphasis on forage production in the region. There is a variation in returns within individual systems depending on the the physiological characteristics of the beef animal. It is difficult to draw conclusions about the profitability of a particular system, since returns are based only on the expected gross margin after variable costs of production are accounted for. The level of return in each system is also dependent on the particular discount rate chosen. Generally the higher the discount rate, the less attractive are the extensive finishing systems.

The second major conclusion that can be drawn is that the level of returns based on the beef finishing model decisions are higher than the level of returns based on fixed marketing and replacement strategies. These results indicate the possible benefits to beef producers of using decision models of this type based on forecasted beef prices. The price forecasting technique that is followed is similar to the rational price expectations approach of the beef producer. This is very important in promoting the use of this type of decision model amongst beef producers.

C. Recommendations

The beef finishing model used in this study is a computer oriented approach to profit maximization over a extended time horizon. In the process the physical, biological and economic criteria of each production system can be accurately described. The procedure provides a useful decision aid to beef producers who want to determine:

1. When to market animals;

2. When to purchase replacement feeders, and
3. What type of ration to feed.

It would seem that with these types of attributes that dynamic programming could be used more extensively to model agricultural production processes. However, dynamic programming techniques have been used in very few North American agricultural economics research studies in the last ten years. The major disadvantage of the use of dynamic programming in agriculture is its requirement of extensive data on livestock physiological and nutritional coefficients at each stage in the production process. It is often quite expensive and time consuming to acquire research data of this type. However, if the ultimate goal of the reseacher is to provide livestock producers with technically accurate and economically relevant information, then the dynamic programming procedure should be used more extensively in agricultural economics research.

The price forecasting techniques based on futures market information, that were used in this research, provide reasonable estimates of subsequent cash prices for beef cattle. Procedures of this type provide future price information that is:

1. determined by market interaction,
2. representative of a particular commodity,
3. readily accessable to producers
4. easily updated, and
5. consistent with rational price expectations theory.

In some research applications, price forecasting procedures of this type would seem to be a practical and relatively inexpensive alternative to more elaborate econometric forecasting models.

The choice of a discount rate or risk adjusted rate has a major impact on the viability of any enterprise. In many agricultural economics studies, the choice of a particular discount rate is not specifically determined by the degree of risk that is inherent in the production process. The author recommends that more research should be devoted to the determination of appropriate procedures to determine discount rates for various agricultural production processes.

The final recommendation is that agricultural decision models, such as the one used in this study, should be as realistic as possible in describing the actual system under consideration. Models of this type should be in a form that is readily comprehensible to livestock producers and extension workers, while still maintaining the essential elements of the production system under consideration.[101] This is essential if agricultural producers are to take advantage of research of this type.

D. Needs for Future Research

In the course of this study the following areas were identified as requiring further research:

1. There needs to be further research into the actual level of historical returns and the riskiness of beef finishing (feedlot) operations. This would provide more accurate information to determine the level of return that is required in operations of this type. This could form the basis of a more probabilistic approach to the modelling of expected producer returns. The evaluation of beef finishing systems in this research has been restricted by a lack of information of this type.
2. The futures market for beef cattle may provide an effective method to forecast subsequent cash prices. However more research needs to be conducted into how these futures market price estimates are formed and their accuracy over an extended historical period. In addition the relationship between U.S. futures market prices and subsequent Canadian beef prices should be evaluated. This is particularly important since there is no Canadian futures market for beef cattle.
3. While the beef finishing model used in this thesis is based on fixed feeding strategies, a linear programming sub-routine to determine least-cost rations could easily be included in

[101]Burt (1982) states:

The primary objective in all modeling is to capture the essential aspects of the phenomenon under study, and yet keep the model as simple as possible. (p.382) the model. This would be beneficial in beef finishing operations where there is a wide range of alternative feeds available.

4. The results of this study are somewhat limited because of the lack of Atlantic Canada data on slaughter and feeder cattle prices. Information of this type would provide much more accurate results.

5. Price forecasting models based on futures market price information would perhaps provide more accurate [illegible] for shorter-term finishing rations than those evaluated in this research. All four systems that were evaluated [illegible]dered as long-term in relation to many of the beef finishing systems in major beef production regions of North America. Decision models of this type may also have some application to hog finishing systems, which are generally of shorter duration than beef finishing systems.

6. The evaluation of alternative marketing options for beef cattle could be enhanced if more accurate information were available on carcass grades at different weight and age classes. This is particularly relevant in Atlantic Canada because of the large percentage of B and C grade carcasses.

Finally, research of this type requires close cooperation between physical and social scientists if accurate results are to be acheived. This is important if the researcher is to fully understand the agricultural process which he is attempting to model and achieve realistic results.

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