AN ANALYSIS OF MACHINERY INVESTMENT/DISINVESTMENT DECISION MAKING USING VARIABLE USAGE REPLACEMENT MODELS

By

LAWRENCE LANG FALCONER

Bachelor of Science in Agriculture

Oklahoma State University

Stillwater, Oklahoma

1978

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1980

AN ANALYSIS OF MACHINERY INVESTMENT/DISINVESTMENT DECISION MAKING USING VARIABLE USAGE REPLACEMENT MODELS

Thesis Approved:

Alan E. Baquet
Thesis Adviser

Harry P. Mapp, Jr.

James N. Trapp

Norman N Durham
Dean of the Graduate College

PREFACE

This study is concerned with the analysis of farm machinery complement replacement decisions for variable rates of machinery use. A systems model containing linear programming, machinery cost calculation and investment/disinvestment decision subsystems is used to examine the effects of variable output prices and yields, varying discount rates and changes in machinery valuation on the machinery complement replacement problem.

The author wises to express his appreciation to his major adviser, Dr. Alan E. Baquet, for his assistance with this study. Appreciation is also expressed to the other committee members, Dr. Harry P. Mapp, Jr. and Dr. James N. Trapp, for their suggestions on the final manuscript.

Many thanks are given to Mrs. Judy Ivy and Mrs. Lori Farris for the typing of the rough draft and to Mrs. Sandi Ireland for the typing of the final manuscript.

Special thanks go to my good friends Mike Shields, Tom Harris, Gregg Parvin and Mike Woods for their help with classes and this paper, and in general, making my Master's program bearable.

Most of all, gratitude is expressed to my parents, Mr. and Mrs. W. L. Falconer, without whose help and encouragement, this study would have been impossible. This study is dedicated to them.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

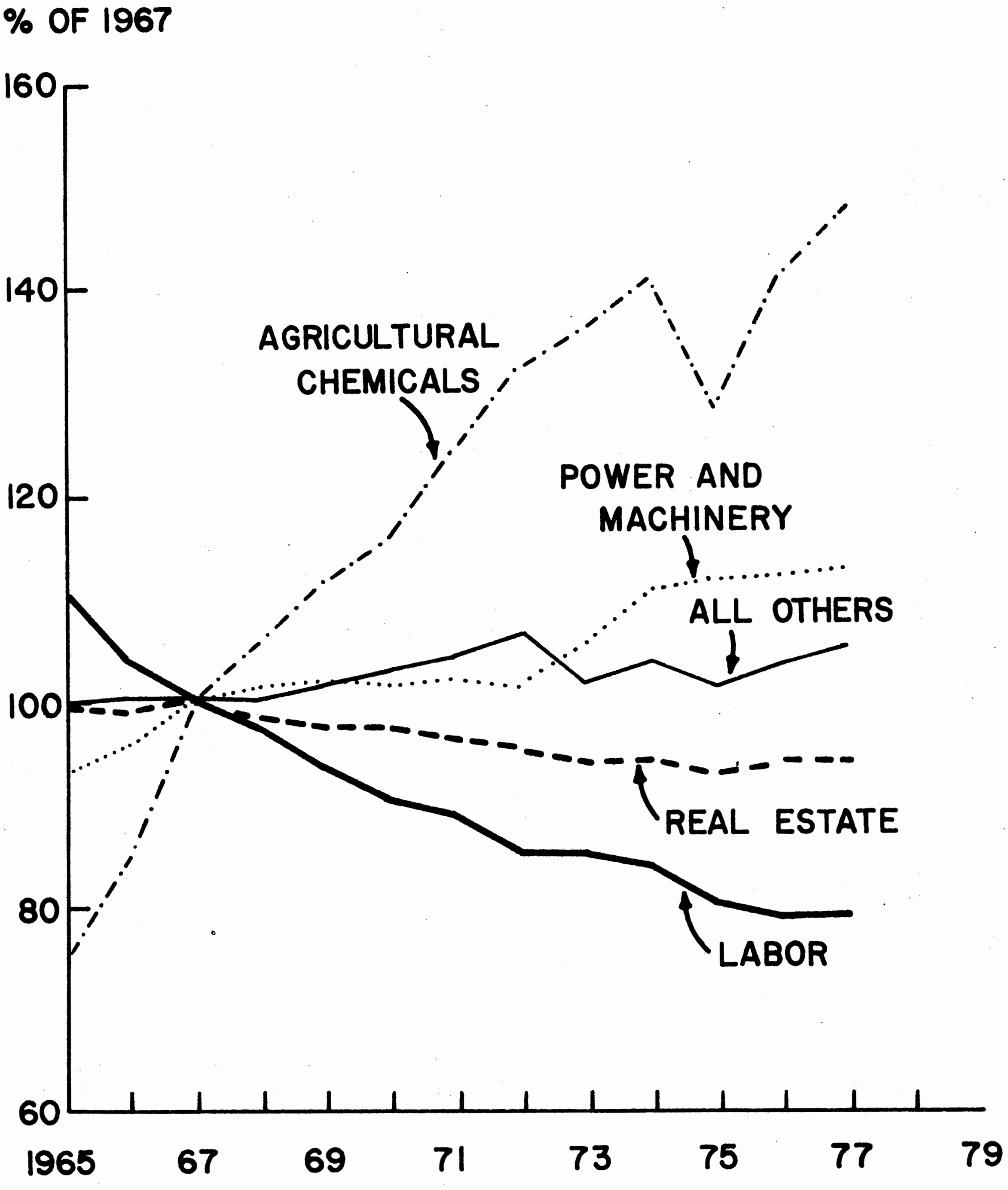
CHAPTER I

INTRODUCTION

The relation of durable assets to production efficiency, supply response, and farm income is considered important in agricultural economic analysis (Edwards, 1959). Agricultural interest in durable asset investment/disinvestment theory is also important. The structure of the farming industry has probably been shaped as much by the tractor and its complements than by any other input. The real volume of farm inputs was nearly the same in 1977 as in 1927 (Tweeten and Huffman, 1979). However, during these 50 years farm output increased 133 percent.

A key element in this increasing productivity is the substitution of profitable and productive capital inputs purchased from the non-farm sector for farm labor (Figure 1). The ratio of farm machinery prices to farm wage rates increased 38 percent from 1945 to 1965 (Figure 2). However, during this period productivity of farm machinery measured by the elasticity of production increased dramatically in relation to that of farm labor (Table I).

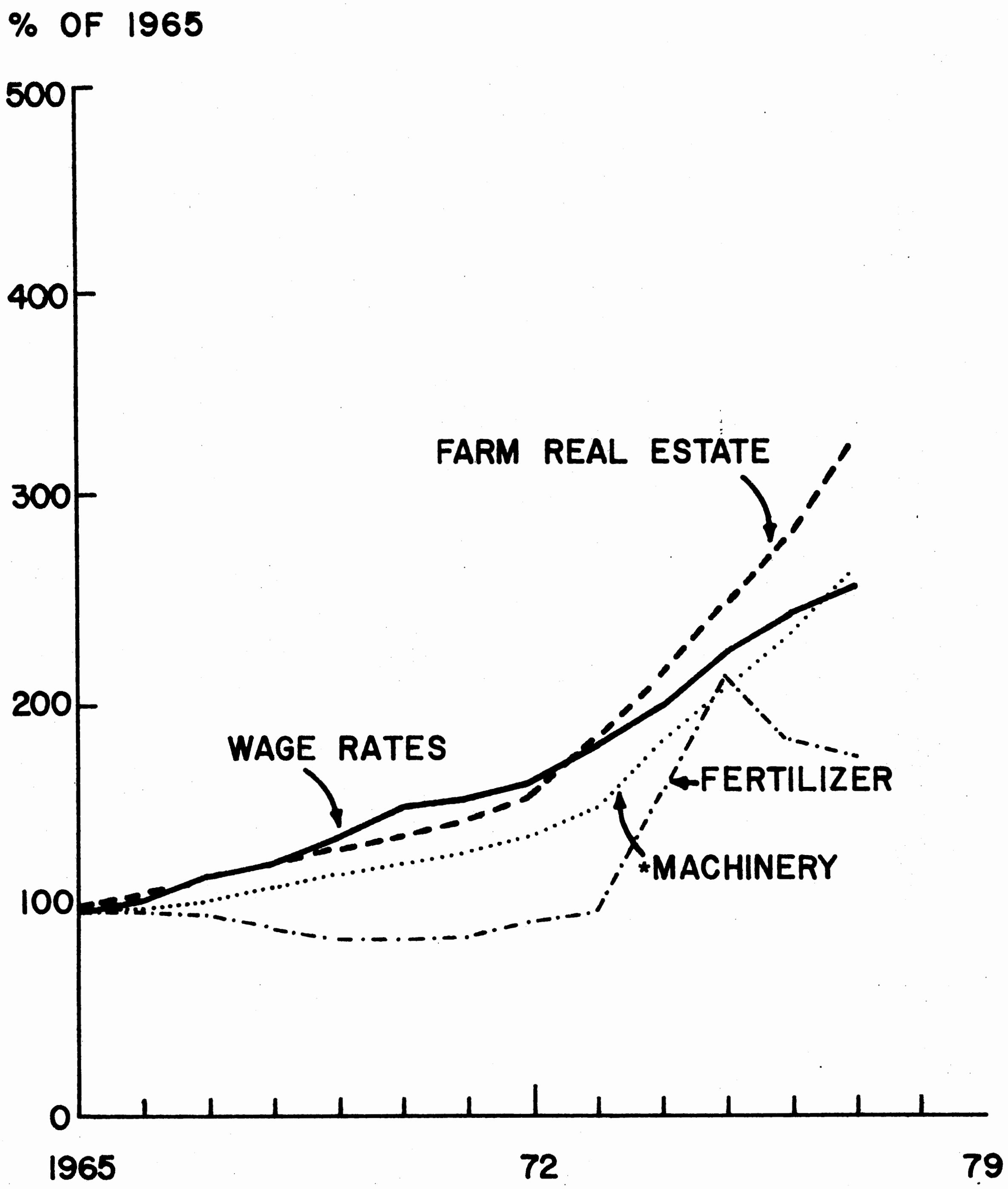
Organizational management is a very critical element for the small and moderate size farms who are competing with large farms for economic survival. As technology, specialization and changes in production and marketing arrangements extend the industrial processes to the farm, the returns to organizational management have increased relative to the returns to the traditional type of operational management. Investment



1977 Preliminary

Source: U. S. Department of Agriculture (November 1977, p. 8).

Figure 1. Use of Selected Farm Inputs



* Tractors and self-propelled machinery. 1977 preliminary.

Source: U. S. Department of Agriculture (November 1977, p. 9).

Figure 2. Prices of Selected Farm Inputs

and/or disinvestment in durable assets is an important part of organizational management.

TABLE I

ESTIMATED ELASTICITIES OF PRODUCTION FOR SELECTED FARM INPUTS IN VARIOUS TIME PERIODS

Input	Period or Year			
	1912-21	1932-41	1952-61	1970
Fertilizer and Lime	.02	.03	.04	.13
Labor	--	.35	.29	.16
Machinery	.08	.06	.09	.12
Real Estate	.34	.24	.24	.20

Source: Tweeten and Huffman (1979).

The Problem

Durable assets are multiperiodic inputs of production. Therefore, a durable asset can contribute a major part of its services to future instead of current production. Most static theories of production economics treat the services of durable assets as stock variables that generate a fixed amount of services per unit of time.

Fixing the amount of services extracted from a durable asset per unit of time is contrary to most typical farming situations. A farm manager often has the option to vary the flow of services extracted from an asset. For example, if the price of wheat was expected to drop substantially, then one would expect a wheat drill to be used less than if the price of wheat was expected to increase substantially. Only the current flow of services from the wheat drill would belong as an input in the production function for wheat. Thus, the flow of services from a durable asset is seldom constant over time.

A model of the firm that takes this stock-flow conversion problem into account would provide more precise information applicable to many farm problems. Agricultural producers might use these results to better maximize current profits and present value of their machinery complements. Farm managers might improve their estimates of machinery purchases used in whole farm planning.

Varying levels of machinery use and maintanance per production period will also have an effect on the expected life of the machine. Since varying use and maintenance levels effect the expected life of the asset and if the machines' expected life is critical to the investment/disinvestment decision, then more reliable calculations of the expected life of the machine based on varying use and maintenance levels can lead to optimal decisions for machinery investment or disinvestment.

Objectives and Procedures

The overall objective of this study is to arrive at an optimal investment/disinvestment pattern for farm machinery complements by application of varying usage replacement models to a typical farm situation in northcentral Oklahoma. The model is developed in a general fashion as to facilitate arriving at optimal investment/disinvestment patterns for machinery complements in other areas. Other specific objectives include:

1. Creation of a computer program to analyze investment/disinvestment patterns for farm machinery complements.
2. Examination of the effects of varying discount rates on equipment investment decisions.
3. Determination of the effects of variable yields and output prices on equipment replacement decisions.

Chapter II contains a discussion of production theory related to fixed assets, the stock-flow conversion problem and replacement models developed to account for varying use of assets during different production periods. Chapter III contains the model specifications and assumptions used in this study. Chapter IV is a presentation of the results of the study along with an analysis of the outcomes. A summary and suggestions for further research are presented in Chapter V.

CHAPTER II

REVIEW OF FIXED ASSET THEORY AND REPLACEMENT MODELS

The analysis of durable asset investment/disinvestment decision making hinges on (a) the definition of a fixed asset, (b) a theory for valuation of fixed assets, and (c) a behavioral principle established to guide the decision-maker (Edwards, 1959). In this chapter we will define fixed assets, develop an appropriate theory for fixed asset valuation and review two durable asset replacement models. Both models incorporate the behavioral principle of profit maximization which will be applied in this study.

Definition of a Fixed Asset

In most discussions of durable asset theory using neoclassical analysis, asset fixity definitions are tied to length of run considerations that involve the ability of the firm manager to vary quantities of durable inputs (Leftwich, 1976). However, when market prices are not applicable for solving resource reallocation problems, neoclassical analysis does not adequantely handle the principles of opportunity cost (Johnson and Quance, 1972).

In his examination of the supply response of United States agriculture to output price variations, Johnson (1959) related durable asset fixity to the differentials in acquisition and salvage prices for durable assets that arise from transportation and ownership transfer costs.

A durable asset can be said to be fixed to the firm when its earning power is too low to justify purchase of more of the durable at the market price for acquisition and too high to justify its liquidation at the market value for salvage. This economic definition of asset fixity will be used in this study.

The Stock-Flow Problem

Static production economics treats the services of durable assets as flow variables and does not consider the economics of generating service flows from stocks of durable assets (Baquet, 1978). For example, a farmer's machinery complement at a certain period of time would be considered a stock variable. The machine hours this machinery complement is able to generate in each production period would be defined as a flow input for the farmer's production process. The problem facing the farmer is how much of his machinery stock should be changed into hours of machinery use so that the farmer's plowing, planting and harvesting can be carried out.

Static theories of production economics recognize the farmer's problem of converting his machinery stock to flows of hours of machinery usage, but assume a constant rate for converting the stock variable to flow variable (Edwards, 1959). If we alter the assumption of a constant usage rate, the value of the service flow becomes important to the investment/disinvestment decision.

The value of the flow of durable asset services for a production period would be approximated in a perfect market by the rental price of the asset per unit of time (Yotopoulos, 1967). This type of data is not usually available for machinery services, so a need for readily available proxies of such services are needed in economic analysis of production. In most empirical research, capital inputs are measured as gross services employed or services netted by a depreciation factor, both stock concepts.

The difference between service flows and stock concepts of capital inputs can be highlighted with the following example (Yotopoulos, 1967). Assume that a durable asset yields a constant stream of annual services ($\bar{R}$) over a life of T periods and has no salvage value. The relationship between the original value of the capital stock and the value of the service flow, given a discount rate r, can be shown as:

$$V_0^T = \frac{\bar{R}}{r}\,\frac{e^{rT} - 1}{e^{rT}} \qquad (2\text{-}1)$$

where

V_n^T = value of the capital stock n in time period T assuming no deterioration in the service flow,

R = value of the service stream per period, and

r = discount rate.

This example is illustrated in Figure 3.

Now, assuming that another identical asset exists for the firm except with a life span of T-1 periods instead of T, then the following equation becomes applicable:

$$V_1^T = \frac{\bar{R}}{r}\,\frac{e^{r(T-1)} - 1}{e^{rT}} \qquad (2\text{-}2)$$

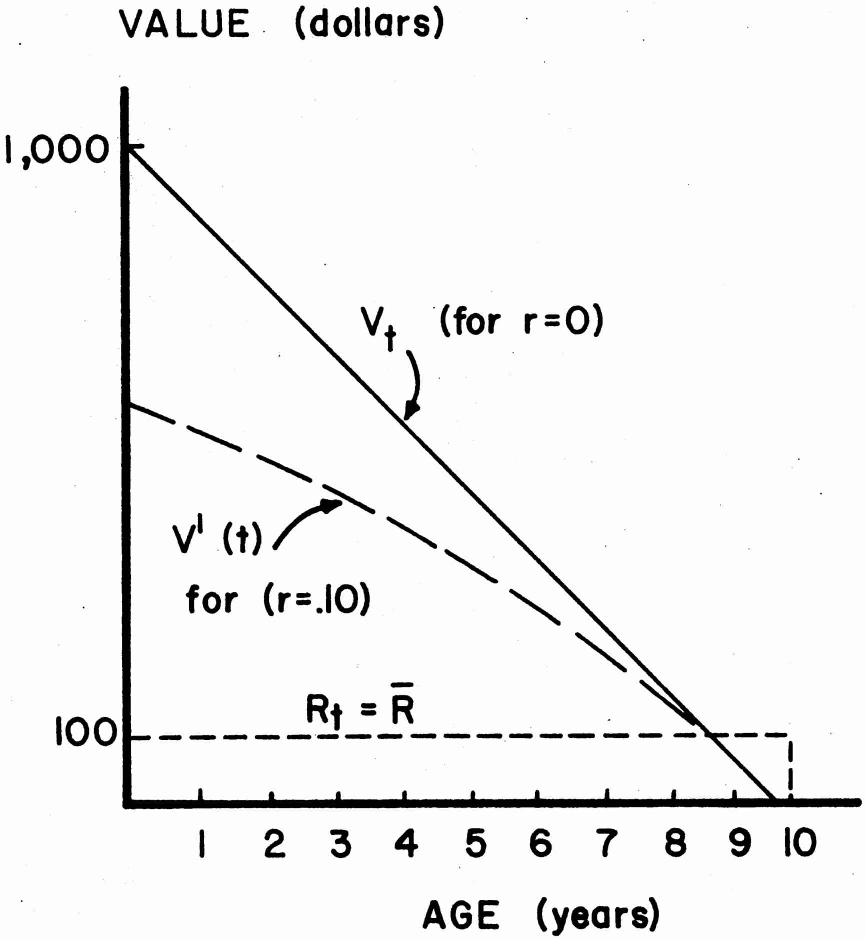


Figure 3. Assets with Regular Stream of Services

Given T and r in both cases a comparison of equations (2-1) and (2-2) can be made as follows:

$$\frac{V_0^T}{\bar{R}} > \frac{V_1^T}{\bar{R}}$$

Therefore, the use of the capital stock concept places more weight on the longer lived asset.

A comparison between the stock and flow concepts can be made by now assuming that the flow of capital services derived from the asset deteriorates over time until the flow becomes zero and the asset is junked with no salvage value. Assuming a straight line deterioration (s) of the service flow, $R(t) = Re^{-st}$, the relationship between the service flow and capital stock is:

$$W_0^T = \frac{R}{r+s} \frac{e^{(r+s)T} - 1}{e^{(r+s)T}} \qquad (2-3)$$

and

$$W_1^T = \frac{R}{r+s} \frac{e^{(r+s)(T-1)} - 1}{e^{(r+s)T}} \qquad (2-4)$$

where

W_n^T = value of the capital stock n in time period T assuming a deterioration of the service flow, and

s = constant assumed rate of deterioration in the service flow.

The following comparison can now be made between equation (2-3) and (2-4).

$$\frac{W_0^T}{R} > \frac{W_1^T}{R}$$

Comparing (2-1) and (2-2) to (2-3) and (2-4), given the time period, discount rate, and rate of service flow deterioration,

$$\frac{V_0^T}{\bar{R}} > \frac{V_1^T}{\bar{R}} > \frac{W_0^T}{R} > \frac{W_1^T}{R}$$

which is illustrated in Figure 4. The ratio of capital stock to flow decreases with age and at any time is greater for assets with longer lives or more recent models of the same asset.

The lack of constant proportionality between the stock and flow ratios, even under the restriction of a proportional (s) decrease in the service flow, would imply that the service flow concept is conceptually more desirable than the stock concept. Therefore, this study will be based on a service flow valuation concept.

Replacement Models

Perrin (1972) develops a generalized replacement model under the assumption of perfect knowledge. Perrin compares the gains from keeping the machine for another production period with the opportunity gains from purchasing a replacement machine and using it in the same period.

The replacement problem can initially be addressed in continuous-time variables for simpler algebraic analysis. The machinery manager is assumed to desire maximization of the present value of the stream of residual earnings from the productive process associated with the machine. The replacement problem is to choose a replacement age for the initial machine that maximizes this present value.

In Perrin's (1972) discussion the term "defender" for an asset that is already in place and the term "challenger" for an asset that can be

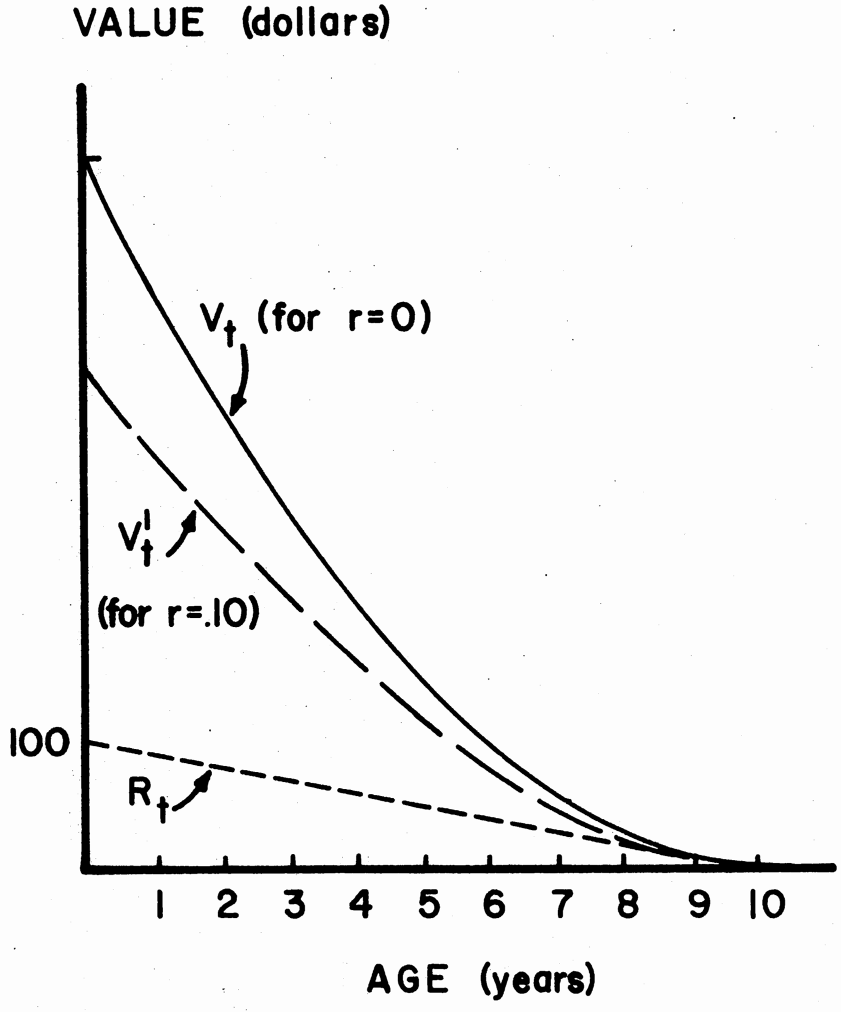


Figure 4. Assets with Irregular (Declining) Stream of Services

purchased to replace a defender are used. Assuming that initially there is no defender in use and that if the challenger is acquired it will be self replaced by an identical asset, the present value of the stream of earnings is:

$$C(b,s,1) = \int_{b}^{s} R(t)e^{-\rho(s-b)}\,dt + M(s)e^{-\rho(s-b)} - M(b) \qquad (2\text{-}5)$$

where

R(t) = net return in period t,

ρ = in (1+r) which is the interest rate that if compounded continuously will give an annual growth rate of r,

t = integer number of years,

M(a) = market value of the asset at age a, and

C(b,s,m) = present value of a stream of net earnings from a challenger purchased at age b and replaced at age s, by a series of m identical challenges.

To arrive at a replacement age which maximizes the present value for only the first asset, the first derivative of equation (2-5) with respect to replacement age s should be taken and set equal to zero (Faris, 1961). This procedure yields the equation:

$$R(s) + M'(s) = \rho M(s) \qquad (2\text{-}6)$$

where M'(s) is a first derivative that indicates the change in the market value of the durable for year s. The value maximizing replacement age is the point at which the residual earnings plus the changes in asset value equals the interest which could be earned by selling the asset.

In most cases it is more appropriate for the manager to attempt to maximize the present value of the entire stream of earnings rather than the stream of returns associated with only the first asset (Perrin, 1972).

Assuming that assets will be acquired at age zero, the present value of the entire stream is:

$$C(0,s,\infty) = \frac{1}{1 - e^{-\rho s}} C(0,s,1) \tag{2-7}$$

which expresses the present value of an annuity of the amount equal to the stream of net returns. To maximize the present value of the entire earnings stream the derivative of equation (2-7) is taken with respect to replacement age and set equal to zero yielding:

$$R(s) + M'(s) = \rho(M(s) + C(0,s,\infty)) \tag{2-8}$$

which, as opposed to the previous criterion (2-6), expresses the opportunity cost of delaying the earnings obtained from future assets. The right hand side of (2-8) represents an "average" opportunity return concept that is appropriate for replacement decisions.

In dealing with actual replacement decisions most firm managers have access to only periodic net revenues and market values. This changes the maximization problem from a continuous to a discrete nature. When dealing with a discrete time problem the decision criteria becomes:

$$R(s + 1) + \Delta M(s + 1) = \frac{r}{1 - (1 + r)^{-s}} V(s) \tag{2-9}$$

where

$$V(s) = \int_{o}^{s} R(t)e^{-\rho t}\, dt + M(s) - M(o)$$

which is the present value of the next asset cycle at the moment of replacement (Perrin, 1972).

However, use of a marginal criterion such as (2-9) for optimizing in a discrete situation presents certain problems. This criterion is not likely to be met exactly for an integer number of periods, and selection of the most nearly satisfying period can lead to a one period error in arriving at the value maximizing solution.

From a computational standpoint it is about as easy to evaluate the following present value directly,

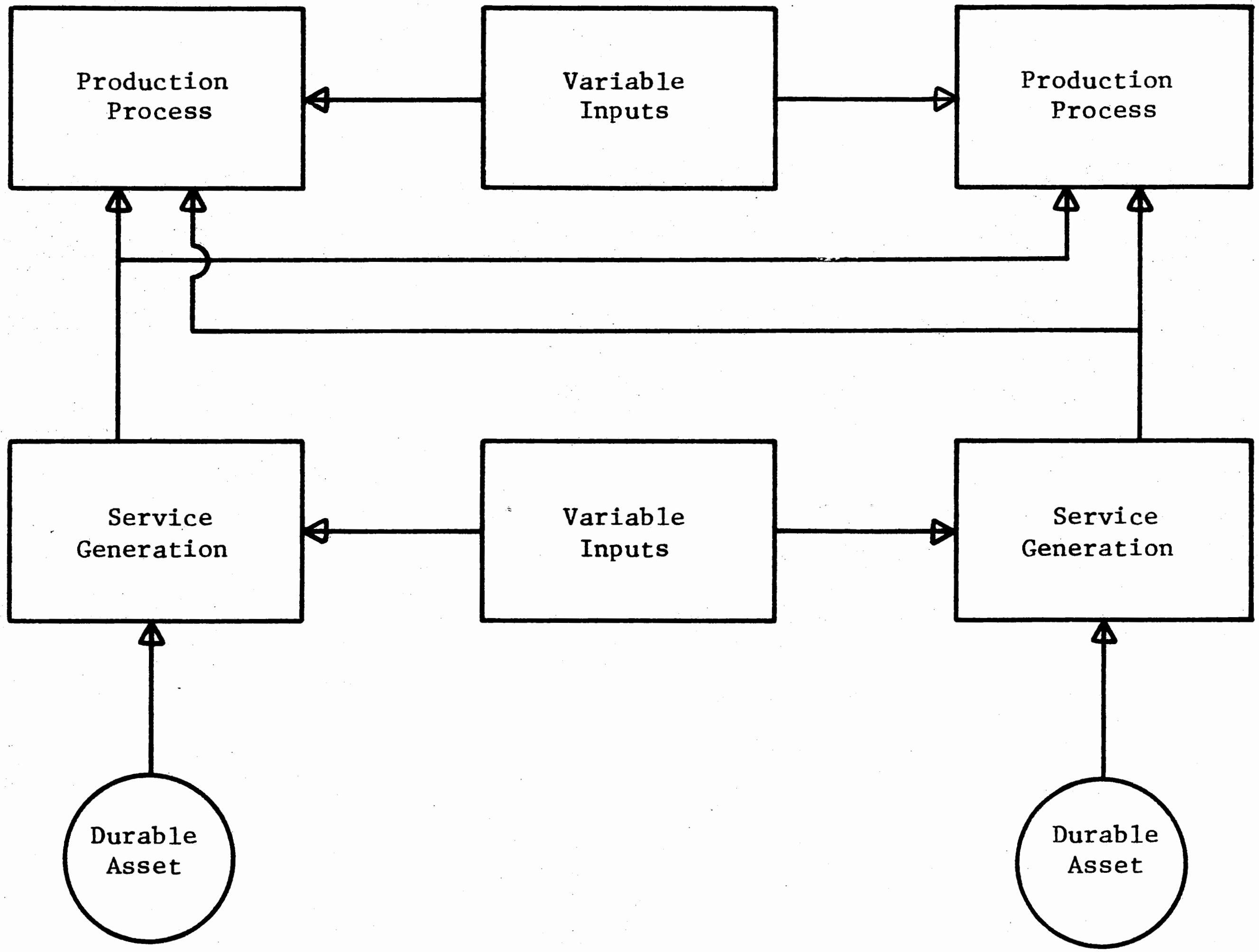
$$C(0,s,\infty) = \frac{1}{1 - (1 - r)^{-s}} V(s) - M(s) \tag{2-10}$$

and given that the marginal criterion may result in a one period error, calculation of present values from (2-10) will provide a more accurate result.

Baquet (1978) develops a model that considers the flow of services from durables to be a component in a vertically integrated production process, linking the production process to investment and disinvestment decisions made by the firm. Service flows from the durable are specified at one level, with this flow used to determine output (Figure 5). The reflected pattern of asset use helps to determine the life of the asset. In the model, determination of the optimal lifetime of the durable determines the time period in which the firm should dispose of the durable asset.

In order to apply the disinvestment criteria to determine the optimal length of asset life, Baquet expresses the durable assets value in use as:

$$NRD_k(\theta_k^*, T_{Dk}) = PVS(T_{Dk}) + S_k(T_{Dk}) \tag{2-11}$$



Source: Baquet, 1978.

Figure 5. Two Tiered Vertically Integrated Production Process

where:

$NRD_k(\theta^*_k, T_{Dk})$ = the net return of durable asset k, with the optimal service flow θ^* with a physical life of the durable T_{Dk}.

$S_k(T_{Dk})$ = salvage value of durable asset k, and

$PVS(T_{Dk})$ = the present value of the net income generated by the durable in its last period of life.

The investment decision criteria is to equate the additions to $PVS(T_{Dk})$ with reductions in $S_k(T_{Dk})$, with the optimal life of the durable being the point where the additions to the present value stream in the upcoming period are less than reductions in the salvage value that will occur in the next production period.

For this study we will employ points developed by both Perrin (1972) and Baquet (1978). While the Perrin model utilizes net returns to the durable asset in its decision criterion, the model does nothing to specify the nature of the production process generating these returns. Baquet allows for the future time pattern of utilization of the durable to be determined within the model. This allows incorporation of the important linkage between production and replacement decisions into this study. By combining the present value decisions criterion developed by Perrin with the service flow determination model developed by Baquet this study will create an investment/disinvestment decision model to arrive at optimal replacement policies for machinery complements.

CHAPTER III

MODEL SPECIFICATION

In investment/disinvestment decision theory there is a strong link between the production process utilizing the services of the durable asset and the machinery investment/disinvestment decision itself (Baquet, 1978). The model developed in this study is constructed so as to incorporate this linkage between production decisions and durable asset investment/disinvestment decisions. A systems model with three major components is used to represent the firm's machinery investment/disinvestment decision making process (Figure 6).

Linear Programming Subsystem

Linear programming is a planning method useful in making decisions when large numbers of alternatives are available. Since the major thrust of this study is in the area of machinery investment/disinvestment decision making, the number of cropping alternatives and resource constraints has been kept small to allow greater emphasis to be placed on the investment/disinvestment decision process.

The Mathematical Programming System-Extended (MPSX) is utilized in the model. The MPSX routine is efficient in evaluating the profitability of activities. The model is constructed to allow for changing resource requirements and crop prices over time, which facilitates the use of

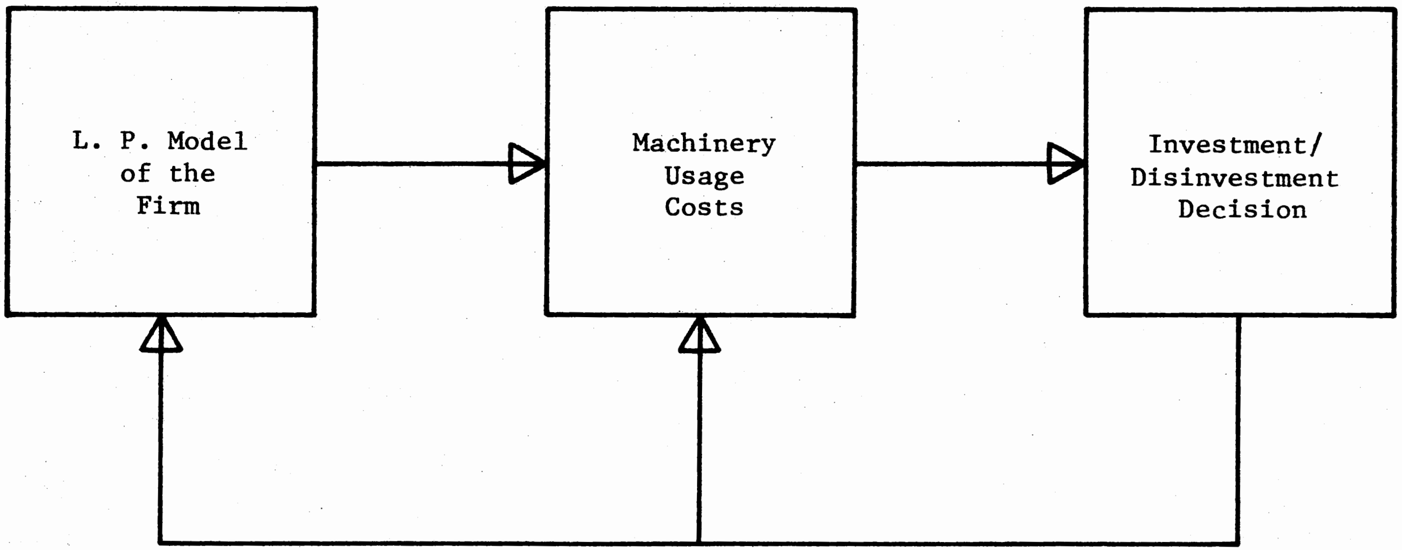


Figure 6. Diagram of the Investment/Disinvestment Decision System for Replacement Patterns

input from historical budgets created by the Oklahoma State University Enterprise Budget Generator.

Machinery Repair Cost Calculations Subsystem

The machinery cost calculations used in this study are based on equations approved by the American Society of Agricultural Engineers and appearing in the 1977 Agricultural Engineers Yearbook. Repair costs are described in the Agricultural Engineers Yearbook as "expenditures necessary to keep a machine operable due to wear, part failures and accidents". While the costs of restoring a machine are highly variable, normal wear deterioration is directly related to use. Maintenance costs are also directly related to use.

The equation used to compute the total accumulated repairs is:

$$\text{Total Accumulated Repairs} = \text{RC1} \times \text{RC2} \times \text{PERCENT LIFE}^{(\text{RC3})} \qquad (3\text{-}1)$$

where RC1 is the ratio of total accumulated repairs (TAR) to the initial list price of the machine. RC2 and RC3 are repair coefficients estimated from actual machinery cost records that go together to determine the shape of the machinery repair rate curve.

In calculating PERCENT LIFE to use in the TAR equation this study departs from the normal procedure that is presently employed. In the Oklahoma State University Enterprise Budget Generator the following calculation is used.

$$\text{PERCENT LIFE} = \frac{(\text{YEARS OWNED} \times \text{HOURS USED ANNUALLY})}{\text{HOURS OF LIFE}} \qquad (3\text{-}2)$$

This equation implies that the machine will be used a fixed number of hours each production period. A more realistic assumption would be to allow a varying amount of machine use each production period.

To incorporate such an assumption into this study the following form of the original equation will be used.

$$\text{PERCENT LIFE} = \frac{\sum_{i=1}^{n} \text{HOURS USED ANNUALLY}}{\text{TOTAL HOURS OF LIFE}} \qquad (3\text{-}3)$$

where i = 1, ..., n and n is the present production period. Total hours of machine life are obtained from the 1977 Agricultural Engineers' Yearbook (Table II). Total hours or life represents the expected hours of usage available from the machine before major maintenance will be required. The economic life of a machine for a particular firm may be considerably shorter than the total hours of the physical life of the machine.

TABLE II

PREDICTED CROPPING PATTERN IN ACRES FOR THE 1973 BASED PLANNING HORIZON

Year	Wheat Acres	Grain Sorghum Acres	Alfalfa Acres	Total Acres
1973	170.42	514.52	50.00	734.94
1974	170.42	514.52	50.00	734.94
1975	100.00	581.36	50.00	731.36
1976	196.52	100.00	103.48	400.00
1977	100.00	581.36	50.00	731.36
1978	242.92	100.00	97.43	440.35
1979	242.92	100.00	97.43	440.35

When the Percent Life expression of equation (3-3) is inserted into the TAR equation, the result will be in line with the varying usage per production period assumption.

Investment/Disinvestment Decision Subsystem

The investment/disinvestment decision under certainty is based on the marginal principle of comparing the gain from keeping the current asset for another production period with the opportunity gains that could be realized from a replacement asset during the same period. Perrin (1972) derives replacement principles in a general manner that can be readily adapted to decisions involving capital equipment.

If the objective is to maximize present value, the asset should be replaced when the net flow of benefits from the initial asset over time equals the flow which could be realized by immediate replacement. Perrin represents the replacement principle as:

$$C(0,s,\infty) = \frac{1}{1-(1+r)^{-s}} V(s) - M(s) \qquad (3\text{-}4)$$

where

$$V(s) = \int_{o}^{s} R(t)e^{-\rho s} + M(s) - M(o)$$

and

$\rho = \ln(1 + r)$ = the interest rate at which, when compounded continuously, results in an annual growth rate of r,

t = integer number of years,

$M(a)$ = the market value of the asset at age a, and

$R(a)$ = the flow of residual earnings from the process where the asset is age a.

System Operation

For determination of the optimal investment/disinvestment policy the system compares the machinery complements' value in use with its acquisition and salvage prices. To arrive at the machinery complements value in use, the system must calculate the optimal rate of services to extract from the machinery complement during each production period. The system contains a linear programming model of the firm which is used to determine the cropping pattern that maximizes net returns to machinery for each production period over the given planning horizon (Table II). The cropping pattern for each period is selected given fixed technological coefficients derived from Oklahoma State University Enterprise Budgets for the base period of the planning horizon (Table III).

Machine usage requirements derived for each production period by multiplying the acreages of recommended crops recommended in the linear programs (Table II) by the machinery requirements per acre which are available from Oklahoma State University Enterprise Budgets (Table IV).

Machinery usage costs per period are then calculated from the machinery usage requirements. Machinery usage costs, along with the net returns to machinery and machinery purchase and salvage price are input for the replacement decision subsystem that determines the optimal investment/disinvestment policy.

For the model, the residual earnings per period are the net returns to the machinery complement for that period minus the costs per period arising from the use of the machinery in that period. This stream of residual earnings is used to represent the machinery complements' value

TABLE III

TECHNICAL COEFFICIENTS AND COSTS OF PRODUCTION PER ACRE FOR ALTERNATIVE ACTIVITIES IN THE 1973 BASE PERIOD

Activity	Dec-Apr Labor (Hours)	May-June Labor (Hours)	July-Sept Labor (Hours)	Oct-Nov Labor (Hours)	Jan-Mar Labor	Apr-June Labor	July-Sept Labor	Oct-Dec Labor	Cost Production
Wheat	.36	.56	2.01	0.00	$2.02	$0.00	$10.57	$0.00	$33.11
Grain Sorghum	.93	.59	.73	.63	$0.93	$5.50	$ 0.52	$0.11	$32.64
Alfalfa	.29	4.30	3.22	0.00	$8.79	$8.19	$ 6.47	$0.00	$65.56

TABLE IV

TOTAL MACHINERY USAGE COEFFICIENTS IN HOURS PER ACRE OF EACH ACTIVITY IN THE 1973 BASE PERIOD

Machine	Activity		
	Wheat	Grain Sorghum	Alfalfa
Tractor	1.44	1.76	3.88
Tandem Disk	.15	.15	.06
Modlboard Plow	.35	.47	.09
Field Cultivator	.24	--	--
Springtooth Harrow	.16	.22	.18
Drill	.22	.22	.04
Row Cultivator	--	.24	--
Spike Harrow	--	--	.04
Sickle Mower	--	--	1.02
Rake	--	--	1.02
P.T.O. Baler	--	--	.88

in use. Associated with durable assets are two types of depreciation. One is the loss in value of a durable asset as a result of its use which is often referred to as use depreciation or user cost. A second type of depreciation is associated with owning the asset over time and can be referred to as time depreciation.

Because data are inadequate to separate user cost and time depreciation for machinery, changes in the salvage prices of the machinery over time will be used to represent the total effect of these two types of depreciation.

A computer program utilizing equation (3-4) was developed for this study (Appendix). This optimizing program utilizes the net returns to machinery for each period along with the machinery usage costs for each production period derived from the linear programming and the machinery cost subsystems of the model to arrive at the flows of residual earnings. The market value for each machine in each time period is taken from National Farm Tractor and Implement Blue Book quotations.

The optimizing program compares the acquisition cost of the asset M(o), with its salvage value M(s) and, along with the flow of net returns discounted for time $R(t)e^{-\rho s}$, chooses as the replacement policy the period when the net present value of the flow of benefits from the durable over time is the greatest.

The system may be used to arrive at a pattern of optimal investment/disinvestment policies over a selected span of time. To accomplish this, the entire system begins a new iteration. The linear programming subsystem is updated with technological coefficients for the new base period. This change in technological coefficients represents the change in production efficiency of the machinery complement arising from the purchase of new machinery.

A new planning horizon is generated based on the updated technological coefficients and the price and yield series for the new base period. Machinery usage requirements are then derived from the cropping patterns of the planning horizon. Machinery costs, calculated from the machinery usage requirements, along with the net returns to machinery, machinery purchase price, and machinery salvage prices are employed by the investment/disinvestment subsystem to arrive at the next optimum replacement policy. If the optimum replacement policy does not meet or exceed the desired span of time, the system would begin another iteration until the pattern of optimal investment/disinvestment policies for the machinery complement is traced out over the desired time span.

Assumptions and Data

The assumptions and data used in this study are outlined in the following section. A hypothetical farm in northcentral Oklahoma with 800 acres of land forms the basis of this study. Assumptions made with regard to the amount of operator labor and capital available are detailed. Cropping practices and the machinery complement used are outlined along with the procedure used to generate net returns to the machinery complement.

Land

The farm firm is assumed to have 800 total acres of land available. Two hundred acres are assumed to be Class I land. The remaining 600 acres are classified as Class II land. Any crop produced on Class II land will suffer a ten percent reduction in yield relative to the same crop grown in Class I land.

Crops

The firm is assumed to be able to produce alfalfa hay, wheat or grain sorghum on its Class I land. On Class II land either wheat or grain sorghum may be produced. A minimum amount of 100 acres of wheat and grain sorghum production is placed in the model along with a minimum of 50 acres of alfalfa production. These boundaries are to insure that some production will take place each period.

Labor

Labor restrictions are delineated into four parts (Capstick, 1973). The four parts are: (1) December-April which includes most of the past harvest and preplant operations, (2) May-June which includes most of the planting operatins, (3) July-September which includes most of the operations between planting and harvest, and (4) October-November which includes fall planting and harvesting. The December-April restriction equals 954 hours, May-June equals 614 hours, July-September equals 874 hours, and the October-November restriction equals 548 hours.

Capital

The operator is assumed to have $15,000 of short term operating capital available in each quarter to cover variable costs. The model does not allow the operator to borrow money over the $15,000 quarterly limit. There is no constraint on intermediate term funding which would restrict the replacement of the machinery complement.

Machinery Complement

The firms machinery complement is assumed to include one 95 horsepower tractor, one sickle mower, one rake, one hay baler, one moldboard plow, one springtooth harrow, one spike harrow, one seed drill, one row cultivator, and one tandem disk. Initial list prices and expected total hours of life for each piece of machinery are shown in Table V.

TABLE V

LIST PRICES AND TOTAL HOURS OF LIFE FOR THE MACHINERY COMPLEMENT WITH THE 1973 BASE PERIOD

Machine	List Price[a]	Total Hours of Life[b]
Tractor	$10,345	12,000
Tandem Disk	2,530	2,500
Moldboard Plow	3,400	2,500
Field Cultivator	3,275	2,500
Springtooth Harrow	1,518	2,500
Spike Harrow	710	2,500
Drill	1,564	2,500
Row Cultivator	1,110	2,500
Planter (4-row)	1,192	2,500
Sickle Mower	729	2,000
Rake	854	2,500
P.T.O. Baler	2,586	2,500

[a] National Market Reports, Inc., 1973.

[b] American Society of Agricultural Engineers Yearbook, 1977.

Net Returns to Machinery

Net returns to machinery were calculated in two stages. From 1973 to 1979 an actual price and yield series for northcentral Oklahoma was employed to calculate gross receipts per acre for each crop. Costs of production were calculated using Oklahoma State University Enterprise budgets. Variable costs, excluding tractor and equipment repair costs, capital and labor costs are included in the costs of production (Table VI). For 1980 and 1981 predicted prices and yields were used to calculate gross receipts per acre. These predictions were for national average yield and price and represent a departure from the initial price series (Table VII).

In this chapter the assumptions and data used within the model are outlined. A description is given of how the model operates and how the subsystems of the model interact to arrive at an optimal replacement policy.

In the next chapter the model will be used to compare the policies recommended by a conventional replacement model using the constant flow of usage assumption with the replacement policy recommended by a model that permits variable usage in each production period. The model will be used to examine what effect changes in machinery valuation have on the replacement decision along with what effect changes in the discount rate have on the replacement decision. Also, changes in the price and yield series will be introduced to see what effect price and yield variations have on the replacement decision.

TABLE VI

NET RETURNS TO MACHINERY PER ACRE OF WHEAT USING ACTUAL PRICE AND YIELD SERIES DATA FOR THE 1973 BASE PERIOD

Year	Yield[a] (bushels per acre) Class I	Class II	Price[a] (dollars per bushel)	Cost of Production[b] (per acre)	Net Return to Machinery (per acre) Class I	Class II
1973	25.5	22.95	3.24	33.11	49.51	41.25
1974	23.9	21.51	4.37	33.11	71.33	60.89
1975	23.9	21.54	3.49	33.11	50.30	41.96
1976	25.0	22.50	3.09	33.11	44.14	36.42
1977	29.9	26.91	2.26	33.11	34.46	27.71
1978	32.7	29.43	2.54	33.11	59.76	50.47
1979	32.7	29.43	3.28	33.11	74.15	63.42

[a] Oklahoma Department of Agriculture, Oklahoma Agricultural Statistics, 1979.

[b] Kletke (1979).

TABLE VII

NET RETURNS TO MACHINERY PER ACRE OF WHEAT USING PREDICTED PRICE AND YIELD SERIES DATA FOR THE 1976 BASE PERIOD

	Yield[a] (bushels per acre)		Price[a] (dollars per bushel)	Cost of Production[b] (per acre)	Net Return to Machinery (per acre)	
Year	Class I	Class II			Class I	Class II
1980	32.49	29.24	3.43	55.00	56.44	45.29
1981	32.63	29.37	3.27	55.00	51.70	41.04

[a] United States Department of Agriculture, <u>Monthly Update and Policy Baseline</u>, 1979.

[b] Kletke (1979).

CHAPTER IV

MODEL APPLICATIONS

In this chapter the model described in Chapter III will be used to compare replacement policies recommended by models using constant usage and variable usage assumptions. The effects of varying yields and prices on replacement policies will be analyzed by comparison of variable usage replacement models. The model will also be employed to examine the effects of change in market salvage valuations for assets on replacement decisions and to observe what effects changes in the discount rate have on replacement policies.

Replacement Pattern Data Generation

For application of the model described in Chapter III data on output prices, output yields, machinery factory list prices and machinery salvage values for the 1973 to 1981 period were acquired. This section outlines the gathering and preparation of the data used to apply the model for the 1973 to 1981 time span.

Output Prices and Yields

Output prices and yields used in the model were taken from two sources. For the years of 1973 to 1979 an actual price and yield series for northcentral Oklahoma was used (Table VIII). For the 1980 to 1981 period predicted prices and yields taken from the United States

TABLE VIII

PRICE AND YIELD DATA FOR THE SELECTED ACTIVITIES ON THE HYPOTHETICAL FARM IN NORTHCENTRAL OKLAHOMA

	Grain Sorghum[a]			Alfalfa Hay[b]		Wheat[c]		
	Yield/Acre					Yield/Acre		
Year	Class I	Class II	Price	Yield/Acre	Price	Class I	Class II	Price
1973	20.57	18.51	$3.36	5.64	$45.79	25.5	22.95	$3.24
1974	20.57	18.51	$4.65	6.12	$55.92	23.9	21.51	$4.37
1975	20.19	18.17	$4.40	5.70	$57.13	23.9	21.51	$3.49
1976	14.80	13.32	$4.03	5.70	$63.92	25.0	22.50	$3.09
1977	22.00	19.80	$3.24	3.32	$66.58	29.9	26.91	$2.26
1978	18.70	16.83	$3.49	4.62	$67.08	32.7	29.43	$2.84
1979	22.00	19.80	$3.70	5.67	$75.83	32.7	29.43	$3.28
1980	30.69	27.62	$2.42	5.04	$55.75	32.5	29.24	$3.43
1981	30.30	27.62	$2.24	5.13	$54.41	32.6	29.37	$3.27

[a] Grain sorghum values shown per hundred weight.

[b] Alfalfa hay values shown per ton.

[c] Wheat figures shown per bushel.

Department of Agriculture 1979 Baseline Crop Estimate report were used.

Machinery Factory List Price

In order to take actual list prices from the National Farm Tractor and Implement Blue Book, a specific brand of machinery needs to be designated. The 4020 series John Deere tractor was found to be nearly identical to the horsepower ratings and list prices specified in the Oklahoma State University Enterprise Budgets, therefore salvage value information for this model tractor was used in this study.

However, after the 1973 model year the 4020 series was discontinued and replaced by a comparable line, the John Deere 4320 (Table IX). Therefore, when any replacement decision is made, the 4020 John Deere will be replaced with the 4320 model.

TABLE IX

COMPARISON OF TRACTOR LIST PRICES AND PERFORMANCE MEASURES

	Enterprise Budget Specifications	John Deere 4020 Series	John Deere 4320 Series
List Price	$11,500*	$10,963*	$14,091[1]
Horsepower	100 horsepower	95.83 horsepower	116.5 horsepower

*1973 prices.

[1] 1975 prices.

Since the list prices for the other equipment in the machinery complement are not specified in the National Farm Tractor and Implement Blue Book, the list prices for the other pieces of equipment in the machinery complement are taken from Oklahoma State University Enterprise Budget data on list prices.

Machinery Salvage Values

Salvage values for the 4020 and 4320 series John Deere tractor were taken from actual National Farm Tractor Implement Blue Book quotations. To obtain salvage values for implements using the National Farm Tractor and Implement Blue Book, the factory list price of the machine is used as an index for the miscellaneous implement valuation schedule found in the National Farm Tractor and Implement Blue Book (Table X).

A common method of valuing used machinery is the straight-line method. In this method a salvage value is assigned to the machine at the end of its expected span of use. This salvage value is subtracted from the asset purchase price, and this difference is divided by the number of years in the span of use with the quotient being the annual depreciation. The market quotations used in this study can be contrasted with a straight-line depreciation schedule yielding the same salvage values at the end of 1979 (Table XI). In every case, the straight-line depreciation schedule over-values the asset for each period relative to the actual market quotations. The actual market quotations (Table X) tend to show a sharp decrease in the value of the machine during the first year, with a leveling off in the rate of decrease in the second through fourth years. From 1976 to 1977, market forces cause an appreciation in the value of machinery, followed by a slight depreciation

TABLE X

MACHINERY SALVAGE VALUES FOR THE 1973 PLANNING HORIZON

Machine	Year 1973	1974	1975	1976	1977	1978	1979
Tractor	$9,550	$7,805	$7,675	$7,460	$8,325	$8,150	$8,425
Tandem Disk	$2,204	$1,729	$1,700	$1,650	$1,700	$1,650	$1,675
Moldboard Plow	$2,962	$2,351	$2,312	$2,250	$2,300	$2,225	$2,275
Field Cultivator	$2,853	$2,282	$2,244	$2,180	$2,250	$2,175	$2,275
Springtooth Harrow	$1,322	$1,037	$1,020	$ 990	$1,025	$ 975	$1,000
Spike Harrow	$ 618	$ 484	$ 476	$ 470	$ 475	$ 450	$ 475
Row Cultivator	$ 967	$ 761	$ 748	$ 730	$ 750	$ 725	$ 750
Sickle Mower	$ 635	$ 484	$ 476	$ 470	$ 475	$ 450	$ 475
Rake	$ 743	$ 553	$ 544	$ 530	$ 550	$ 525	$ 525
P.T.O. Baler	$2,253	$1,798	$1,768	$1,720	$1,775	$1,700	$1,750

Source: National Market Reports, Inc., National Farm Tractor and Implement Blue Book, 1979.

TABLE XI

STRAIGHT LINE DEPRECIATION SCHEDULE FOR THE MACHINERY COMPLEMENT

Machine	Year						
	1973	1974	1975	1976	1977	1978	1979
Tractor	$10,600	$10,238	$9,875	$9,573	$9,150	$8,788	$8,425
Tandem Disk	$ 2,408	$ 2,286	$2,164	$2,041	$1,919	$1,797	$1,675
Moldboard Plow	$ 3,239	$ 3,079	$2,918	$2,758	$2,596	$2,436	$2,275
Field Cultivator	$ 3,132	$ 2,989	$2,846	$2,704	$2,561	$2,418	$2,275
Springtooth Harrow	$ 1,444	$ 1,370	$1,296	$1,222	$1,148	$1,074	$1,000
Spike Harrow	$ 676	$ 643	$ 609	$ 576	$ 542	$ 509	$ 475
Row Cultivator	$ 1,059	$ 1,007	$ 956	$ 904	$ 853	$ 801	$ 750
Sickle Mower	$ 723	$ 686	$ 650	$ 614	$ 578	$ 541	$ 475
Rake	$ 807	$ 760	$ 713	$ 666	$ 619	$ 572	$ 525
P.T.O. Baler	$ 2,467	$ 2,347	$2,228	$2,108	$1,989	$1,869	$1,750

in 1978, followed by 3.37 percent appreciation in salvage value for 1979.

Expected Net Returns to Machinery

To begin the analysis, a seven year price and yield series from 1973 to 1979 and 1973 technological coefficients (Tables XII and XIII) were fed into the model. Nineteen hundred and seventy-three was chosen as the base period since it is the earliest date that the Oklahoma State University Enterprise Budgets needed to derive usage coefficients and cost of production data for the linear programming subsystem were available. Expected net returns to machinery generated for the planning horizon by the linear programming subsystem are shown in Table XII. The net returns to machinery range from a low of $29,933.53 in 1977 to a high of $56,073.29 in 1979. The planning horizon begins with a return of $33,001.99 in 1973 which is followed by a 61.2 percent increase in 1974 due to sharply increased output prices. This sharp rise in 1974 is followed by 13.46 percent decline in 1975 which yielded $46,037.45 in net returns. A sharp decrease occurred between 1976 and 1977 with a 26.85 percent decline from $40,923.11 to $29,933.53. From the low in 1977, net returns rose 87.33 percent to the high in 1979. This pattern for net returns to machinery is roughly the same as the trend depicted in Figure 7 for net farm income over the same period.

Constant Usage Base Soluation

To begin the analysis of the replacement model application, a traditional constant flow of usage problem for the hypothetical farm in northcentral Oklahoma was solved. By including any deterioration in the flow of services into the definition of current costs[1], the value of the services rendered by the machinery complement in the constant usage problem is irrelevant to the replacement decision and will be ignored here, since by definition the flow of usage is positive and constant (Perrin, 1972).

TABLE XII

EXPECTED NET RETURNS TO MACHINERY FOR THE 1973 BASED SEVEN YEAR PLANNING HORIZON

Year	Expected Net Returns
1973	$33,001.99
1974	$53,198.59
1975	$46,037.45
1976	$40,923.11
1977	$29,933.53
1978	$37,682.18
1979	$56,073.29

The solution of the constant usage replacement problem for the hypothetical farm assuming a ten percent discount rate and a seven year planning horizon is presented in Table XIII. Column 3 shows the summation of the salvage values for all the equipment in the machinery complement at the end of each production period. Column 4 shows the

---

[1] Repair equations put forth in the Agricultural Engineers Yearbook, 1977 take into account the costs needed to keep a constant quality service flow.

TABLE XIII

CONSTANT USAGE REPLACEMENT SOLUTION FOR THE SEVEN YEAR PLANNING HORIZON BASED IN 1973 ASSUMING A TEN PERCENT DISCOUNT RATE

Year (1)	Period (2)	Period Ending Asset Value (3)	Repair Cost (4)	Marginal Cost (5)	V(A) (6)	Capital Recovery Factor Times V(A) (7)	Present Value of Costs (8)
1973	1	25,469.00	746.03	4,516.02	4,448.20	4,893.04	74,399.44
1974	2	20,390.00	1,238.30	6,317.30	10,550.59	6,079.18	81,181.81
1975	3	20,051.00	2,285.91	2,624.91	12,607.04	5,069.50	70,745.94
1976	4	19,510.00	3,016.27	3,557.27	15,208.20	4,797.76	67,487.63
1977	5	20,725.00	4,266.22	3,051.22	16,642.19	4,390.19	64,626.86
1978	6	20,075.00	5,175.25	5,825.25	20,213.49	4,641.18	66,486.81
1979	7	20,700.00	6,586.71	5,961.71	22,968.53	4,717.88	67,878.75

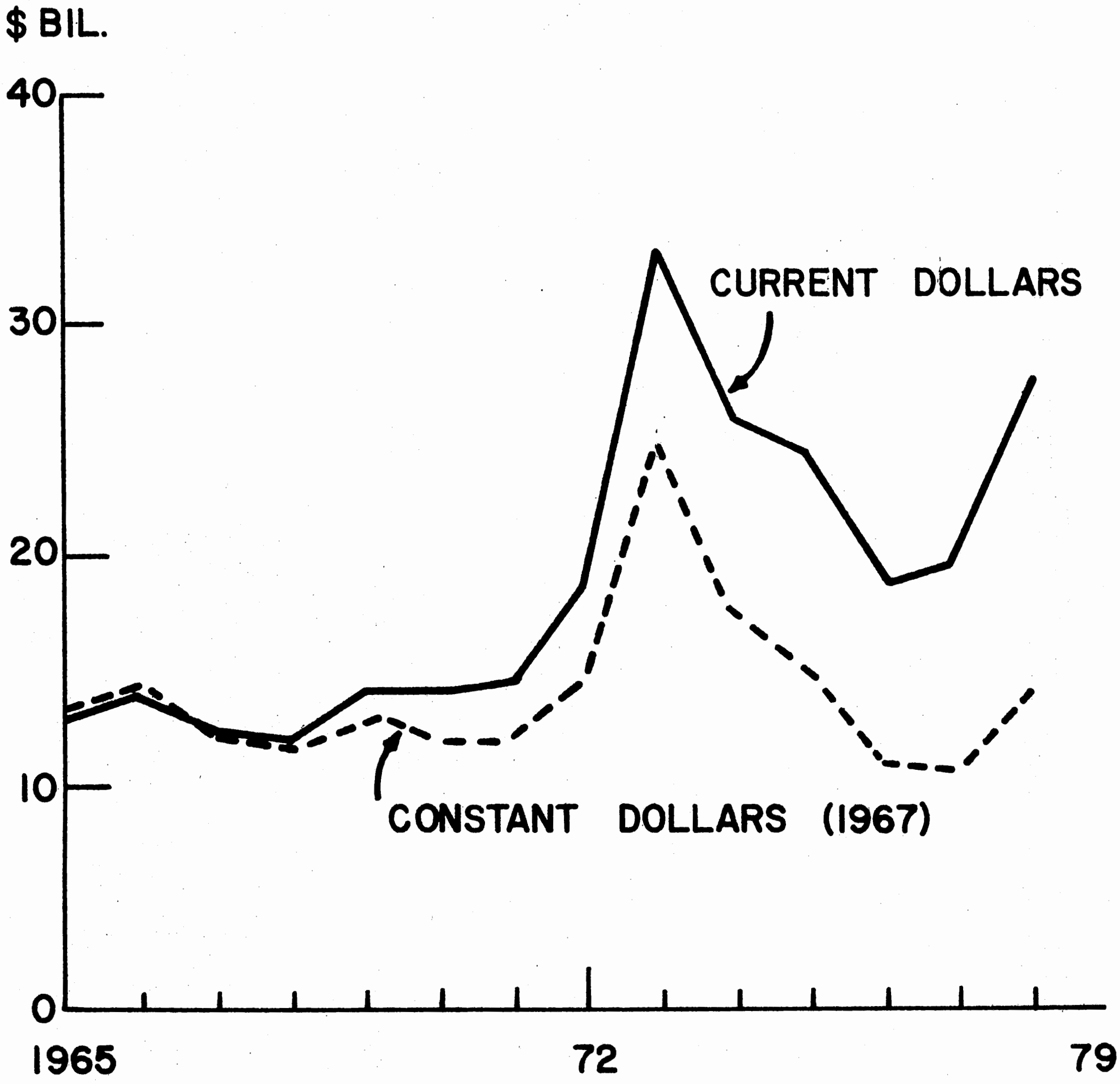


Figure 7. Net Farm Income from 1965 to 1979

total expected annual repair costs for the entire machinery complement as calculated by the machinery cost subsystem. For this problem, annual repair costs are based on an average usage figure, calculated by taking the total number of hours of use for each machine over the planning horizon, and dividing that total by the number of production periods in the planning horizon. Column 5 lists the period repair costs plus the change in the salvage value of the machinery complement during that period. Column 5 represents both user cost and time depreciation along with repair costs per period, and will be defined as marginal cost for this study. Column 4 is the total repair costs stream incurred discounted to the machinery complements current age (a) plus the salvage value of the machinery complement in year (a).

The marginal replacement criterion (2-9) requires that the marginal cost for year (a + 1) equal the discounted repair stream plus the salvage value in year (a) multiplied by a capital recovery factor[2] for year (a) (Column 7). This criterion is most nearly met by replacing the machinery complement in 1978. However, as can be seen from Column 8, the present value of costs for a seven year planning horizon calculated with equation (2-10), is smallest in 1977 with a cost of $64,626.86. In this case, application of the marginal criterion (2-9) leads to a one year error costing $1,859.95. This result supports Perrin's (1972) conclusion that direct calculation of present values is a better search procedure than the marginal replacement criterion.

---

[2] The capital recovery factor $\rho/(1 - e^{-\rho s})$ converts the value of the annuity expressed in column six to an equivalent constant flow of earnings.

Straight-Line Depreciation Versus Market Salvage Values

To test to see what affect market salvage valuations have on the replacement decision, the basic constant usage model was resolved using the straight-line depreciation values found in Table XI. The solution to the straight-line depreciation salvage value replacement problem, still assuming a ten percent discount rate, is shown in Table XIV. As would be expected, Column 3 of Table XIV shows a consistently higher value for the machinery complement at the end of each period compared to Table XIII. These higher machinery complement salvage values result in lower total marginal costs (Column 5).

Examination of Column 8 of Table XIV reveals that the smallest present value of costs occurs in period one. Comparing this result to the constant usage base solution, it can be seen that a difference in the optimal replacement policy in four years arises from the change in machinery complement valuation. If the firm manager purchased a new machinery complement and applied the constant usage replacement model using National Farm Tractor and Implement salvage values to determine the optimal replacement policy, he would replace the machinery after five production periods. If the farmer applied the exact same model, except using straight-line depreciation values he would replace the same machinery complement after one production period. This implies that the constant usage replacement model is sensitive to changes in the salvage valuations of the machinery complement.

TABLE XIV

CONSTANT USAGE REPLACEMENT SOLUTION WITH STRAIGHT LINE DEPRECIATION SALVAGE VALUES

Year (1)	Period (2)	Period Ending Asset Value (3)	Repair Cost (4)	Marginal Cost (5)	V(A) (6)	Capital Recovery Factor Times V(A) (7)	Present Value of Costs (8)
1973	1	27,917.00	746.03	2,068.03	2,000.21	2,200.24	49,919.38
1974	2	26,511.00	1,238.30	2,644.30	4,429.59	2,552.30	52,034.02
1975	3	25,343.00	2,285.00	3,453.91	7,315.04	2,941.50	54,757.97
1976	4	24,165.00	3,016.27	4,194.27	10,553.20	3,329.24	57,457.40
1977	5	23,055.00	4,266.22	5,376.22	14,312.19	3,775.54	60,810.36
1978	6	21,855.00	5,175.25	6,375.25	18,433.49	4,232.48	64,179.82
1979	7	20,700.00	6,586.71	7,741.71	22,968.53	4,717.88	67,878.75

Variable Usage Replacement Problem Analysis

We will now drop the assumption of constant usage that was used in the previous analysis. Since the flow of machine services is not now held constant, the value of the services rendered by the machinery complement becomes relevant to the replacement problem and must be included in this analysis.

The solution of the variable usage replacement problem for the hypothetical farm, assuming a ten percent discount rate and a seven year planning horizon, is presented in Table XV. Column 3 shows the resale value of the machinery complement at the end of each production period. Column 6 shows the expected returns generated by the linear programming subsystem (Table XII) minus the annual repair costs from the machinery cost calculation subsystem appearing in Column 4. Column 5 lists the repair costs plus the change in the salvage value of the machinery complement, which is the total marginal cost for each year. Column 7 is the net return (Column 6) discounted to year (a) plus a salvage value of the machinery complement in year (a) (Column 3). Column 9 shows the present value of the flow of net returns for each period in the planning horizon. The appropriate decision rule is to maximize the present value of these net returns. The maximum present value of the net returns occurs after three years of use at a value of $361,746.90. Therefore, an optimum decision assuming variable machinery usage would be to replace the machinery complement after the 1975 season. By relaxing the assumption of constant usage, a policy is chosen that replaces the machinery complement two years earlier than the policy recommended by the constant usage replacement model.

TABLE XV

VARIABLE USAGE REPLACEMENT SOLUTION FOR THE SEVEN YEAR PLANNING HORIZON BASED IN 1973 ASSUMING A TEN PERCENT DISCOUNT RATE

Year (1)	Period (2)	Period Ending Asset Values (3)	Repair Cost (4)	Marginal Cost (5)	Net Returns (6)	V(A) (7)	Capital Recovery Factor Times V(A) (8)	Present Value of Net Returns (9)
1973	1	25,469.00	965.90	4,735.89	32,036.09	25,353.73	27,889.23	253,423.30
1974	2	20,390.00	1,595.40	6,674.40	51,603.19	61,922.00	36,255.24	342,162.30
1975	3	20,051.00	2,960.94	3,299.94	43,076.51	94,947.06	38,179.80	361,746.90
1976	4	19,510.00	2,901.44	3,442.44	38,021.67	120,375.40	37,975.11	360,241.00
1977	5	20,725.00	5,424.52	4,209.52	24,509.01	136,808.60	36,089.93	340,174.10
1978	6	20,075.00	4,570.84	5,220.84	33,111.34	154,849.10	35,554.64	335,471.30
1979	7	20,700.00	7,191.13	6,566.13	48,882.16	180,558.50	37,087.85	350,178.40

Replacement Pattern Generation

The 1973 based variable usage model will be used as the basis for the replacement pattern generated for the hypothetical farm in this study. The three-year replacement policy will be adopted as the initial replacement decision for a replacement pattern spanning the 1973 to 1981 time period. This period was chosen because of the availability of historical data for the 1973 to 1979 period along with availability of predictions on prices and yields for 1980 and 1981.

After making the decision to replace the machinery complement after the third season, the linear programming subsystem of the model is updated with new technological coefficients to represent the changes in efficiency brought about by the replacement of the machinery complement. The linear programming subsystem is also provided with price and yield data for the 1980 and 1981 production periods so as to cover the remaining length of the time span. The linear programming subsystem now generates the expected net returns to machinery for the six year planning horizon based in 1976 (Table XVI). The 1976 based net returns to machinery range from a low of $2,210.74 in 1977 to a high of $36,090.93 in 1981. The series of expected returns begins with a value of $19,129.57 in 1976 followed by an 88.44 percent decrease to the 1977 low. Nineteen hundred and seventy-eight shows a large increase to $14,539.79, which is followed by a 117.45 percent increase to $31,617.09 in 1979. The large increase in 1979 is followed by an increase to $36,090.93 in 1980 and an expected net return to machinery of $33,528.71 in 1981.

TABLE XVI

EXPECTED NET RETURNS TO MACHINERY FOR THE SIX YEAR PLANNING HORIZON BASED IN 1976

Year	Expected Net Returns
1976	$19,129.57
1977	$ 2,210.74
1978	$14,539.79
1979	$31,617.09
1980	$36,090.93
1981	$33,528.71

Machinery list prices and salvage values appear in Table XVII. The 1976 based salvage prices reflect a sharp decrease in machine value after the first year of use followed by smaller decreases thereafter.

The solution to determine the second optimal variable usage replacement policy in the 1973 to 1981 pattern appears in Table XVIII. The solution once again assumes a ten percent discount rate. For the six year planning horizon beginning in 1976, the maximum present value of net returns from Column 9 occurs in 1981 with a value of $131,994.10. This replacement solution, coupled with the previous result, recommends that for the hypothetical farming situation the optimal replacement pattern, assuming a ten percent discount rate, would be to trade the machinery complement after the third and ninth production periods.

TABLE XVII

MACHINERY SALVAGE VALUES FOR THE 1976 PLANNING HORIZON

Machine	List Price	Salvage Value in Year					
		1976	1977	1978	1979	1980*	1981*
Tractor	$15,058	$14,450	$11,600	$11,325	$10,725	$9,160	$8,015
Disk	$ 2,300	$ 2,001	$ 1,575	$ 1,500	$ 1,425	$1,170	$ 990
Plow	$ 3,050	$ 2,654	$ 2,050	$ 1,975	$ 1,875	$1,534	$1,293
Field Cultivator	$ 2,505	$ 2,179	$ 1,700	$ 1,650	$ 1,550	$1,288	$1,094
Springtooth Harrow	$ 1,380	$ 1,201	$ 950	$ 925	$ 875	$ 736	$ 636
Spike Harrow	$ 645	$ 561	$ 400	$ 400	$ 375	$ 294	$ 239
Row Cultivator	$ 2,200	$ 1,914	$ 1,775	$ 1,450	$ 1,375	$1,144	$ 950
Sickle Mower	$ 835	$ 726	$ 550	$ 525	$ 500	$ 400	$ 329
Rake	$ 915	$ 796	$ 600	$ 600	$ 550	$ 452	$ 378
P.T.O. Baler	$ 5,175	$ 4,502	$ 3,525	$ 3,400	$ 3,250	$2,968	$2,310

*1980 and 1981 salvage values are predicted from separate ordinary least square equations for each asset.

TABLE XVIII

VARIABLE USAGE REPLACEMENT SOLUTION FOR THE SIX YEAR PLANNING HORIZON BASED IN 1976 ASSUMING A TEN PERCENT DISCOUNT RATE

Year (1)	Period (2)	Period Ending Asset Values (3)	Repair Cost (4)	Marginal Cost (5)	Net Returns (6)	V(A) (7)	Capital Recovery Factor Times V(A) (8)	Present Value of Net Returns (9)
1976	1	33,986.00	478.69	4,005.69	18,650.88	13,428.35	14,771.25	113,726.50
1977	2	27,100.00	817.64	7,703.64	1,393.10	7,693.68	4,433.04	17,230.44
1978	3	26,050.00	1,507.86	2,557.86	13,031.93	16,434.77	6,608.70	40,036.94
1979	4	24,225.00	2,015.03	3,840.03	29,602.86	34,828.98	10,987.57	85,650.69
1980	5	20,972.00	3,440.63	6,693.63	32,650.30	51,849.25	13,677.76	115,805.50
1981	6	17,804.00	4,192.59	7,360.59	29,336.12	65,240.75	14,979.82	131,994.10

Effects of Discount Rates on Variable Usage Replacement Decisions

To examine the effects of changes in the discount rate the solution to the initial seven year planning horizon variable usage problem assuming a ten percent discount rate will be used as a basis for comparison (Table XV). The discount rate was allowed to vary from ten to nineteen percent. Between ten and sixteen percent, the replacement decision for the hypothetical farm is not sensitive to changes in the discount rate.

Assuming a discount rate of 17 percent will lead to a one year delay in replacement of machinery complement (Table XIX) relative to the ten percent assumption in the earlier solution. Assuming a 17 percent discount rate, the optimal replacement of the machinery complement takes place after the fourth period, with the maximum net present value being $200,358.30 (Column 9). By delaying the replacement decision one year, the operator makes a gain of $16.00, a difference between $200,358.40 and $200,342.30.

A later optimum replacement age resulting from an increase in the discount rate highlights a point discussed by Perrin (1972). It would normally be assumed that a higher discount rate would result in an earlier optimum replacement period. However, Perrin shows that the replacement decision depends not only on the discount rate but also on the asset's value, the asset's purchase price, and the part of the stream of residual earnings up to the optimal replacement age.

TABLE XIX

VARIABLE USAGE REPLACEMENT SOLUTION FOR THE SEVEN YEAR PLANNING PERIOD BASED IN 1973 ASSUMING A SEVENTEEN PERCENT DISCOUNT RATE

Year (1)	Period (2)	Period Ending Asset Values (3)	Repair Cost (4)	Marginal Cost (5)	Net Returns (6)	V(A) (7)	Capital Recovery Factor Times V(A) (8)	Present Value of Net Returns (9)
1973	1	25,469.00	965.90	4,735.89	32,036.09	23,611.29	27,625.30	137,032.80
1974	2	20,390.00	1,595.40	6,674.40	51,603.19	56,229.19	35,471.16	188,263.90
1975	3	20,051.00	2,960.94	3,299.94	43,076.51	82,785.94	37,466.86	200,342.30
1976	4	19,510.00	2,901.44	3,442.44	38,021.67	102,535.20	37,377.60	200,358.30
1977	5	20,725.00	5,424.52	4,209.52	24,509.01	114,929.10	35,922.79	190,585.50
1978	6	20,075.00	4,570.84	5,220.84	33,111.34	127,187.20	35,436.34	188,374.00
1979	7	20,700.00	7,191.13	6,566.13	48,882.16	144,099.60	36,737.89	195,405.20

Yield Variation Effects on the Replacement Decision

To see what effect yield variation has on the replacement decision, a ten percent decrease in the original yields will be introduced for each year of the seven year planning horizon based in 1973. By holding all other parameters constant, the solution presented in Table XV will serve as a basis for comparison with the reduced yield solution.

As would be expected, the net returns to machinery generated by the linear programming subsystem are much lower for the yield series incurring the ten percent reduction (Table XX). The reduced yield expected return series has a minimum value of $24,425.53 occurring in 1977, which is 18.4 percent lower than the low return in the base solution. The maximum value for the new series occurs in 1979 at $48,674.70, which is 16.2 percent lower than the maximum return in the base solution. However, the general pattern over time of the net returns is not changed. Beginning in 1973 with a value of $27,566.53, the model generates a 64.35 percent increase in 1974 to $45,405.22. This 1974 high is followed by declines of 14.19 percent to $38,875.10 in 1975 and 9.52 percent to $35,175.32 in 1976. The series bottoms out in 1977 at $24,425.53, followed by an increase of 38.4 percent to $33,916.28 in 1978. The maximum return in the series occurs after a 43.53 percent increase in 1979 to $48,674.70.

The solution to the reduced yield series replacement problem, assuming a ten percent discount rate appears in Table XXI.

The reduction in machinery use can be seen by comparing hours of tractor usage in each period for the reduced yield model (Table XXII) with the corresponding tractor usage figures from Table XXIII. In 1973, the model shows a 32.8 percent decrease in tractor usage from the base solutions 1,344.96 hours to 903.82 hours. In 1974 the tractor hours are identical at 1,344.96. In 1975 the reduced yield model increases tractor usage by 7.42 percent to 1,462.60 hours from the base solution's 1,361.19. For 1976, tractor use is almost identical at 860 hours. During 1977, in both cases, another 7.42 percent increase occurs in use from the base models 1,344.96 hours to 1,462.60 hours. Tractor usage in 1978 and 1979 is identical at 903.82 hours for both cases. Total tractor usage for the reduced yield model over the seven year planning horizon is 7,842.22 hours compared to 8,080.45 hours for the base solution.

TABLE XX

EXPECTED NET RETURNS TO MACHINERY WITH A TEN PERCENT DECREASE IN YIELDS

Year	Expected Net Returns
1973	$27,566.53
1974	$45,305.22
1975	$38,875.10
1976	$35,175.32
1977	$24,425.53
1978	$33,911.28
1979	$48,674.70

TABLE XXI

VARIABLE USAGE REPLACEMENT SOLUTION FOR A REDUCED YIELD OF TEN PERCENT DURING THE SEVEN YEAR PLANNING HORIZON BASED IN 1973 ASSUMING A TEN PERCENT DISCOUNT RATE

Year (1)	Period (2)	Period Ending Asset Values (3)	Repair Cost (4)	Marginal Cost (5)	Net Returns (6)	V(A) (7)	Capital Recovery Factor Times V(A) (8)	Present Value of Net Returns (9)
1973	1	25,469.00	496.30	4,266.29	27,070.23	20,839.32	22,923.35	203,764.50
1974	2	20,390.00	1,406.92	6,485.92	43,898.30	52,039.95	29,985.07	279,460.60
1975	3	20,051.00	2,452.55	2,791.55	36,422.55	79,065.75	31,793.66	297,885.50
1976	4	19,510.00	2,668.51	3,209.51	32,506.80	100,727.30	31,776.69	298,256.80
1977	5	20,725.00	4,950.93	3,735.93	19,474.60	114,034.50	30,082.16	280,096.50
1978	6	20,075.00	4,303.88	4,953.88	29,607.40	130,097.10	29,871.39	278,638.80
1979	7	20,700.00	6,684.76	6,059.76	41,989.94	152,269.70	31,277.16	292,071.50

TABLE XXII

MACHINE USAGE IN HOURS PER YEAR FOR THE TEN PERCENT YIELD REDUCTION SOLUTION

Machine	Year 1973	1974	1975	1976	1977	1978	1979
Tractor	903.82	1,344.96	1,462.60	860.30	1,462.60	903.82	903.82
Tandem Disk	54.44	105.74	105.20	50.69	105.20	54.44	54.44
Moldboard Plow	40.79	305.97	312.74	125.10	312.74	140.79	140.79
Field Cultivator	58.30	40.90	24.00	47.16	24.00	58.30	58.30
Springtooth Harrow	78.40	149.46	152.90	72.07	152.90	78.40	78.40
Drill	79.34	152.69	151.90	69.37	151.90	79.34	79.34
Spike Harrow	3.90	2.00	2.00	4.14	2.00	3.90	3.90
Row Cultivator	24.00	123.48	139.53	24.00	139.53	24.00	24.00
Sickle Mower	99.38	51.00	51.00	105.55	51.00	99.38	99.38
Rake	99.38	51.00	51.00	105.55	51.00	99.38	99.38
P.T.O. Baler	85.74	44.00	44.00	91.06	44.00	85.74	85.74

TABLE XXIII

MACHINE USAGE IN HOURS PER YEAR FOR THE BASE SOLUTION

Machine	Year 1973	1974	1975	1976	1977	1978	1979
Tractor	1,344.96	1,344.96	1,361.19	860.49	1,361.19	903.83	903.83
Tandem Disk	105.74	105.74	105.20	50.69	105.20	57.28	57.28
Moldboard Plow	305.97	305.97	312.74	125.10	312.74	141.69	141.69
Field Cultivator	40.90	40.90	24.00	47.16	24.00	58.30	58.30
Springtooth Harrow	159.26	159.26	150.90	69.37	151.90	79.34	79.34
Drill	149.46	149.46	152.90	72.07	152.90	78.40	78.40
Spike Harrow	2.00	2.00	2.00	4.14	2.00	3.90	3.90
Row Cultivator	123.48	123.48	139.53	24.00	139.53	24.00	24.00
Sickle Mower	51.00	51.00	51.00	105.55	51.00	99.38	99.38
Rake	51.00	51.00	51.00	105.55	51.00	99.38	99.38
P.T.O. Baler	44.00	44.00	44.00	91.06	44.00	85.74	85.74

This reduction in machine use leads to lower repair costs (Table XXI), which in turn leads to lower marginal costs per period (Column 5) relative to the base solution shown in Table XV. However, the substantially lower yields offset any reduced costs and result in substantially lower net returns. Examination of the present value of net returns (Column 9) also reveals lower outcomes relative to the base solution. With a ten percent reduction in yields, the highest present value of net revenues occurs in period four, as opposed to period three in the base solution. This delay on one period in the replacement decision may be attributed to the reduced use of the machinery complement, since the pattern of expected net returns has remained essentially the same.

Price Variation Effects on the Replacement Decision

To examine the effects of price variation on the replacement decision, a ten percent increase will be introduced into the original price series used to establish the seven year planning horizon based in 1973. To establish a basis for comparison, all other parameters will be held constant so that the solution may be compared with that in Table XV.

The expected net returns generated by the model are considerably higher than the original series, as would be expected (Table XXIV). The new expected return series based on the higher price level has a high of \$63,487.79 occurring in 1979 with a low of \$35,558.82 occurring in 1977. Once again, the pattern of net returns is essentially the same as the pattern for the base solution (Table XII).

TABLE XXIV

EXPECTED NET RETURNS TO MACHINERY WITH A TEN PERCENT INCREASE IN PRICE

Year	Expected Net Returns
1973	$38,898.49
1974	$61,149.40
1975	$53,196.48
1976	$43,590.95
1977	$35,448.82
1978	$45,335.29
1979	$63,487.79

The solution to the increased price series replacement problem, with the assumption of a ten percent discount rate, appears in Table XXV. With respect to the base solution, the increase in price has very little impact on repair costs through increases in machinery usage.

As seen in Table XXVI, tractor usage in 1974 and 1975 is 1,344.96 hours, representing no change from the base solution (Table XXIII). There is a 7.45 percent increase in tractor usage in 1975 for the increased price model over the base solutions 1,361.19. In 1976, the tractor hours increase from 860.49 in the base solution to 913.49. For 1977, an increase of 7.45 percent occurs from the base solution's 1,361.49 to 1,362.90 hours. For 1978 and 1979 tractor hours are identical at 903.82 for both cases. Total tractor hours for the increased price model is 8,336.71 compared to 8,080.45 for the base solution.

TABLE XXV

VARIABLE USAGE REPLACEMENT SOLUTION FOR A TEN PERCENT INCREASE IN THE PRICE SERIES DURING THE SEVEN YEAR PLANNING HORIZON BASED IN 1973 ASSUMING A TEN PERCENT DISCOUNT RATE

Year (1)	Period (2)	Period Ending Asset Values (3)	Repair Cost (4)	Marginal Cost (5)	Net Returns (6)	V(A) (7)	Capital Recovery Factor Times V(A) (8)	Present Value of Net Returns (9)
1973	1	25,469.00	963.07	4,733.07	37,935.41	30,716.76	33,788.59	312,416.90
1974	2	20,390.00	1,591.27	6,670.27	59,588.13	74,859.38	43,133.48	410,944.60
1975	3	20,051.00	3,055.34	3,394.34	50,141.14	112,192.10	45,144.35	431,092.40
1976	4	19,510.00	2,977.58	3,578.58	40,613.37	139,390.60	43,973.89	420,228.80
1977	5	20,725.00	5,663.79	4,448.79	29,785.04	159,099.80	41,970.33	398,978.10
1978	6	20,075.00	4,661.95	5,311.95	40,673.34	181,408.90	41,653.00	396,454.90
1979	7	20,700.00	7,444.18	6,819.18	56,043.61	210,793.20	43,298.26	412,282.50

TABLE XXVI

MACHINE USAGE IN HOURS PER YEAR FOR THE TEN PERCENT PRICE INCREASE SOLUTION

Machine	Year 1973	1974	1975	1976	1977	1978	1979
Tractor	1,344.96	1,344.96	1,462.60	913.85	1,462.60	903.82	903.82
Tandem Disk	105.74	105.74	105.20	56.54	105.20	54.44	54.44
Moldboard Plow	305.97	305.97	312.74	131.93	312.74	140.79	140.79
Field Cultivator	40.90	40.90	24.00	24.00	24.00	58.30	58.30
Springtooth Harrow	149.46	149.46	152.90	81.73	152.90	78.40	78.40
Drill	152.69	152.69	151.90	73.73	151.90	79.34	79.34
Spike Harrow	2.00	2.00	2.00	4.00	2.00	3.90	3.90
Row Cultivator	123.48	123.48	139.53	52.07	139.43	24.00	24.00
Sickle Mower	51.00	51.00	51.00	102.00	51.00	99.38	99.38
Rake	51.00	51.00	51.00	102.00	51.00	99.38	99.38
P.T.O. Baler	44.00	44.00	44.00	88.00	44.00	85.74	85.74

Returning to Table XXV, it can be seen in Column 5 that the marginal costs follow the same pattern as in the base solution, but at a slightly higher level over the entire planning horizon. Net returns follow roughly the same pattern in the increased price model, as would be expected from the pattern of net returns to machinery (Table XXIV). Similarly, examination of the present value of net returns column indicates that the present value of net returns also tend to follow the pattern established in the base solution. Not surprisingly, the optimal replacement decision is recommended to be made after the third period, as in the base solution, with a present value of net returns of $451,092.40.

This result would indicate that changes in the pattern of machinery use have a greater bearing on the optimum replacement policy than do changes in the level of net returns to machinery. As can be seen in the reduced yield problem (Table XXII) total machinery usage was reduced markedly in the first four production periods in relation to the machinery usage in the base solution (Table XXIII). While the pattern of net returns was not significantly changed, the reduction in machine usage in the early years of the planning horizon led to an optimum replacement policy which is one year longer than that of the base solution. In the case of the price increase problem, the absolute level of net returns is increased but there is little change in the amount of machinery hours used. Assumptions on the amount of labor available in the hypothetical farm situation do not allow a large increase in machinery use to take place. The result of this inability to increase the amount of machinery usage in response to increased product price is that there is no change in the optimal replacement policy with respect to the base solution.

Price and Discount Rate Effects

To examine the effects of a change in price with a simultaneous change in the discount rate, a ten percent reduction in the price series was introduced and the discount rate was varied between ten and nineteen percent. The expected net returns to machinery generated by the linear programming subsystem are shown in Table XXVII. The series of net returns to machinery has a high of $48,693.08 in 1979 and a low of $24,423.54. The pattern of expected net returns is not radically different from the pattern of expected net returns to machinery generated in the base solution (Table XII), and is approximately the same absolute pattern as shown in Table XX for the ten percent reduction in yield replacement problem.

Hours of machinery use in each year of the planning horizon for the reduced price-varying discount rate problem are presented in Table XXVIII. As can be seen in a comparison with Table XXII, the machine usage per period resulting from a ten percent decrease in the price series assumed in the base solution is almost identical to the machinery usage per period for the reduced yield problem.

The solution to the reduced price series replacement problem assuming a 12 percent discount rate appears in Table XXIX. The repair costs per period (Column 4) for the reduced price model do not vary significantly from the repair costs per period for the ten percent yield reduction problem (Table XXI). The marginal cost and net returns per period are also very similar for the two problems. The maximum present value of net returns (Column 9) in Table XXIX occurs in the fourth period at a level of $245,739.30, which indicate an optimal machinery complement replacement policy of replacing the machinery complement after four years.

TABLE XXVII

EXPECTED NET RETURNS TO MACHINERY FOR THE 1973 BASED SEVEN YEAR PLANNING HORIZON ASSUMING A TWELVE PERCENT DISCOUNT RATE AND TEN PERCENT REDUCTION IN THE PRICE SERIES

Year	Expected Net Returns
1973	$27,660.78
1974	$45,244.48
1975	$39,795.70
1976	$35,169.25
1977	$24,423.54
1978	$33,851.89
1979	$48,683.08

The four year replacement policy recommendation is in line with the previous results in the yield reduction and variable discount rate problem analysis. While in this analysis, both the variable discount rate and yield reduction situations result in longer equipment usage policies than for the base solution, the combinations of these two effects need not necessarily result in the same replacement policy (Perrin, 1972)

TABLE XXVIII

MACHINE USAGE IN HOURS PER YEAR FOR THE TEN PERCENT PRICE REDUCTION AND TWELVE PERCENT DISCOUNT RATE

Machine	Year						
	1973	1974	1975	1976	1977	1978	1979
Tractor	908.22	1,344.69	1,462.60	860.30	1,462.60	903.82	903.82
Tandem Disk	58.59	105.74	105.20	50.69	105.20	54.44	54.44
Moldboard Plow	101.36	305.97	312.74	125.10	312.74	140.79	140.79
Field Cultivator	28.44	40.90	24.00	47.16	24.00	58.30	58.30
Springtooth Harrow	86.31	149.46	152.90	72.07	152.90	78.40	78.40
Drill	82.01	152.69	151.90	69.37	151.90	79.34	79.34
Spike Harrow	3.26	2.00	2.00	4.14	2.00	3.90	3.90
Row Cultivator	57.47	123.48	139.53	24.00	139.53	24.00	24.00
Sickle Mower	83.10	51.00	51.00	105.55	51.00	99.38	99.38
Rake	83.10	51.00	51.00	105.55	51.00	99.38	99.38
P.T.O. Baler	71.69	44.00	44.00	91.06	44.00	85.74	85.74

TABLE XXIX

VARIABLE USAGE REPLACEMENT SOLUTION FOR A TEN PERCENT DECREASE IN THE PRICE SERIES DURING THE SEVEN YEAR PLANNING HORIZON BASED IN 1973 ASSUMING A TWELVE PERCENT DISCOUNT RATE

Year (1)	Period (2)	Asset Values (3)	Repair Cost (4)	Marginal Cost (5)	Net Returns (6)	V(A) (7)	Capital Recovery Factor Times V(A) (8)	Present Value of Net Returns (9)
1973	1	25,469.00	504.34	4,274.34	27,156.44	20,476.82	22,934.04	165,648.00
1974	2	20,390.00	1,415.69	6,494.69	43,828.79	50,377.88	29,784.85	227,817.00
1975	3	20,051.00	2,466.43	2,805.43	37,329.27	76,569.13	31,879.50	245,611.40
1976	4	19,510.00	2,675.33	3,216.33	32,493.92	96,678.56	31,829.93	245,739.30
1977	5	20,725.00	4,968.85	3,753.85	19,454.69	108,932.60	30,218.98	231,099.80
1978	6	20,075.00	4,309.11	4,959.11	29,542.79	123,249.80	29,977.55	229,737.90
1979	7	20,700.00	6,701.52	6,076.52	41,981.56	142,865.10	31,304.30	240,169.20

CHAPTER V

SUMMARY AND CONCLUSIONS

The primary objective of this study was to analyze investment/disinvestment decision making with variable usage rates for machinery complements. A secondary objective of this study was to examine the effect of changes in the discount rate on the investment/disinvestment decisions. A third objective was to determine what effect varying yields and output prices would have on equipment replacement decisions.

A systems model representing the firm's investment/disinvestment decision making process was constructed. The system model is composed of three subsystems. A linear programming model is used as a subsystem to represent the production planning of the firm. This leads to decisions on hours of machinery use to employ for each production period. A subsystem to calculate machinery usage costs per period from the use recommendations of the linear programming model was developed. The costs are based on cost equations adopted by the American Society of Agricultural Engineers. Finally, an investment/disinvestment decision subsystem was developed that utilizes the machinery complement's value in use, original market price, salvage price and repair costs per period to arrive at optimal investment/disinvestment policies.

For model testing purposes, a hypothetical farm situation for northcentral Oklahoma was created. The farm consisted of a total of 800 tillable acres divided into two classes, with 200 acres of Class I land and 600 acres of Class II land. Grain sorghum, alfalfa hay or wheat could be grown on Class I land. Grain sorghum or wheat grown on Class II land has a ten percent lower yield than on Class I land. To insure that the machinery would be used each period, the model was forced to contain at least 100 acres of wheat and grain sorghum per period along with at least 50 acres of alfalfa. Labor restrictions were divided into four periods: December-April period with 854 hours available, May-June with 614 hours available, July-September with 874 hours available and October-November with 548 hours available. The operator was assumed to have $15,000 of short term operating capital available each quarter.

Price and yield data for the hypothetical farm were taken from actual price and yield series data for northcentral Oklahoma for the 1973 to 1979 time period. United States Department of Agriculture estimates were used for 1980 and 1981 prices and yields. Technological coefficients linking the production activities to labor and capital constraints for the linear programming subsystem were taken from Oklahoma State University Enterprise Budgets. Costs of production for each activity were also taken from Oklahoma State University Enterprise Budgets. Data on machinery list prices were taken from the National Farm Tractor and Implement Blue Books and from Oklahoma State University Enterprise Budgets. Data on machinery salvage values were taken from the National Farm Tractor and Implement Blue Books.

As a basis for comparison, a replacement policy was developed for the hypothetical farm based on the usual assumption of a constant flow of machine usage per production period. The optimal replacement policy for the machinery complement for the hypothetical farm under the assumption of a constant flow of machinery use was found to be to replace equipment after five years of use. The assumption of constant usage was then relaxed and the pattern of machinery usage for a seven year planning horixon based in 1973 was generated. The suggested pattern of machinery usage resulted in an optimal replacement policy of three years, as opposed to the five year replacement policy for the constant usage model. Using this initial replacement policy as a base, a replacement pattern for the years 1973 to 1981 was developed by application of the systems model. For the hypothetical farm situation, the optimum replacement pattern based on varying machinery usage would be composed of a three year replacement policy followed by a six year policy.

Changes in the discount rate were introduced using the 1973 variable usage replacement decision problem as a basis for comparison. The discount rate for the 1973 problem was varied between ten and nineteen percent. For the ten to sixteen percent rate the replacement decision was insensitive to changes in the discount rate. However, at the 17 percent discount rate, the optimum replacement policy changed and a four year replacement policy was then recommended.

Similarly, yields and prices were varied from the 1973 variable usage base solution. A ten percent reduction in yield resulted in a lower level of machinery usage, which in turn led to a years delay in the recommended replacement decision. A ten percent increase was introduced into the price series utilized in the base model, but because of restrictions on the amount of labor available to the firm, little change in machinery usage relative to the base solution occurred. With the nearly identical machine usage pattern and the same relative pattern of net returns to machinery over time, there was no change in the optimal replacement policy brought about by an increase in the price series.

In a final application, the model was provided with a ten percent decrease in the price series. The discount rate was varied simultaneously to see what compounded effects these two parameters have on the replacement decision. Once again, machine usage was decreased as in the reduced yield model, and the optimal replacement policy was four years, a delay of one year relative to the 1973 variable usage base solution.

Limitations and Need for Further Research

The scope of this study was limited to basically one power unit, the tractor and its complements. Difficulties in arriving at a satisfactory method of valuing the contribution of each machine to the overall production process necessitated handling the tractor and its complements as if they were one asset. In many actual cases, due to changes in manufacturing and technological improvements, when the tractor is replaced most of the major implements are also replaced. However, any advances in the area of agricultural economics or agricultural engineering that would lead to estimates of the value that each piece of equipment contributed to the production process would enhance the possible number of applications of this model. Because of the limited series of Oklahoma State University Budgets available, the span of time which this study was able to cover was not extremely long. However, as the series of budgets that are available over time increases, there will be more reliable data to base the machine usage requirements on. A lack of available data on predicted machinery list prices for future time periods along with predictions for future salvage values hindered the application of the model to obtain a solution for an extremely long replacement pattern into the future. A study that would provide a method to reliably predict future machinery list prices and future machinery salvage values would enable the model to be applied to long range prediction problems which would enhance long range farm budgeting processes.

Tax considerations were not included in this study. The lumpy nature of machinery investment can make tax considerations an important factor in the machinery investment/disinvestment process. Incorporation of tax considerations into the replacement model system could be a theme for further research.

The replacement model system in this study operates in a recursive fashion. Changes in the investment/disinvestment decision model that would allow the effects of changes in the machinery complement and changes in machinery usage cost to be arrived at simultaneously could also be an area for further research.

Even with these limitations, the model can be applied to many durable asset replacement problems. A farm manager who has some idea of what his future production pattern might be can bypass the linear programming subsystem and place his expected machinery usage demand into the cost calculation subsystem. Along with the expected costs he could place the list price of the machinery he has chosen into the model and can arrive at a predicted replacement policy to aid in his long range budgeting. By altering the machinery cost calculation equations, other machinery replacement problems can be addressed. A person involved in a wheat or cattle hauling operation could plug in his estimates of yearly use and yearly returns to arrive at a predicted replacement policy for his tractor-trailer trucks. Corporations such as railroads could employ the model to see what effects varying rates of traffic might have on track replacement policies.

By using predicted usage requirements and by tailoring the cost calculation subsystem, the variable usage model could be applied to these and other similar problems.

A SELECTED BIBLIOGRAPHY

American Society of Agricultural Engineers Farm Machinery Management Committee. "Agricultural Machinery Management Data." A.S.A.E. Yearbook, 1977, (May, 1977), pp. 326-333.

Anderson, Jock R., John L. Dillon and Brian Hardaker. Agricultural Decision Analysis. 1st Ed. Ames: Iowa State University Press, 1977.

Baquet, Alan E. "A Theory of Investment and Disinvestment Including Optimal Lives, Maintenance and Usage Rates for Durables." (Unpublished Ph.D. dissertation, Michigan State University, 1978.)

Beneke, Raymond R. and R. D. Winterboer. Linear Programming Applications to Agriculture. 1st Ed. Ames: Iowa State University Press, 1973.

Bowers, Wendell. Costs of Owning and Operating Farm Machinery. Stillwater: Oklahoma State University, November, 1969.

Capstick, Daniel F. "Quadratic Programming Analysis of Farm Organization in Northern Arkansas." (Unpublished Ph.D. dissertation, Oklahoma State University, 1973.)

Chisholm, Anthony H. "Criteria for Determining the Optimum Replacement Pattern," Journal of Farm Economics, 48 (February, 1966), pp. 107-112.

Crane, Donald R., Jr. "The Sugarcane Stubble Replacement Decision for South Florida." (Unpublished M.S. thesis, University of Florida, 1979.)

Edwards, Clark. "Resource Fixity and Farm Organization," Journal of Farm Economics, 41 (November, 1959), pp. 747-759.

Faris, J. Edwin. "Analytic Techniques Used in Determining the Optimum Replacement Pattern," Journal of Farm Economics, 43 (November, 1961), pp. 952-955.

Hughes, Joan K. Programming the IBM 1130. 1st Ed. New York: John Wiley and Sons, Inc., 1969.

Johnson, Glenn L. "Supply Function--Some Facts and Notions," Agricultural Adjustment Problems in a Growing Economy, ed. Heady, Dresslin, Jensen and Johnson. Ames: Iowa State University Press, 1958, pp. 74-93.

Johnson, Glenn L. and C. Leroy Quance. The Overproduction Trap in U. S. Agriculture. Baltimore: Johns Hopkins University Press, 1972.

Kletke, Darrel D. "Theory and Application of Economically Optimum Farm Machinery Replacement Criteria." (Unpublished Ph.D. dissertation, Oklahoma State University, 1969.)

__________. Operations Manual for the Oklahoma State University Enterprise Budget Generator. Stillwater: Oklahoma Agricultural Experiment Station Research Report P-790, August, 1979.

Leftwich, Richard H. The Price System and Resource Allocation. 6th Ed. Hinsdale, Illinois: The Dryden Press, 1976.

Libbin, James D., Charles A. Moorhead, and Neil R. Martin, Jr. A User's Guide to the IBM MPSX Linear Programming Package, Part I--Small Models. Urbana-Champaign, Illinois Department of Agricultural Economics, AE 4316, June, 1973, pp. 1-37.

National Market Reports, Inc. National Farm Tractor and Implement Blue Book. Chicago, Illinois, 1973-1979.

Oklahoma Department of Agriculture. Oklahoma Agricultural Statistics. Oklahoma City, Oklahoma, 1979.

Patton, John E. "The Development of a Computerized Algorithm to Measure the Individual Machine Cost." (Unpublished M.S. thesis, Oklahoma State University, 1971.)

Perrin, R. K. "Asset Replacement Principles," American Journal of Agricultural Economics, 54 (February, 1972), pp. 60-67.

Rockeman, Kurt A. "An Economic Analysis of Ranching in Northwest Oklahoma Under Variable Forage Yield and Quality Conditions and Selected Beef Prices." (Unpublished M.S. thesis, Oklahoma State University, 1978.)

Terborgh, George. Dynamic Equipment Policy. 1st Ed. New York: McGraw-Hill Book Company, Inc., 1949.

Tweeten, Luther and Wallace Huffman. "Structural Change: An Overview." (Paper presented to the Small Farm Conference, Lincoln, Nebraska, January 30-February 2, 1979.) Stillwater: Oklahoma State University, Department of Agricultural Economics, 1979.

United States Department of Agriculture. Monthly Update and Policy Baseline, February, 1979. Washington: Economic, Statistics, and Cooperative Service, 1979.

__________. 1977 Handbook of Agricultural Charts. Washington: Economic, Statistics, and Cooperative Service, Agricultural Handbook No. 524, 1977.

__________. 1979 Handbook of Agricultural Charts. Washington: Economic, Statistics, and Cooperative Service, Agricultural Handbook No. 561, 1979.

Yotopoulos, Pan A. "From Stock to Flow Capital Inputs for Agricultural Production Functions: A Microanalytic Approach," Journal of Farm Economics, 49 (May, 1967), pp. 476-490.

APPENDIX

The data input format necessary to employ the asset replacement optimizer program appears in Figure 8. The first card of the data set contains the number of assets to be processed in the run. The program can process up to 100 assets in one computer run. The number of assets (IASST) must be punched in columns 1 through 3 of the header card and should be right-justified. After the header card, the data set for each asset is read into the program. The desired initial discount rate (RATE) should be punched, with decimal point, in columns 1 through 5. The desired length of the planning horizon (MLIFE) should be punched right-justified in columns 9-10. The program can accommodate a planning horizon of up to 20 years. The list price of the asset (PNEW) should be punched, with decimal point, in columns 16 through 25. The total expected life of the asset (TOTLF) should be punched, with decimal point, in columns 26 through 35. The machinery cost (A.S.A.E., 1977) should be punched right-justified in columns 39 through 40. The second card of the asset data set contains the annual usage requirements of the asset (ANUSE). The usage figure for each period in the planning horizon should be punched in a ten column field across the card. If the planning horizon exceeds eight periods in length the usage series should be continued on the next card. After completing input of the usage series, the next data input is the salvage price series (PRICE). The PRICE series follows the same input pattern as does the ANUSE series.

After input of the desired number of asset data sets, the series of net returns (RTRN) is read in. The format used to punch RTRN is identical to that of ANUSE. A generalized flow chart of the replacement program appears in Figure 9.

Cols. 1-3	
IASST	header card

Cols. 1-5	Cols. 9-10	Cols. 16-25	Cols. 26-35	Cols. 39-40	
RATE	MLIFE	PNEW	TOTLF	IEQ	1st card

Cols. 1-10	Cols. 11-20	. . . .	Cols. 71-80	
ANUSE (1)	ANUSE (2)	. . . .	ANUSE (8)	2nd card

Cols. 1-10	Cols. 11-20	. . . .	Cols. 71-80	
PRICE (1)	PRICE (2)	. . . .	PRICE (8)	3rd card

Cols. 1-10	Cols. 11-20	. . . .	Cols. 71-80	
RTRN (1)	RTRN (2)	. . . .	RTRN (8)	trailer card

Figure 8. Data Input Format for the Replacement Decision Optimizer Program

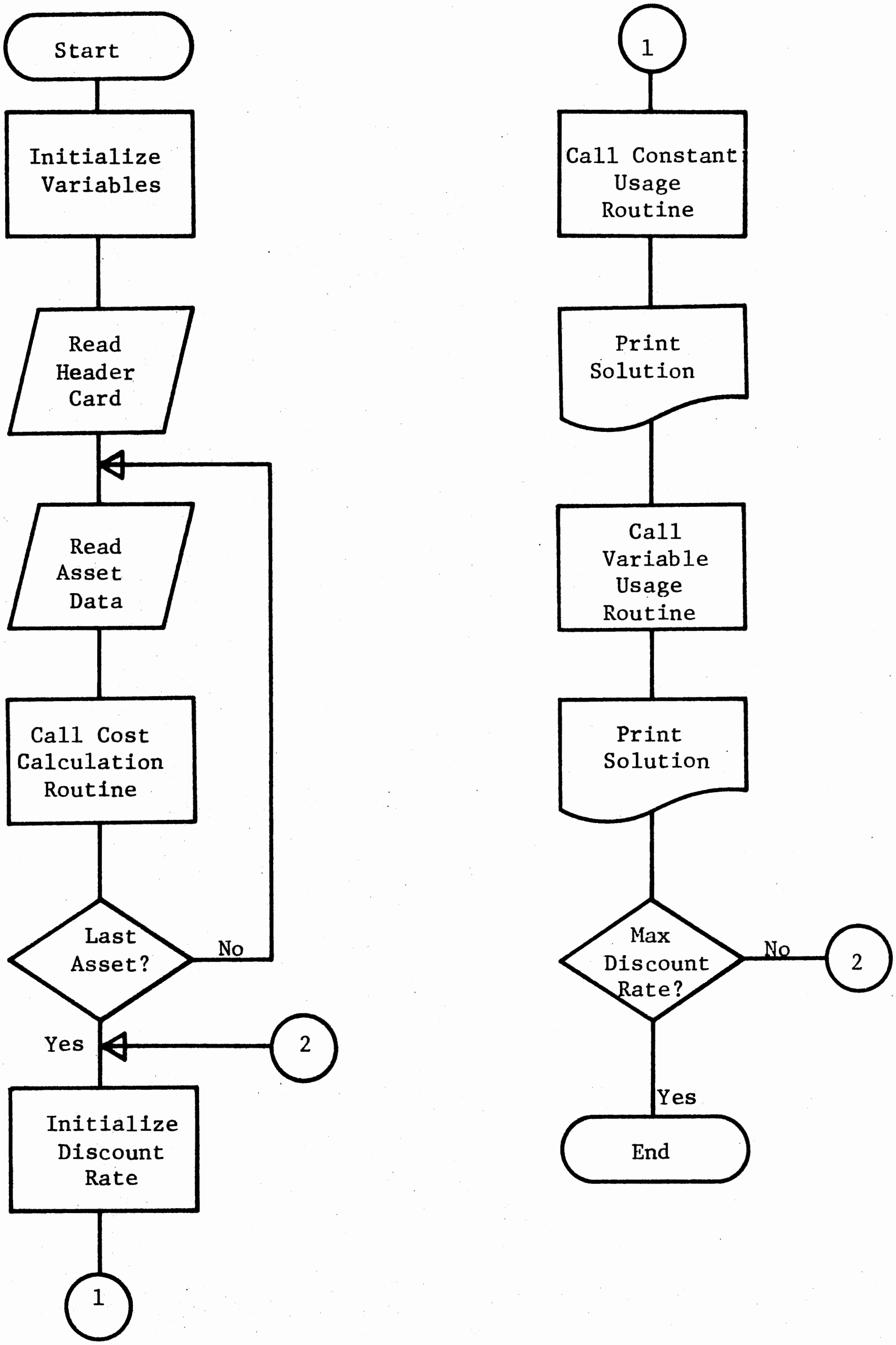


Figure 9. Generalized Flow Chart for Replacement Decision Optimizer Program

TABLE XXX

VARIABLE USAGE REPLACEMENT PROGRAM

```
$JOB
C       PROGRAM: PERRIN INVESTMENT/DISINVESTMENT OPTIMIZER
C       PROGRAMMER: LAWRENCE FALCONER   OKLA. STATE  UNIV. SPRING 1979
C
C       MAJOR VARIABLES
C
C       MLIFE = MAXIMUM LIFE OF THE ASSET
C       RATE = INTEREST RATE FOR DISCOUNT PURPOSES
C       RTRN = 21 X 1 ARRAY OF RETURNS FROM THE ASSET FOR EACH PROD PERIOD
C       COST = 21 X 1 ARRAY OF COST OF OPERATING ASSET FOR PROD PERIOD
C       PUSED = 21 X 1 ARRAY OF MKT VALUES FOR THE USED ASSET
C       PNEW = PURCHASE PRICE OF THE ASSET
C       IASST = NUMBER OF ASSETS TO BE PROCESSED PER RUN
C       VRUSE = 21X1 ARRAY USED TO REFLECT VARYING USE SALVAGE VALUES
C       VCOST = 21X1 ARRAY USED TO REFLECT VARYING USE OPERATING COSTS
C
        COMMON MLIFE,RATE,RTRN(21),COST(21),PUSED(21),PNEW
        COMMON VRUSE(21),VCOST(21),ANUSE(21),TOTLF,DLIST
        COMMON  IEQ,PRICE(21),TCOST(21),CST1(21)
C
        DO 5 I=1;21
           PRICE(I) = 0.0
           PUSED(I) = 0.0
           VRUSE(I) = 0.0
           VCOST(I) = 0.0
            COST(I) = 0.0
      5 CONTINUE
        DLIST = 0.0
C
        READ(5,1000)IASST
   1000 FORMAT(I3)
C
C       INPUT THE FIRST 20 PRODUCTION PERIOD DATA
C
        DO 10 N=1,IASST
        READ(5,2000)RATE,MLIFE,PNEW,TOTLF,IEQ
        DLIST = DLIST + PNEW
   2000 FORMAT(F5.2,3X,I2,5X,2F10.2,3X,I2)
        READ(5,3000)(ANUSE(I),I=1,MLIFE)
        READ(5,3000)(PRICE(K),K=1,MLIFE)
C
C       CALL VARIABLE COST CALCULATING SUBROUTINE
C
        CALL CALC
C
        DO 10 J=1,20
           VCOST(J) = VCOST(J) + TCOST(J)
           COST(J) = COST(J) + CST1(J)
           PUSED(J) = PUSED(J) + PRICE(J)
           VRUSE(J) = VRUSE(J) + PRICE(J)
        WRITE(6,3)VCOST(J),COST(J),PUSED(J),VRUSE(J)
      3 FORMAT(4F10.2)
C
     10 CONTINUE
C
        READ(5,3000)(RTRN(J),J=1,MLIFE)
C       SET UP LAST PERIOD DATA FOR THE MARGINAL CRITERIA
C
        PUSED(MLIFE + 1) = 0.0
        VRUSE(MLIFE + 1) = 0.0
```

TABLE XXX (Continued)

```
      COST(MLIFE+1) = COST(MLIFE)
      VCOST(MLIFE + 1) = VCOST(MLIFE)
      RTRN(MLIFE+1) = RTRN(MLIFE)
      DO 30 I=1,2
C
C     CALL SUBROUTINE FOR CONSTANT USEAGE PER PERIOD OPTIMIZATION
C
      CALL CUSE
C
C     CALL SUBROUTINE FOR VARIABLE USEAGE PER PERIOD OPTIMIZATION
C
      CALL VUSE
      RATE = RATE + 0.01
   30 CONTINUE
      WRITE(6,3500)
 3000 FORMAT(8F10.2)
 3500 FORMAT(1H1)
      STOP
      END

      SUBROUTINE CUSE
C     CUSE SUBROUTINE OPTIMIZES ASSET INVESTMENT FOR CONSTANT USE EACH
C     PRODUCTION PERIOD
C
      COMMON MLIFE,RATE,RTRN(21),COST(21),PUSED(21),PNEW
      COMMON VRUSE(21),VCOST(21),ANUSE(21),TOTLF,DLIST
      COMMON  IEN,PRICE(21),TCOST(21),CST1(21)
C     INITIALIZE VARIABLES FOR BEGINNING OF OPTIMIZATION PROCESS
C
C     RCHCE USED FOR MARGINAL ANALYSIS = COST(A+1) - DISCOUNTED RETURN
C     TCHNG IS THE CHANGE IN ASSET VALUE EACH PRODUCTION PERIOD
C     RDUMB = DUMMY VARIABLE FOR MARGINAL ANALYSIS COMPARISON
C     RCDMB = DUMMY VARIABLE FOR CONTINUOUS ANALYSIS COMPARISON
C
      RCHCE = 0.0
      TCHNG = DLIST
      IMBST = 0
      ICBST = 0
      RDUMB = 1000000.0
      RCDMB = 1000000.0
      WRITE(6,4000)
 4000 FORMAT(1H1)
      WRITE(6,5000)
 5000 FORMAT('-',T41,'CONSTANT USEAGE REPLACEMENT PARAMETERS',///' ',T5,
     1'AGE',T13,'PERIOD ENDING',T33,'REPAIR',T53,'PERIOD',T71,'V(A)',T85
     2,'CAPITAL RECOVERY',T108,'PRESENT VALUE',/' ',T5,'(A)',T14,'ASSET
     3VALUE',T34,'COST',T54,'COSTS',T85,'FACTOR * V(A)',T110,'C(0,A,*)',
     4//' ',T5,115('*'))
C
C     BEGINNING OF OPTIMIZATION LOOP
C
      DO 20 K=1,MLIFE
      LTOT = K
      DCOST = 0.0
C
C         BEGINNING OF LOOP TO DISOUNT ASSET COSTS
C
          DO 10 I=1,LTOT
          CCST = 0.0 - COST(I)
          DSCNT = CCST     / (1.0 + RATE) ** I
```

TABLE XXX (Continued)

```
            DCOST = DCOST + DSCNT
   10 CONTINUE
      TRADE = PUSED(K) - DLIST
C
C     PVRC = PRESENT VALUE OF THE REPLACEMENT CYCLE
C
      PVRC = TRADE + DCOST
      RK = FLOAT(K)
      RK = 0.0 - RK
C
C     CRF  = CAPITAL RECOVERY FACTOR
C
      CRF = RATE / ( 1.0 - ((1.0 + RATE)** RK))
C
C     DPVRC = DISCOUNTED  VALUE OF THE PRESENT VALUE OF REPLACEMENT CYCLE
C
      DPVRC = PVRC * CRF
C
C     RPOLY = CONTINUOUS REPLACENT DECISION VALUE
C
      RPOLY = (PVRC /(1.0 - (1.0 + RATE)**RK)) - PUSED(K)
C
C     THIS SECTION SETS UP A+1 PERIOD FOR MARGINAL ANALYSIS ALONG WITH
C     CURRENT (A) PERIOD VALUES FOR MARGINAL  ANALYSIS
C
      TCHNG = TCHNG - PUSED(K)
      TPRM  = PUSED(K) - PUSED(K+1)
      ANCST = COST(K) + TCHNG
      ANPRM = COST(K+1) + TPRM
      TCHNG = PUSED(K)
      RABS = ANPRM + DPVRC
      RCHCE = ABS(RABS)
C
C     THIS SECTION CHECKS FOR OPTIMUM PERIOD WITH MARGINAL TECHNIQUE
C
      IF( RCHCE .LE. RDUMB) IMBST = K
      IF(RCHCE.LE.RDUMB) RDUMB = RCHCE
C
C     THIS SECTION CHECKS FOR OPTIMUM PERIOD WITH CONTINUOUS TECHNIQUE
C
      CABS = ABS(RPOLY)
      IF( CABS.LE.RCDMB) ICBST = K
      IF( CABS.LE.RCDMB ) RCDMB = CABS
      WRITE(6,6000)K,PUSED(K),COST(K),ANCST,PVRC,DPVRC,RPOLY
 6000 FORMAT('0',T5,I2,T13,F10.2,T32,F8.2,T48,F12.2,T68,F9.2,T88,F9.2,T1
     109,F10.2)
   20 CONTINUE
      WRITE(6,6500)
 6500 FORMAT('-',T5,115('*'))
      QRATE = RATE * 100.0
      WRITE(6,7500)QRATE
 7500 FORMAT('-',T42,'INTEREST RATE',3X,F5.2,3X,'PERCENT')
      WRITE(6,7000)IMBST,ICBST
 7000 FORMAT('-',T23,'OPTIMUM DISCRETE REPLACEMENT PERIOD',2X,I2,T68,'OP
     1TIMUM CONTINUOS REPLACEMENT PERIOD',2X,I2)
      RETURN
      END

      SUBROUTINE VUSE
C
```

TABLE XXX (Continued)

```
C       VUSE SUBROUTINE OPTIMIZES ASSET INVESTMENT FOR VARYING USE EACH
C       PRODUCTION PERIOD
C
        COMMON MLIFE,RATE,RTRN(21),COST(21),PUSED(21),PNEW
        COMMON VRUSE(21),VCOST(21),ANUSE(21),TOTLF,DLIST
        COMMON  IFO,PRICE(21),TCOST(21),CST1(21)
C
C       INITIALIZE VARIABLES FOR BEGINNING OF OPTIMIZATION PROCESS
C
C       TCHNG IS THE CHANGE IN ASSET VALUE PER PRODUCTION PERIOD
C       RCOMB = DUMMY VARIABLE FOR CONTINUOUS ANALYSIS COMPARISON
C
        TCHNG = DLIST
        RCOMB = -1000000000.0
        ICHST = 0
        WRITE(6,8000)
 8000   FORMAT(1H1)
        WRITE(6,9000)
 9000   FORMAT('-',T41,'VARIABLE USEAGE REPLACEMENT PARAMETERS',///' ',T5,
       1'AGE',T15,'PERIOD ENDING',T33,'RETURN',T53,'PERIOD',T71,'V(A)',T85
       2,'CAPITAL RECOVERY',T108,'PRESENT VALUE',/' ',T5,'(A)',T14,'ASSET
       3VALUE',T34,'(NET)',T54,'COSTS',T85,'FACTOR * V(A)',T110,'C(0,A,*)'
       4,/' ',T5,115('*'))
C
C       BEGINNING OF OPTIMIZATION LOOP
C
        DO 20 K=1,MLIFE
        LTOT = K
        DSNET = 0.0
C
C           BEGINNING OF LOOP TO DISCOUNT NET RETURNS
C
        DO 10 I=1,LTOT
        RNET = RTRN(I) - VCOST(I)
            DSCNT = RNET     / (1.0 + RATE) ** I
            DSNET = DSNET + DSCNT
   10   CONTINUE
        TRADE = VRUSE(K) - DLIST
C
        TCHNG = TCHNG - VRUSE(K)
        ANCST = VCOST(K) + TCHNG
        TCHNG = VRUSE(K)
C
C       PVRC = PRESENT VALUE OF THE REPLACEMENT CYCLE
C
        PVRC = TRADE + DSNET
        RK = FLOAT(K)
        RK = 0.0 - RK
C
C       CRF = CAPITAL RECOVERY FACTOR
C
        CRF = RATE / ( 1.0 - ((1.0 + RATE)** RK))
C
C       DPVRC = DISCOUNTED VALUE OF THE PRESENT VALUE OF THE REPLACEMENT
C       CYCLE
C
        DPVRC = PVRC * CRF
C
C       RPOLY = CONTINUOUS REPLACEMENT DECISION VALUE
C
```

TABLE XXX (Continued)

```
      RPOLY = (PVRC / (1.0 - (1.0 + RATE)**RK)) - VRUSE(K)
C
C
C     THIS SECTION CHECKS FOR OPTIMUM PERIOD WITH CONTINUOS TECHNIQUE
C
      IF(RPOLY.GT.RCOMB)ICHST = K
      IF( RPOLY.GT.RCOMB ) RCOMB = RPOLY
      WRITE(6,9250)K,VRUSE(K),RNET,ANCST,PVRC,DPVRC,RPOLY
 9250 FORMAT('0',T5,I2,T13,F10.2,T32,F6.2,T48,F12.2,T68,F9.2,T88,F9.2,T1
     109,F10.2)
   20 CONTINUE
      WRITE(6,9375)
 9375 FORMAT('-',T5,115('*'))
      QRATE = RATE * 100.0
      WRITE(6,9750) QRATE
 9750 FORMAT('-',T42,'INTEREST RATE',3X,F5.2,3X,'PERCENT')
      WRITE(6,9500)ICHST
 9500 FORMAT('-',T44,'OPTIMUM REPLACEMENT PERIOD',2X,I2)
      WRITE(6,7)DLIST
    7 FORMAT(F10.2)
      RETURN
      END

      SUBROUTINE CALC
C     CALC SUBROUTINE CALCULATES COSTS FOR EACH ASSET
C
      COMMON MLIFE,RATE,RTRN(21),COST(21),PUSED(21),PNEW
      COMMON VRUSE(21),VCOST(21),ANUSE(21),TOTLF,DLIST
      COMMON  IEQ,PRICE(21),TCOST(21),CST1(21)
      DO 5 I=1,21
         TCOST(I) = 0.0
         CST1(I) = 0.0
    5 CONTINUE
C
C     INITIALIZE SUMMATION OF USE VARIABLE
C
      USE = 0.0
C
      USE =  USE + ANUSE(1)
C
C
      IF(IEQ.EQ.4)GO TO 30
      IF(IEQ.EQ.7)GO TO 40
C     SPECIALIZED COST EQUATION FOR 2W DRIVE TRACTOR
C
      TAR = 0.120 * ((( USE /  TOTLF ) * 100.0) **1.5)
      TCOST(1) =  ( TAR / 100.0) * PNEW
      WRITE(6,1000)TAR,TCOST(1)
      DO 10 I=2,MLIFE
      USE = USE + ANUSE(I)
      TAR = 0.120 * ((( USE /  TOTLF ) * 100.0) **1.5)
      TAR = ( TAR / 100.0 ) * PNEW
      TCOST(I) = TAR - TCOST(I - 1)
      WRITE(6,1000)TAR,TCOST(I)
 1000 FORMAT(2F10.2)
   10 CONTINUE
C
C     CONSTANT COST CALCULATION
C
      ADV = USE / FLOAT(MLIFE)
```

TABLE XXX (Continued)

```
      USE = ADV
      TAR = 0.120 * ((( USE / 12000.0) * 100.0 ) ** 1.5)
      CST1(1) = (TAR/ 100.0) * PNEW
      DO 20 I = 2,MLIFE
      USE = USE + ADV
      TAR = 0.120 * ((( USE / 12000.0) * 100.0 ) ** 1.5)
      TAR = ( TAR / 100.0 ) * PNEW
      CST1(I) = TAR - CST1(I - 1)
   20 CONTINUE
      RETURN
   30 TAR = 0.127 * ((( USE / TOTLF) * 100.0) ** 1.4)
      TCOST(1) =  ( TAR / 100.0) * PNEW
      WRITE(6,1000)TAR,TCOST(1)
      DO 35 I = 2,MLIFE
      USE = USE + ANUSE(I)
      TAR = 0.127 * ((( USE / TOTLF) * 100.0) ** 1.4)
      TAR = ( TAR / 100.0 ) * PNEW
      TCOST(I) = TAR - TCOST(I - 1)
      WRITE(6,1000)TAR,TCOST(I)
   35 CONTINUE
C     CONSTANT COST CALCULATION
      ADV = USE / FLOAT(MLIFE)
      USE = ADV
      TAR = 0.127 * ((( USE / TOTLF) * 100.0) ** 1.4)
      CST1(1) = (TAR/ 100.0) * PNEW
      DO 36 I=2,MLIFE
      USE = USE + ADV
      TAR = 0.127 * ((( USE / TOTLF) * 100.0) ** 1.4)
      TAR = (TAR / 100.0) * PNEW
      CST1(I) = TAR - CST1(I - 1)
   36 CONTINUE
      RETURN
   40 TAR = 0.301 * ((( USE / TOTLF) * 100.0) ** 1.3)
      TCOST(1) =  ( TAR / 100.0) * PNEW
      WRITE(6,1000)TAR,TCOST(1)
      DO 45 I = 2,MLIFE
      USE = USE + ANUSE(I)
      TAR = 0.301 * ((( USE / TOTLF) * 100.0) ** 1.3)
      TAR = ( TAR / 100.0 ) * PNEW
      TCOST(I) = TAR - TCOST(I - 1)
      WRITE(6,1000)TAR,TCOST(I)
   45 CONTINUE
C     CONSTANT COST CALCULATION
      ADV = USE / FLOAT(MLIFE)
      USE = ADV
      TAR = 0.301 * ((( USE / TOTLF) * 100.0) ** 1.3)
      CST1(1) = (TAR/ 100.0) * PNEW
      DO 46 I=2,MLIFE
      USE = USE + ADV
      TAR = 0.301 * ((( USE / TOTLF) * 100.0) ** 1.3)
      TAR = (TAR / 100.0) * PNEW
      CST1(I) = TAR - CST1(I-1)
   46 CONTINUE
      RETURN
      END
$ENTRY
```

VITA

Lawrence Lang Falconer

Candidate for the Degree of

Master of Science

Thesis: AN ANALYSIS OF MACHINERY INVESTMENT/DISINVESTMENT DECISION MAKING USING VARIABLE USAGE REPLACEMENT MODELS

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in McAlester, Oklahoma, February 18, 1956, the son of Mr. and Mrs. W. L. Falconer.

Education: Graduate from Stigler High School, Stigler, Oklahoma, in May, 1974; received the Bachelor of Science degree in Agriculture with a major in Agricultural Economics from Oklahoma State University in May, 1978; completed requirements for the Master of Science degree at Oklahoma State University in May, 1980.

Professional Experience: Graduate Research Assistant, Department of Agricultural Economics, Oklahoma State University, September, 1978-January, 1980.