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OPTIMIZATION OF FARM EQUIPMENT SELECTION

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by

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CHAPTER 1

INTRODUCTION

American agriculture is becoming a mechanized industry. Since 1950, the input of farm labor has declined greatly. This decline in labor input has resulted in an increase in machinery input. These facts are illustrated in Figure 1.1. Of course, mechanization compounded by rising machinery prices, as illustrated in Figure 1.2, has meant an increase in the amount of capital invested in machinery. Based on Figure 1.3, approximately 20% of the total dollars spent by American farm operators was spent on farm machinery in 1969. As long as farm machinery costs are a major portion of production expenditures, sound machinery management is required if farmers are to make ends meet.

No doubt, the decline in farm population as well as the decline in the number of operating farms is due in part to poor machinery management. Misjudgments in purchasing farm equipment can be costly, especially when initial costs are high or when the functions required must be performed accurately and on time.

A computer program which may be used as an aid in selecting tractors and farm implements has been written by Donnell Hunt (7). The program makes an economic analysis of a farm machine system and selects equipment sizes which minimize the annual cost of operation. In an attempt to increase the effectiveness and usefulness of Hunt's program this study was undertaken.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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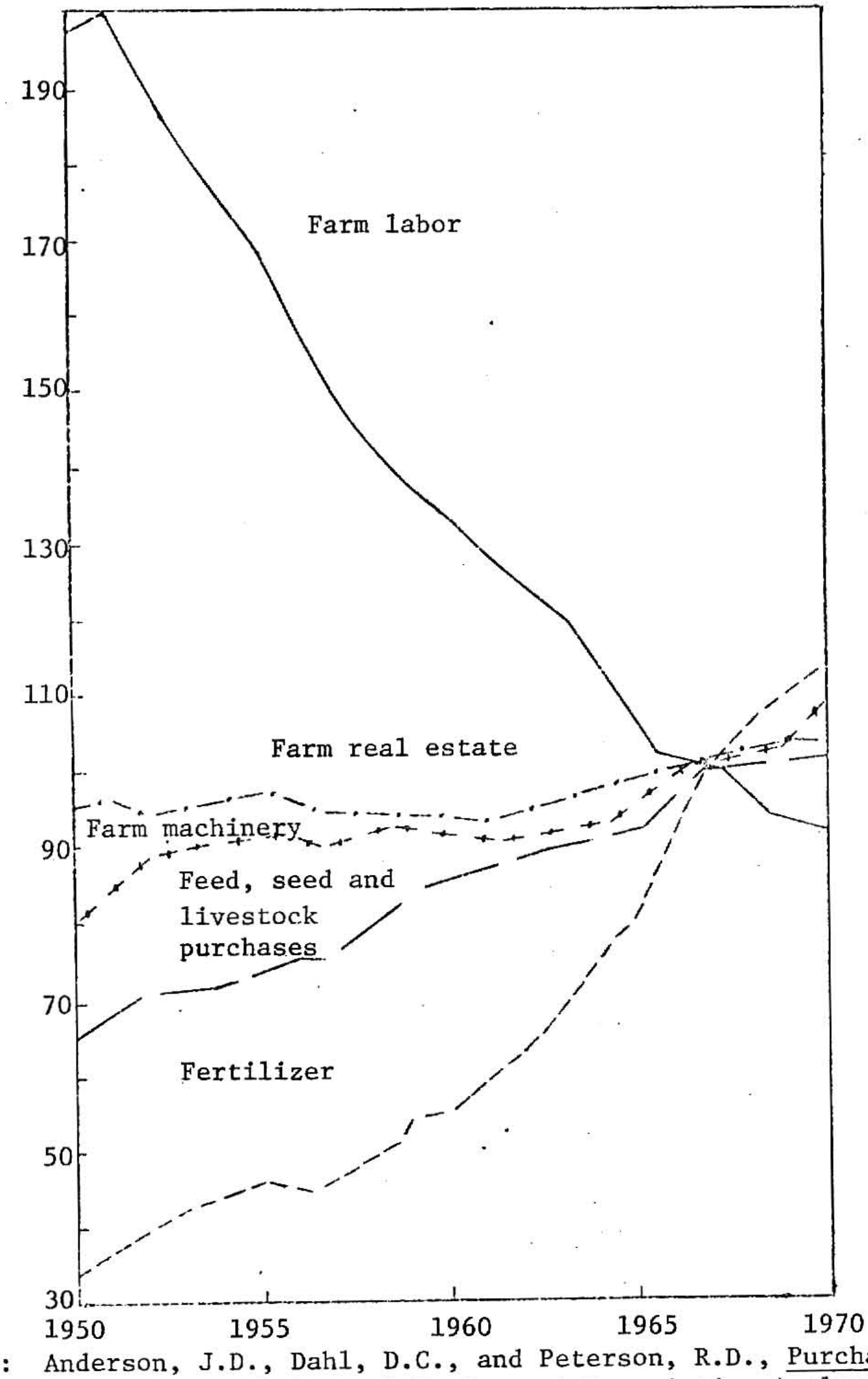
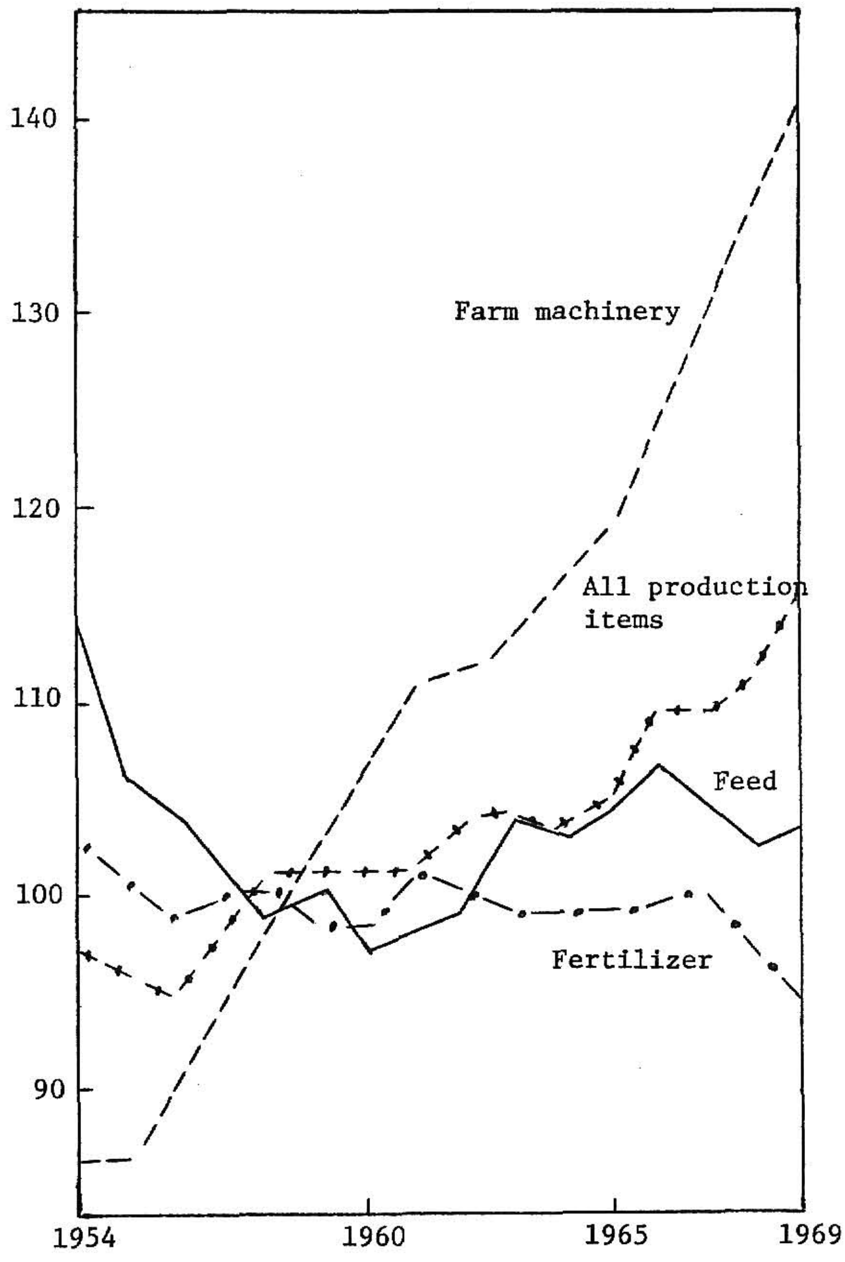
Figure 1.1. Indexes of selected farm input category purchases, 1950-1970.

(1967 = 100)



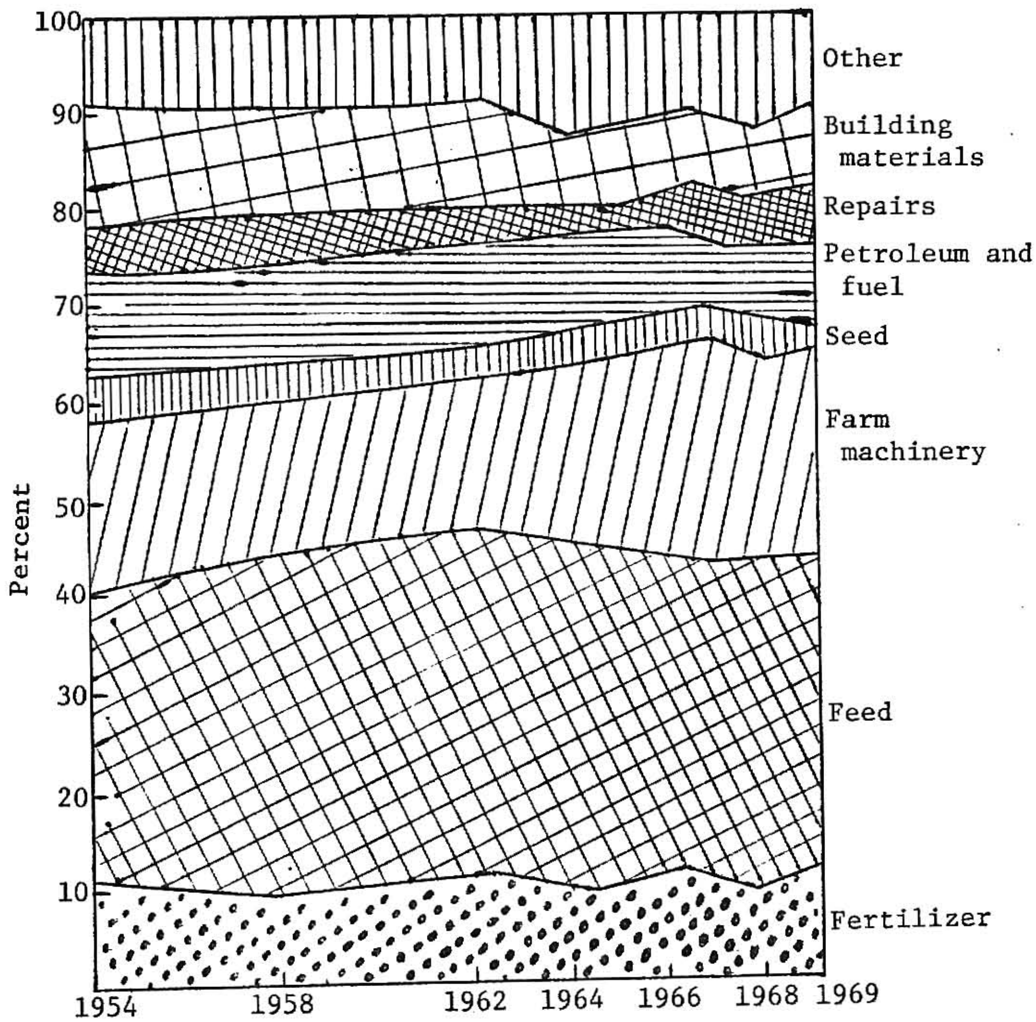
Source: Anderson, J.D., Dahl, D.C., and Peterson, R.D., Purchased Farm Inputs in the North-Central Region: A Descriptive Analysis of Selected Markets, Agricultural Experiment Station, University of Minnesota, Miscellaneous Report 109, 1971, p. 6.

Figure 1.2. Indexes of prices paid for production items, feed, fertilizer and farm machinery, U.S., 1954-1969. (1957=100)



Source: Anderson, J.D., Dahl, D.C., and Peterson, R.D., Purchased Farm Inputs in the North-Central Region: A Descriptive Analysis of Selected Markets, Agricultural Experiment Station, University of Minnesota, Miscellaneous Report 109, 1971, p. 16.

Figure 1.3. Percentage distribution of production expenditures by farm operators, U.S., 1954-1969.



Source: Anderson, J.D., Dahl, D.C., and Peterson, R.D., Purchased Farm Inputs in the North-Central Region: A Descriptive Analysis of Selected Markets, Agricultural Experiment Station, University of Minnesota, Miscellaneous Report 109, 1971, p. 5.

1.1 Hunt's Program

Donnell Hunt's program, written in FORTRAN IV, consists of one main program. The selection procedure is based on a search method for obtaining the optimum tractor horsepower. For a given tractor horsepower, optimum implement widths are determined by an "optimum width equation" (6). Basically, the form of the optimum width equation is as follows:

$$w = \sqrt{\left(\frac{8.25A}{FC\%\cdot p\cdot S\cdot e}\right)(L + T + K\cdot A\cdot Y\cdot V)}. \tag{1.1}$$

Equation 1.1 is derived from an implement annual cost equation by the methods of differential calculus. Hunt constructed an implement annual cost equation of the following form (6):

$$AC = FC\%\cdot p\cdot w + \left(\frac{8.25A}{S\cdot w\cdot e}\right)(rm\cdot p\cdot w + L + o\cdot w + f\cdot w + T + K\cdot A\cdot Y\cdot V). \tag{1.2}$$

Where:

AC = implement annual cost, \$/yr;

FC% = implement fixed cost rate;

p = purchase price of an implement, \$/ft;

w = theoretical width of implement, ft;

S = ground speed of implement, mph;

e = field efficiency;

A = implement annual acres, acres/yr;

rm = repair and maintenance cost factor, decimal/hr;

L = implement labor rate, \$/hr;

o = oil cost per hour on a per foot of implement width basis;

f = fuel cost per hour on a per foot of implement width basis;

T = cost of tractor use by the machine, \$/hr; T = 0 if implement is self-propelled;

K = timeliness factor, decimal/hr;

Y = potential crop yield, bushels, tons, etc., per acre;

V = value of crop, dollars per bushel, ton, etc.

Now by the methods of differential calculus;

$$\frac{d(AC)}{dw} = 0 = FC\% \cdot p - \left(\frac{8.25A}{S \cdot w^2 \cdot e}\right)(L + T + K \cdot A \cdot Y \cdot V), \tag{1.3}$$

$$= FC\% \cdot p \cdot w^2 - \left(\frac{8.25A}{S \cdot e}\right)(L + T + K \cdot A \cdot Y \cdot V). \tag{1.4}$$

Solving for w,

$$w = \sqrt{\left(\frac{8.25A}{FC\% \cdot p \cdot S \cdot e}\right)(L + T + K \cdot A \cdot Y \cdot V)}.$$

The above method of obtaining the least cost implement width has the advantage of being easily calculated. Equation 1.2 is minimized by the precise mathematical answer for implement width obtained from Equation 1.1. However, the practicality of such a solution may be questionable. For instance, in Equation 1.2 fuel and oil cost terms are given as simple functions of implement width, w. Such terms are desirable, since by differential calculus these terms will not appear in the "optimum width equation". However, in practice it is rather difficult to express fuel and oil costs as simple functions of implement width, w. For these reasons, it was felt that an implement annual cost equation should be written containing expressions which may be more practical. Several methods, no doubt, are used by agricultural economists to calculate fuel and oil costs. Some may use the methods suggested in the Agricultural Engineers Yearbook. For this work, those equations which Hunt has incorporated into his machinery selection program will be used to calculate fuel and oil costs.

An area limiting the utilization of Hunt's program is in the selection of fuels for engines in the farm machine system. With the present program, one fuel type may be selected for all engines in the machine system, which means that if the tractor uses diesel fuel so does the self-propelled combine. This will not always be the case. Therefore, the usefulness of Hunt's program could be increased by altering the program to allow for the selection of a fuel type for each engine in the farm machine system.

Presently, all power requirements in Hunt's program are based on an all inclusive term known as a force factor. The force factor gives the pounds of force needed to power a foot of width of an implement. Supposedly, the user of the program can determine a suitable value for the force factor of any kind of implement. This may be rather difficult for certain implements, especially when much of the available data is not given in such terms for implements driven by the power take-off shaft of the tractor or an engine. To overcome a certain amount of this difficulty, the program should be designed to make use of implement data given in terms of energy requirements.

Tractor drawbar performance is affected by soil conditions, travel speed, tractor weight, and method of implement attachment. The 1971 Agricultural Engineers Yearbook contains information which may be used to attempt to optimize tractor drawbar performance. The program should include this information in an effort to obtain more reliable solutions.

General improvements could also be made to Hunt's program. Present optimization procedures should be replaced by techniques used in the field of management science. Furthermore, the program should be redesigned to facilitate program changes without studying the entire program. This could be achieved by separating the program into a set of subroutines each concerned with some logical portion of the machinery selection process.

1.2 Statement of the Problem

The overall objective is to refine Hunt's program and make it more general in its application. This will be achieved by accomplishing the following intermediate goals.

1) Construct a more precise annual cost equation by utilizing equations employed in Hunt's program to express the cost factors of all implements.
2) Increase the utility of Hunt's program by allowing a different fuel type for each engine in the farm machine system.

3) Include in Hunt's program information available in the Agricultural Engineers Yearbook concerning

   a. energy needed for equipment driven by the power take-off shaft of the tractor or an engine, and

   b. tractor drawbar performance.

4) Improve Hunt's program by

   a. making use of optimization techniques used in management science, and

   b. redesigning the program as a set of subroutines.

CHAPTER 2

BASIC DEFINITIONS

In order to understand certain terms and factors of equations in the following chapters, it will be necessary to present various definitions and develop several equations. Such terms as machine capacity, field efficiency, horsepower, and energy are important in the development of an implement annual cost equation for a farm machine system of tractors and implements.

2.1 Machine Capacity

Theoretical field capacity is achieved if the machine performs its function without interruption at the given speed and given width. C_t, the theoretical field capacity in acres per hour, may be calculated from the following equation:

$$C_t = \frac{S \cdot w}{8.25} . \qquad (2.1)$$

Where:

C_t = theoretical field capacity, acres/hr;

S = ground speed of machine, mph;

w = theoretical width of machine action, ft;

$$\frac{1}{8.25} = \frac{5,280 \text{ ft}}{\text{mile}} \times \frac{\text{acre}}{43,560 \text{ ft}^2} .$$

For example, if

$$S = 5 \text{ mph},$$

and

$$w = 10 \text{ ft},$$

then;

$$C_t = \frac{5 \times 10}{8.25},$$

$$= 6.06 \text{ acres/hr.}$$

Effective field capacity is the actual rate of land covered or crop processed in a given time, based upon total field time. For instance, 40 acres of land tilled in 8 hours would result in an effective field capacity of 5 acres per hour. Letting C_e be the effective field capacity,

$$C_e = \frac{\text{total area tilled}}{\text{total time spent to till area}}, \tag{2.2}$$

$$= \frac{40 \text{ acres}}{8 \text{ hours}},$$

$$= 5 \text{ acres/hr.}$$

Field efficiency is the ratio of effective field capacity to the theoretical field capacity. Continuing with the above example and letting e denote field efficiency;

$$e = \frac{C_e}{C_t}, \tag{2.3}$$

$$= \frac{5 \text{ acres/hr}}{6.06 \text{ acres/hr}},$$

$$= 0.825.$$

Conversely, if the field efficiency is known it is possible to predict the effective field capacity of a machine since,

$$C_e = C_t \cdot e ,$$

$$= \frac{S \cdot w \cdot e}{8.25} . \qquad (2.4)$$

Where:

C_e = effective field capacity, acres/hr;

e = field efficiency.

It should be mentioned here that a specific value of field efficiency is usually given as a percent. However, for all equations in this work field efficiency will always be used in the decimal form.

2.2 Horsepower Requirements

Horsepower, denoted by hp, will be considered as the basic unit of power and is defined as follows:

$$1 \text{ hp} = \frac{33{,}000 \text{ ft-lb}}{\text{min}} , \qquad (2.5)$$

$$= \frac{550 \text{ ft-lb}}{\text{sec}} .$$

Power take-off horsepower is power obtained from the power take-off shaft of the tractor or engine (4). The PTO hp required by an implement is given by the following formula:

PTO hp = (power or energy requirement)(machine size or performance rate).

Since this work will only be concerned with power take-off energy requirements in terms of horsepower-hours per ton, the PTO hp required is obtained from the following equation:

$$\text{PTO hp} = \text{HHT} \cdot Y \cdot C_e . \tag{2.6}$$

Where:

PTO hp = power take-off horsepower, hp;

HHT = power take-off energy requirement, $\frac{\text{hp-hr}}{\text{ton}}$;

Y = crop yield, tons/acre;

C_e = effective field capacity, acres/hr.

Drawbar horsepower is power required to move the implement through or over the soil or crop. It is developed through the wheels or tracks of the tractor (4). The following equation gives the required drawbar horsepower, DB hp, to power an implement:

$$\text{DB hp} = \frac{S \cdot w \cdot ff}{375} . \tag{2.7}$$

Where:

DB hp = drawbar horsepower, hp;

S = ground speed of machine, mph;

w = theoretical width of machine action, ft;

ff = force factor, lbs/ft;

$$\frac{1}{375} = \frac{\text{hr}}{60 \text{ min}} \times \frac{5{,}280 \text{ ft}}{\text{mile}} \times \frac{\text{min-hp}}{33{,}000 \text{ ft-lb}} .$$

Since tractors are generally rated in terms of PTO hp, it is necessary to convert DB hp to an equivalent PTO hp. Because of power losses due to friction in the drive train of the tractor, tractor rolling resistance, soil conditions, etc. a conversion factor is used to convert from DB hp to equivalent PTO hp (6). The conversion factor, commonly termed "tractive efficiency ratio", is the ratio of the DB hp to axle horsepower. Axle horsepower being, in general for selective gear transmissions, 96% of the available PTO hp (4). Therefore,

$$\text{DB hp}_{\text{PTO equiv}} = \frac{\text{DB hp}}{0.96\ \text{TER}} \quad (2.8)$$

Where;

$\text{DB hp}_{\text{PTO equiv}}$ = drawbar horsepower expressed as an equivalent power take-off horsepower,

TER = tractive efficiency ratio.

The total equivalent power take-off horsepower required to power an implement then, is the sum of the required PTO hp and DB $\text{hp}_{\text{PTO equiv}}$;

$$\text{hp}_{\text{PTO equiv}} = \text{PTO hp} + \text{DB hp}_{\text{PTO equiv}} \quad (2.9)$$

Where;

$\text{hp}_{\text{PTO equiv}}$ = total horsepower required to power an implement in terms of PTO hp.

Many times it is desirable to have a certain amount of reserve tractor horsepower for tough soil conditions, steep slopes, starting the implement, etc. When this is so, the required tractor horsepower, hp_T, is obtained by dividing the required implement horsepower as calculated in Equation 2.9 by a loading factor denoted by $(\%L)_T$. So that,

$$hp_T = \frac{hp_{PTO\ equiv}}{(\%L)_T} . \qquad (2.10)$$

Where:

hp_T = tractor horsepower, PTO hp;

$(\%L)_T$ = tractor loading factor.

For example, if on the average it was desired to use 90% of the available tractor power $(\%L)_T$ would be 0.90.

It should be noted that hydraulic horsepower, the power required to operate the hydraulic system of the tractor and implement is also important. Published tractor horsepower ratings generally are the net available horsepower above the hydraulic horsepower requirement of the tractor. Since the hydraulic horsepower required by an implement does not in general exceed that required by the tractor, it need not be considered when determining the amount of tractor horsepower needed to power an implement.

2.3 Energy Requirements

In order to accomplish a given amount of work a certain amount of energy will be expended. It is possible to calculate the amount of energy needed to complete a given operation with a given implement. Using Equation 2.4 for the effective field capacity of an implement, the number of hours worked per year may be computed. Since;

$$H = \frac{A}{C_e} ,$$

$$= \frac{8.25A}{S \cdot w \cdot e} . \qquad (2.11)$$

Where:

H = annual hours worked, hr/yr;

A = implement annual acres, acres/yr.

After expanding Equation 2.10, it is possible to solve for the product of speed times width.

$$hp_T = \frac{1}{(\%L)_T} \left(\frac{HHT \cdot Y \cdot S \cdot w \cdot e}{8.25} + \frac{S \cdot w \cdot ff}{375 \cdot 0.96 \cdot TER} \right),$$

$$= \frac{S \cdot w}{(\%L)_T} \left(\frac{HHT \cdot Y \cdot e}{8.25} + \frac{ff}{360TER} \right) . \qquad (2.12)$$

Solving for the product of S times w,

$$S \cdot w = \frac{(\%L)_T hp_T}{\frac{HHT \cdot Y \cdot e}{8.25} + \frac{ff}{360TER}} . \qquad (2.13)$$

Substituting into Equation 2.11,

$$H = \left(\frac{8.25A}{e \cdot (\%L)_T \cdot hp_T} \right) \left(\frac{HHT \cdot Y \cdot e}{8.25} + \frac{ff}{360TER} \right) . \qquad (2.14)$$

Simplifying,

$$H = \left(\frac{1}{(\%L)_T \cdot hp_T}\right)\left(HHT \cdot A \cdot Y + \frac{8.25A \cdot ff}{360e \cdot TER}\right) . \quad (2.15)$$

Then multiplying through by hp_T:

$$E = \frac{1}{(\%L)_T}\left(HHT \cdot A \cdot Y + \frac{8.25A \cdot ff}{360e \cdot TER}\right) . \quad (2.16)$$

Where:

E = tractor energy required to perform a given field operation with a given implement, $\frac{hp\text{-}hr}{yr}$.

For this work it will be assumed that the horsepower requirement for field operations is large enough to supply the power for processing and transporting material. In other words, the tractors which supply the power for field operations will also supply the power for the transportation and processing of materials.

Energy requirements for processing operations such as grinding corn, loading manure, etc. are determined from the following formula:

$$EP = G \cdot W . \quad (2.17)$$

Where:

EP = energy required for processing operation, $\frac{hp\text{-}hr}{yr}$;

G = energy requirement for the specific process, $\frac{hp\text{-}hr}{ton}$;

W = weight of material processed annually, tons/yr.

Values of G may be obtained from Table 2.1.

TABLE 2.1

Energy Requirements For Processing Operations

Operation	G, $\frac{\text{hp-hr}}{\text{ton}}$
Loading manure	0.2
Shelling corn	1.2
Grinding - ear corn	5.5
- shelled corn	8.0
- oats	17.0
Blowing silage	1.5
Crop drying	2.8

Source: Hunt, D., Farm Power and Machinery Management, Iowa State University Press, Ames, Iowa, (4th ed.), 1964, p. 214.

Energy requirements for transporting materials are obtained from the following equation;

$$ET = 1.1D \cdot W \ . \tag{2.18}$$

Where:

ET = energy required for transporting material, $\frac{\text{hp-hr}}{\text{yr}}$;

D = one-way distance material is transported, miles;

W = weight of material transported annually, tons/yr.

CHAPTER 3

DEVELOPMENT OF AN ANNUAL COST EQUATION

In order to develop an annual cost equation for a farm machine system it is necessary to examine several areas which reduce the profit of such an organization. In general, the annual operating cost of an implement or tractor can be divided into two areas, fixed and variable costs. Wherever possible, cost factors in the written material which follows will be expressed in terms of horsepower, hp, or width, w, whichever is appropriate, since it is desired to eventually solve for the horsepower of the tractor and implement widths which yield the least cost farm machine system.

3.1 Fixed Costs

Fixed costs are costs of ownership and are independent of use. Such costs as depreciation, interest on investment, taxes, insurance, and shelter are known as fixed costs. The annual fixed cost percentage method will be used to determine fixed costs for implements, implement attachments, and tractors (6). By this procedure a fixed portion of the purchase price is charged yearly to cover each of the fixed costs mentioned above. The total amount of the fixed costs is determined by a fixed cost rate or percentage. This percentage value is based on existing rates of depreciation, interest, taxes, etc. For instance, according to KSU Farm Management Guide, MF-273, a 1971 publication of the Cooperative Extension

Service at Kansas State University (13), the fixed cost charges for 1971 were based on percentages as shown in Table 3.1. By the fixed cost percentage method the annual fixed costs would be approximately 17% of the purchase price.

TABLE 3.1

Estimated Percent of Purchase Price Charged Annually to Cover Fixed Costs in 1971, Assuming Straight Line Depreciation Method and 10 Year Life

Fixed Cost	Percent
Depreciation	10
Interest	4
Taxes, insurance, housing	3

Source: Schlender, J. R. and Figurski, L., A Look at Machinery Costs, MF-273, Cooperative Extension Service, Kansas State University, Manhattan, December 1971.

For this work, the fixed cost rate, denoted by FC%, will be determined from equations used in the machinery selection program developed by Hunt (7). These equations charge 6% of the purchase price to cover costs of interest, taxes, insurance, and housing. A fixed cost rate is also calculated to cover depreciation costs and is based on the straight line method of depreciation and assumes a 10% salvage value. The fixed cost rate covering depreciation is adjusted to allow for increases or decreases in the depreciation amount caused by differences in the expected life, X, and trade in age, T. The following equations will be used to determine the fixed cost rate for all implements, implement attachments, and tractors.

$$FC\% = 0.06 + \frac{0.9}{X}, \quad \text{if } X \leq T . \tag{3.1}$$

And,

$$FC\% = 0.06 + \frac{1.8}{X+T}, \quad \text{if } X > T . \tag{3.2}$$

Where:

FC% = fixed cost rate, which is used to determine the total amount of fixed costs due to depreciation, interest on investment, taxes, insurance, and shelter;

X = expected life of machine, yr;

T = trade in age of machine, yr.

The expected life, X, may be determined from published data or from the records of the machinery manager. The trade in age, T, may simply be the expected life of the machine or it may be arbitrarily chosen by the farm machinery manager.

For an implement, the annual fixed cost would include the fixed costs of any attachments that go with the implement. For example, a combine may have a corn head attachment in addition to a platform. In general, the fixed cost of implement i, FC_i, would include the fixed costs of a_i attachments and is expressed as follows:

$$FC_i = FC\%_i p_i w_i + \sum_{k=1}^{a_i} FC\%_{ki} p_{ki} w_i; \qquad \text{for } i = 1, 2, 3, \ldots,$$

n number of implements. (3.3)

Where:

FC_i = annual fixed cost of implement i, \$/yr;

$FC\%_i$ = fixed cost rate for implement i;

p_i = purchase price of implement i, \$/ft;

w_i = theoretical width of machine action, ft;

$FC\%_{ki}$ = fixed cost rate for attachment k of implement i;

p_{ki} = purchase price of attachment k of implement i, \$/ft.

For tractors the fixed cost, FC_T, is expressed in Equation 3.4.

$$FC_T = FC\%_T p_T hp_T. \qquad (3.4)$$

Where:

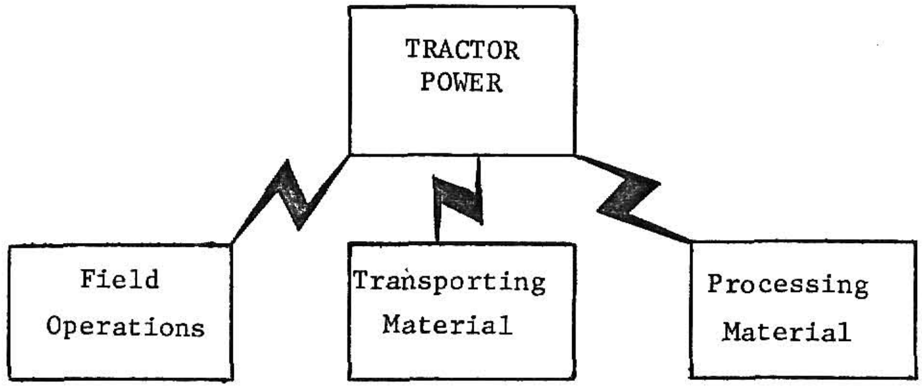
$FC\%_T$ = fixed cost rate of tractor;

p_T = purchase price of tractor, \$/PTO hp;

hp_T = maximum PTO hp of tractor.

As stated in Chapter 2, it will be assumed that the tractors which supply the power to perform field operations will also supply the power for transporting and processing material. See Figure 3.1. Since tractor power supplies energy in three areas, the fixed costs of the tractor should not be charged entirely to field operations nor to transportation and/or processing operations. Therefore, a method for determining the portion of tractor fixed costs that should be charged to field operations is needed. The method used by Hunt will be used here; i.e., tractor fixed costs will be prorated on the basis of the energy requirements in each

Figure 3.1. Illustration of tractor power supplying energy in three areas.



area (7). For instance, suppose that energy requirements existed as in Table 3.2. By the use of Hunt's method, 80% of the total fixed cost of the tractor would be charged to field operations, since,

$$0.80FC_T = \frac{400}{400 + 75 + 25} FC_T.$$

TABLE 3.2

Example of Energy Requirements In Three Areas

ENERGY REQUIRED FOR	AMOUNT/YR
Field operations	400 hp-hrs
Transporting material	75 hp-hrs
Processing material	25 hp-hrs
Total	500 hp-hrs

The portion of the tractor fixed cost charged to each implement will also be based on the ratio of the amount of energy needed to power the implement and the total energy supplied by the tractor, E_{TOT}, for field operations and processing and transporting materials.

$$E_{TOT} = E_{FO} + E_{PM} + E_{TM} . \tag{3.5}$$

Where:

E_{TOT} = grand total of energy supplied by the tractor, $\frac{hp\text{-}hr}{yr}$;

E_{FO} = total energy needed for field operations, $\frac{hp\text{-}hr}{yr}$;

E_{PM} = total energy needed for processing material, $\frac{hp\text{-}hr}{yr}$;

E_{TM} = total energy needed for transporting material, $\frac{hp\text{-}hr}{yr}$.

E_{FO}, E_{PM}, and E_{TM} can be calculated by making use of the equations presented in Chapter 2.

Equation 2.16 may be used to obtain the energy required for one specific field operation with a given implement over a certain number of acres annually. Letting E_{Tij} denote the energy supplied by the tractor to power implement i for operation j, Equation 2.16 can be re-written with subscripts.

$$E_{Tij} = \frac{HHT_{Tij} A_{ij} Y_j}{(\%L)_T} + \frac{8.25 A_{ij} ff_{Tij}}{360 e_j (\%L)_T TER_{Tij}} . \tag{3.6}$$

Where:

E_{Tij} = total tractor energy needed to power implement i for operation j, $\frac{hp\text{-}hr}{yr}$;

HHT_{Tij} = tractor PTO energy needed to power implement i for operation j, $\frac{hp\text{-}hr}{ton}$;

A_{ij} = acres involving operation j and implement i, acres/yr;

Y_j = yield of crop involved for operation j, bushels, tons, etc., per acre;

$(\%L)_T$ = loading factor for tractor, decimal;

ff_{Tij} = force factor for tractor powered implement i in operation j, lb/ft;

e_j = field efficiency of operation j;

TER_{Tij} = tractive efficiency ratio for tractor powering implement i in operation j.

In general, a farm machine system would have m field operations in which implement i may or may not be used. The total tractor energy needed to power implement i, E_{Ti}, would be as in Equation 3.7.

$$E_{Ti} = \sum_{j=1}^{m} E_{Tij}. \qquad (3.7)$$

Where;

E_{Ti} = total tractor energy needed to power implement i, $\frac{hp\text{-}hr}{yr}$.

The equations presented from this point on will be given in general terms with the use of subscripts. As stated earlier, implement i may or may not be used in operation j. No problem exists in the use of the equations as long as i is used in j. However, if implement i is not used in operation j, what is the functional value of an equation such as

Equation 3.7? To be mathematically correct, another variable should be incorporated into the equation—a variable that could be used as an indicator. For example, if implement i was used in operation j, the variable would have a value of 1; if i was not used in j then it would have a value of zero. However, adding another variable would make the equation even more cumbersome. So the approach taken, is that if i and j are not a proper combination, then the functional value of the equation is zero, or the equation is ignored since it does not apply to situations when implement i is not used in operation j. For instance, suppose E_{Ti} is wanted for implement number 10 (i=10) and suppose for operation number 4 (j=4) that implement number 6 is used rather than implement number 10. Then in Equation 3.7, $E_{Tij} = E_{T,10,4} = 0.0$ since i=10 and j=4 is not a proper combination. This point should be kept in mind for the remaining equations to be presented in this work. The total energy for m field operations involving n implements, E_{FO}, can be expressed as follows:

$$E_{FO} = \sum_{i=1}^{n} E_{Ti} ,$$

$$= \sum_{i=1}^{n} \sum_{j=1}^{m} E_{Tij} ,$$

$$= \sum_{i=1}^{n} \sum_{j=1}^{m} \left(\frac{HHT_{Tij} A_{ij} Y_{ij}}{(\%L)_T} + \frac{8.25 A_{ij} ff_{Tij}}{360 e_j (\%L)_T TER_{Tij}} \right) . \qquad (3.8)$$

The energy needed for a processing operation is given by Equation 2.17. After expressing it in a more general form with the use of subscripts, the total energy needed for p processing operations is given by

$$E_{PM} = \sum_{i=1}^{p} G_i W_i \ . \qquad (3.9)$$

Where:

E_{PM} = total energy needed for processing material, $\frac{\text{hp-hr}}{\text{yr}}$;

G_i = energy requirement for process i, $\frac{\text{hp-hr}}{\text{ton}}$;

W_i = weight of material processed with operation i, tons/yr.

A more general form of Equation 2.18 can be used to determine the total energy required for t transportation operations, E_{TM}.

$$E_{TM} = \sum_{t=1}^{t} 1.1 D_i W_i \ . \qquad (3.10)$$

Where:

E_{TM} = total energy needed for transporting material, $\frac{\text{hp-hr}}{\text{yr}}$;

D_i = one-way distance material is transported for operation i, miles;

W_i = weight of material hauled in operation i, tons/yr.

Now with the foregoing information, the fixed cost of the tractor charged to implement i, FC_{Ti}, is expressed as follows:

$$FC_{Ti} = \frac{E_{Ti}}{E_{TOT}} FC\%_T p_T hp_T \ . \qquad (3.11)$$

Where:

FC_{Ti} = fixed cost of tractor charged to implement i, \$/yr.

3.2 Variable Costs

Costs of operation are termed variable costs and are related to use. For this work, variable costs will be considered to be directly related to the units of machine use. Variable costs include the costs of fuel and oil, labor, repair and maintenance, and timeliness.

Fuel costs are directly related to fuel consumption. Fuel consumption and consequently, fuel costs may be considered to have no effect on the optimum width of an implement for light draft implements (6). However, for implements such as heavy offset disks, subsoilers, chisels, plows, etc., fuel costs may be a large cost depending on soil and/or crop conditions and tillage depth or implement performance rate. Therefore, in order to develop a more general annual cost equation for both light and heavy draft equipment fuel consumption equations used in the selection program developed by Hunt will be used (7). Tractor fuel efficiency for operation j involving implement i depends on the equivalent power take-off horsepower required, the available tractor horsepower, and several constants. Accordingly, a general expression for the equivalent power take-off horsepower will be given here for implement i used in operation j.

$$\left(hp_{PTO\ equiv}\right)_{Tij} = \frac{HHT_{Tij}Y_jS_jw_ie_j}{8.25} + \frac{S_jw_iff_{Tij}}{360TER_{Tij}} \qquad (3.12)$$

Where:

$\left(hp_{PTO\ equiv}\right)_{Tij}$ = equivalent PTO hp required of the tractor to power implement i in operation j;

HHT_{Tij} = tractor power take-off energy required by implement i in operation j, $\frac{\text{hp-hr}}{\text{ton}}$;

Y_j = crop yield, tons/acre;

S_j = ground speed of machine in operation j, mph;

w_i = theoretical width of implement i, ft;

e_j = field efficiency for operation j;

ff_{Tij} = force factor for tractor powered implement i in operation j, lbs/ft;

TER_{Tij} = tractive efficiency ratio for tractor powering implement i in operation j.

Now the tractor fuel efficiency, FE_{Tij}, in gallons per horsepower hour for operation j involving implement i may be calculated from the following equation:

$$FE_{Tij} = F_{1,f_T} \frac{\left(hp_{PTO\ equiv}\right)_{Tij}}{hp_T} + F_{2,f_T} -$$

$$F_{3,f_T}\left(F_{4,f_T} \frac{\left(hp_{PTO\ equiv}\right)_{Tij}}{hp_T} + F_{5,f_T}\right)^{\frac{1}{2}} . \qquad (3.13)$$

Where:

FE_{Tij} = fuel efficiency for tractor powering implement i in operation j, $\frac{gal}{hp\text{-}hr}$;

hp_T = available tractor horsepower, PTO hp;

F_{c,f_T} are constants depending on the tractor fuel type, f_T;

f_T = 1-gasoline, 2-diesel, 3-LP gas. See Table 3.3.

Equation 3.13 was developed by Hunt from the average variable-load fuel efficiency of tractors tested in the Nebraska Tractor Tests (7).

TABLE 3.3

Constants Used in Fuel Efficiency Equations for Tractors and Implement Auxiliary Engines

Fuel Type, f	Constants				
	$F_{1,f}$	$F_{2,f}$	$F_{3,f}$	$F_{4,f}$	$F_{5,f}$
1-gasoline	0.540	0.620	0.04	697.0	0.0
2-diesel	0.520	0.768	0.04	738.5	173.0
3-LP gas	0.534	0.618	0.04	645.9	0.0

Source: Donnell Hunt's Machinery Selection Program (7).

The use of the values from Table 3.3 is demonstrated by the following example. For a diesel tractor, Equation 3.13 would appear as follows with the appropriate values from Table 3.3.

$$FE_{Tij} = 0.52 \frac{\left(hp_{PTO\ equiv}\right)_{Tij}}{hp_T} + 0.768 -$$

$$0.04\left(738.5 \frac{\left(hp_{PTO\ equiv}\right)_{Tij}}{hp_T} + 173.0\right)^{\frac{1}{2}} .$$

The number of gallons of fuel consumed is determined by multiplying the fuel efficiency by the energy required, and the cost of fuel would simply be the product of the gallons consumed and the cost per gallon of fuel. The total cost of tractor fuel to power implement i, $FUEL_i$, would be determined by the following equation:

$$FUEL_{Ti} = \sum_{j=1}^{m} FE_{Tij} E_{Tij} p_{f_T}. \tag{3.14}$$

Where:

$FUEL_{Ti}$ = annual cost of tractor fuel used to power implement i, \$/yr;

FE_{Tij} = fuel efficiency for tractor powering implement i in operation j, $\frac{gal}{hp\text{-}hr}$;

E_{Tij} = tractor energy required to power implement i in operation j, $\frac{hp\text{-}hr}{yr}$;

p_{f_T} = unit cost of tractor fuel type f_T, \$/gal.

Many times an implement will require an additional amount of power. This may occur when tractor power would be a limiting constraint on the width of an implement such as a roto tiller or high capacity forage chopper, or it may be needed to better control the performance of an implement such as a baler. When this is so, an auxiliary engine is used to power a certain part of the machine's operation. Therefore, implement fuel costs must also include the costs of fuel needed to operate any auxiliary engine which an implement may have.

Fuel efficiency for an auxiliary engine, FE_{Aij}, used to power implement i in operation j can be determined by using an equation of the same form as Equation 3.13.

$$FE_{Aij} = F_{1,f_{Ai}} \frac{\left(hp_{PTO\ equiv}\right)_{Aij}}{hp_{Ai}} + F_{2,f_{Ai}} -$$

$$F_{3,f_{Ai}} \left(F_{4,f_{Ai}} \frac{\left(hp_{PTO\ equiv}\right)_{Aij}}{hp_{Ai}} + F_{5,f_{Ai}}\right)^{\frac{1}{2}} . \qquad (3.15)$$

Where:

FE_{Aij} = fuel efficiency for implement i's auxiliary engine in operation j, $\frac{gal}{hp\text{-}hr}$;

$\left(hp_{PTO\ equiv}\right)_{Aij}$ = equivalent PTO hp required of implement i's auxiliary engine in operation j;

hp_{Ai} = available horsepower of implement i's auxiliary engine, PTO hp;

$F_{c,f_{Ai}}$ are constants depending on the auxiliary engine fuel type, f_{Ai}; f_{Ai} = 1-gasoline, 2-diesel, 3-LP gas. See Table 3.3.

The equivalent power take-off horsepower required of the auxiliary engine is determined from Equation 3.16.

$$\left(hp_{PTO\ equiv}\right)_{Aij} = \frac{HHT_{Aij}Y_jS_jw_ie_j}{8.25} + \frac{S_jw_iff_{Aij}}{360TER_{Aij}} . \qquad (3.16)$$

Where:

HHT_{Aij} = auxiliary power take-off energy required by implement i in operation j, $\frac{hp\text{-}hr}{ton}$;

ff_{Aij} = force factor for power supplied by implement i's auxiliary engine in operation j, lbs/ft;

TER_{Aij} = tractive efficiency ratio for auxiliary engine powering implement i in operation j.

The total cost of auxiliary engine fuel for implement i, $FUEL_{Ai}$, is given by

$$FUEL_{Ai} = \sum_{j=1}^{m} FE_{Aij}E_{Aij}P_{f_{Ai}} . \qquad (3.17)$$

Where:

$FUEL_{Ai}$ = annual cost of fuel used by implement i's auxiliary engine, \$/yr;

FE_{Aij} = fuel efficiency for implement i's auxiliary engine in operation j, $\frac{gal}{hp\text{-}hr}$;

E_{Aij} = auxiliary energy needed to power implement i in operation j, $\frac{hp\text{-}hr}{yr}$;

$p_{f_{Ai}}$ = unit cost of type f_{Ai} auxiliary engine fuel, \$/gal.

Oil costs may also be considered to have no effect on the optimum width of an implement. This is probably a safe assumption since oil consumption is not too great unless the tractor or engine is in dire need of an overhaul. However, the equations used in Hunt's selection program will also be used in developing a new implement annual cost equation. The oil consumption equation for implement i and operation j has the following form:

$$OC_{Tij} = O_{1,f_T} hp_T + O_{2,f_T} \quad . \tag{3.18}$$

Where:

OC_{Tij} = rate of tractor oil consumption for operation j using implement i, gal/hr;

hp_T = available tractor horsepower, PTO hp;

O_{c,f_T} are constants which depend on the tractor fuel type, f_T;

f_T = 1-gasoline, 2-diesel, 3-LP gas. See Table 3.4.

Equation 3.18 was developed by Hunt from information regarding engine oil capacities and recommended oil change frequencies (7).

TABLE 3.4

Constants Used in Oil Consumption Equations for Tractors and Implement Auxiliary Engines

Fuel Type, f	Constants $O_{1,f}$	$O_{2,f}$
1-gasoline	0.00011	0.00657
2-diesel	0.00021	0.00573
3-LP gas	0.00008	0.00750

Source: Donnell Hunt's Machinery Selection Program (7).

For a diesel tractor, Equation 3.18, with the appropriate values from Table 3.4, would appear as follows:

$$OC_{Tij} = 0.00021hp_T + 0.00573.$$

In order to calculate the cost of oil used it is necessary to determine the number of hours worked in operation j with implement i. This is obtained from Equation 2.11. Rewriting it, using subscripts, the hours of use for implement i in operation j, H_{ij}, would be

$$H_{ij} = \frac{8.25A_{ij}}{S_j w_i e_j} . \qquad (3.19)$$

Where:

H_{ij} = annual hours worked with implement i in operation j, hr/yr;

A_{ij} = acres covered by implement i in operation j, acres/yr;

S_j = ground speed of implement in operation j, mph;

w_i = theoretical width of implement i, ft;

e_j = field efficiency for operation j.

The total cost of tractor oil consumed while powering implement i, OIL_{Ti}, is determined by the following equation:

$$OIL_{Ti} = \sum_{j=1}^{m} H_{ij} OC_{Tij} o_{f_T} ,$$

$$= \sum_{j=1}^{m} \frac{8.25 A_{ij}}{S_j w_i e_j} OC_{Tij} o_{f_T} . \qquad (3.20)$$

Where:

OIL_{Ti} = annual cost of tractor oil used with implement i, \$/yr;

OC_{Tij} = rate of tractor oil consumed in operation j using implement i, gal/hr;

o_{f_T} = unit cost of tractor oil depending on fuel type f_T, \$/gal.

As with fuel costs, oil costs of any auxiliary power units must also be considered. The oil consumption rate of an auxiliary engine is given by the following equation:

$$OC_{Aij} = O_{1,f_{Ai}} hp_{Ai} + O_{2,f_{Ai}} \quad . \tag{3.21}$$

Where:

OC_{Aij} = oil consumption rate for auxiliary engine on implement i for operation j, gal/hr;

hp_{Ai} = available horsepower of implement i's auxiliary engine, PTO hp;

$O_{c,f_{Ai}}$ are constants which depend on the fuel type of implement i's engine, f_{Ai}; f_{Ai} = 1-gasoline, 2-diesel, 3-LP gas. See Table 3.4.

The cost of oil consumed by an auxiliary engine on implement i, OIL_{Ai}, is calculated with the following equation:

$$OIL_{Ai} = \sum_{j=1}^{m} \frac{8.25A_{ij}}{S_j w_i e_j} OC_{Aij} o_{f_{Ai}} \quad . \tag{3.22}$$

Where:

OIL_{Ai} = annual cost of engine oil consumed by implement i's auxiliary engine, \$/yr;

OC_{Aij} = rate of oil consumed by implement i's auxiliary engine in operation j, gal/hr;

$o_{f_{Ai}}$ = unit cost of auxiliary engine oil for implement i depending on fuel type, f_{Ai}, \$/gal.

Labor costs are variable. For hired labor, labor costs are a product of the hours worked and the hourly rate. However, no definite method for determining labor costs for owner-operators exists although, several methods have been suggested by Hunt (6). The Agricultural Engineers Yearbook suggests that for neither the owner-operator nor the hired labor should the labor rate be less than a typical, community labor rate (4). In any case the cost of labor would be the product of the hours worked times the hourly rate.

The total hours of use for implement i, H_i, would be the sum of the hours used in each operation where implement i is used. With the use of Equation 3.19 the total hours of use would be

$$H_i = \sum_{j=1}^{m} H_{ij},$$

$$= \sum_{j=1}^{m} \frac{8.25A_{ij}}{S_j w_i e_j} . \qquad (3.23)$$

Where:

H_i = annual hours of use for implement i, hr/yr.

The cost of labor for implement i, L_i, would then be

$$L_i = H_i l_i ,$$

$$= \sum_{j=1}^{m} \frac{8.25A_{ij} l_i}{S_j w_i e_j} . \qquad (3.24)$$

Where:

L_i = annual cost of labor for implement i, \$/yr;

l_i = labor rate for the operator of implement i, \$/hr.

The cost of tractor labor, L_{Ti}, incurred by implement i must also be considered and may be obtained from the following formula:

$$L_{Ti} = H_i l_T,$$

$$= \sum_{j=1}^{m} \frac{8.25 A_{ij} l_T}{S_j w_i e_j} . \qquad (3.25)$$

Where:

L_{Ti} = annual cost of tractor labor charged to implement i, \$/yr;

l_T = labor rate for the tractor operator, \$/hr.

Repair and maintenance costs are the result of keeping a machine operable, and are computed as a decimal quantity of the purchase price per hour of use. RM_i, the repair and maintenance cost for implement i, having a_i attachments, is given by

$$RM_i = H_i rm_i p_i w_i + \sum_{k=1}^{a_i} \sum_{j=1}^{m} H_{kij} rm_{ki} p_{ki} w_i ,$$

$$= \sum_{j=1}^{m} \frac{8.25 A_{ij} rm_i p_i w_i}{S_j w_i e_j} + \sum_{k=1}^{a_i} \sum_{j=1}^{m} \frac{8.25 A_{kij}}{S_j w_i e_j} rm_{ki} p_{ki} w_i . \qquad (3.26)$$

Where:

RM_i = annual repair and maintenance cost of implement i, \$/yr;

rm_i = repair and maintenance cost factor for implement i, decimal/hr;

p_i = purchase price of implement i, \$/ft;

w_i = theoretical width of implement i, ft;

A_{kij} = acres covered by the kth attachment of implement i in operation j, acres/yr;

rm_{ki} = repair and maintenance cost factor for attachment k of implement i, decimal/hr;

p_{ki} = purchase price of attachment k of implement i, \$/ft.

The repair and maintenance cost of the tractor charged to implement i, RM_{Ti}, is expressed in a similar equation.

$$RM_{Ti} = \sum_{j=1}^{m} \frac{8.25 A_{ij} rm_T p_T hp_T}{S_j w_i e_j} \quad (3.27)$$

Where:

RM_{Ti} = annual tractor repair and maintenance cost charged to implement i, \$/yr;

rm_T = repair and maintenance cost factor for tractor, decimal/hr;

p_T = purchase price of tractor, \$/PTO hp;

hp_T = maximum PTO hp of tractor.

The repair and maintenance cost factors, rm_i and rm_T, are currently developed from data published in the Agricultural Engineers Yearbook. For tractors and many implements, the yearbook gives the estimated wear out life in hours and the total repairs during the wear out life as a percent of the list price. For example, the 1971 yearbook gives the estimated wear out life of a two wheel drive tractor as 12,000 hours, and the total repairs during the wear out life as 120% of the list price. Therefore, the annual repair and maintenance cost of the tractor charged to implement i, RM_{Ti}, can be determined by the following equation:

$$RM_{Ti} = H_i rm_T p_T hp_T ,$$

$$= H_i \cdot \frac{1.20}{12,000} p_T hp_T ,$$

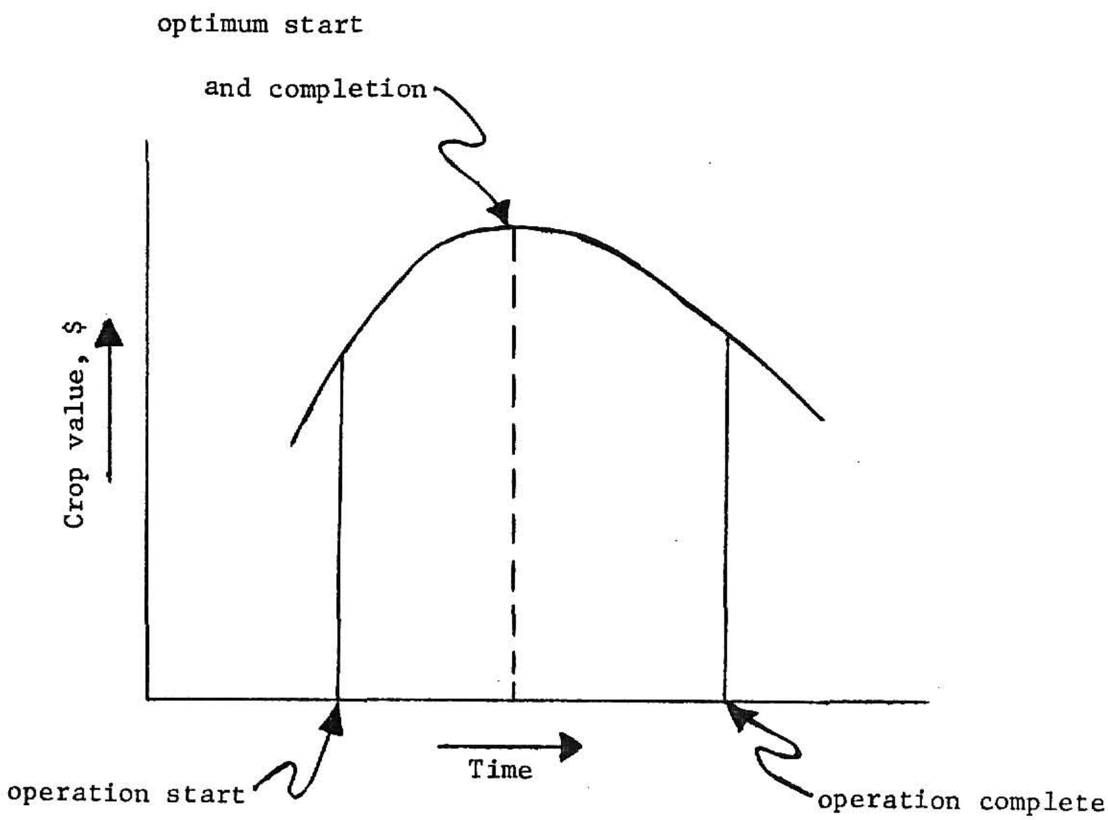
$$= 0.0001 H_i p_T hp_T .$$

Timeliness is a measure of ability to perform a job at a time that gives optimum quality and quantity of product. The inability of an implement to complete an operation within a certain period of time may be an important cost to the farm machine system. A paper presented at the 1972 Winter Meeting of the American Society of Agricultural Engineers was concerned with timeliness costs. In the paper entitled Estimating Farm Machinery Costs, on page 11, the author, Walter W. Hinz, made the following statement concerning timeliness costs (5).

> When we look at the magnitude of the costs that can be encountered when operations are not timely, the errors in estimating fixed and variable costs seem less important. All costs are important. However, we are convinced that it is essential for timeliness costs to be included in our cost estimating procedures.

A method used by Hunt to determine the cost of timeliness charges an implement a certain monetary value for every hour that is spent completing an operation (6). For a given operation and type of implement a low capacity machine will be charged a greater amount for timeliness than will a higher capacity machine. This method assumes that there is an optimum time for an operation to take place and that this optimum time falls somewhere within the start and finish of an operation (6). See Figure 3.2.

Figure 3.2. Graphic illustration of timeliness costs.



A table of timeliness factors has been developed which will be used in this work (6). By using the timeliness factors given in Table 3.5, timeliness costs charged to implement i for operation j, TC_{ij}, depends on the number of hours required to do the job, the gross value of the product involved, and the particular timeliness factor from Table 3.5.

$$TC_{ij} = H_{ij}K_jA_{ij}Y_jV_j \ ,$$

$$= \frac{8.25A_{ij}}{S_jw_ie_j} K_jA_{ij}Y_jV_j \ . \qquad (3.28)$$

Where:

TC_{ij} = timeliness cost charged to implement i for operation j, \$/yr;

K_j = timeliness factor from Table 3.5 for operation j, decimal/hr;

Y_j = yield of crop involved in operation j, bushels, tons, etc., per acre;

V_j = monetary value of crop involved in operation j, dollars per bushel, ton, etc.

To illustrate, if a tillage operation was performed in 8 hours on 40 acres to be planted to wheat yielding 15 bushels per acre and worth \$1.35 per bushel, the timeliness cost, TC, for whatever tillage tool used would be

$$TC = HKAYV,$$

$$= 8.0 \times 0.00005 \times 40.0 \times 15.0 \times 1.35,$$

$$= \$0.32.$$

TABLE 3.5

Table of Timeliness Factors, K, for Various Field Operations

FIELD OPERATION	K, 1/HR
Seeding	0.00030
Tillage	0.00005
Cultivation	0.00020
Grain harvesting	0.00030
Hay harvesting	0.00050
Green forage harvesting	0.00010

Source: Hunt, D., Farm Power and Machinery Management, Iowa State University Press, Ames, Iowa, (4th ed.), 1964, p. 209.

The total cost of timeliness for implement i, $TIME_i$, would be the sum of the timeliness costs charged for each operation.

$$TIME_i = \sum_{j=1}^{m} TC_{ij} ,$$

$$= \sum_{j=1}^{m} \frac{8.25A_{ij}}{S_j w_i e_j} K_j A_{ij} Y_j V_j \ . \qquad (3.29)$$

Where:

$TIME_i$ = annual cost of timeliness charged to implement i, \$/yr.

3.3 More on Tractor and Timeliness Costs

The foregoing development of expressions for each of the areas of cost for a farm implement is adequate when there is one implement and tractor per field operation. However, an occasion may arise where there is more than one implement per field operation. For example, a planting operation is usually preceded by an operation which prepares a seed bed. Many times the implement which prepares the seed bed and the implement used for planting will be hooked together so that in one pass a tillage operation and planting is accomplished. When this situation occurs, one implement is used in combination with another. For such combination operations energy and horsepower requirements must include requirements of all implements involved. For this work, it will be assumed that there will be at most two implements in combination with each other. Now, the total tractor energy needed for operation j, E_{Ticj}, would be determined by

$$E_{Ticj} = E_{Tij} + E_{Tcj} \quad . \tag{3.30}$$

Where:

E_{Ticj} = total tractor energy needed for operation j, $\frac{\text{hp-hr}}{\text{yr}}$;

E_{Tij} = total tractor energy needed to power implement i for operation j, $\frac{\text{hp-hr}}{\text{yr}}$;

E_{Tcj} = total tractor energy needed to power combination implement c for operation j, $\frac{\text{hp-hr}}{\text{yr}}$.

E_{Tcj} can be calculated from an equation of the same form as Equation 3.6.

$$E_{Tcj} = \frac{HHT_{Tcj}A_{cj}Y_j}{(\%L)_T} + \frac{8.25A_{cj}ff_{Tcj}}{360e_j(\%L)_T TER_{Tcj}} . \quad (3.31)$$

Where:

HHT_{Tcj} = tractor PTO energy needed to power combination implement c for operation j, $\frac{\text{hp-hr}}{\text{yr}}$;

A_{cj} = acres covered by combination implement c in operation j, acres/yr;

= A_{ij}, since implement i and combination implement c cover the same number of acres in operation j;

ff_{Tcj} = force factor for tractor powered combination implement c for operation j, lbs/ft;

TER_{Tcj} = tractive efficiency ratio for tractor powering combination implement c in operation j.

So, Equation 3.30 expanded and simplified would have the following form:

$$E_{Ticj} = \frac{\left(HHT_{Tij} + HHT_{Tcj}\right) A_{ij} Y_j}{(\%L)_T} +$$

$$\frac{8.25 A_{ij}}{360 e_j (\%L)_T} \left(\frac{ff_{Tij}}{TER_{Tij}} + \frac{ff_{Tcj}}{TER_{Tcj}}\right). \qquad (3.32)$$

The PTO equivalent horsepower required by the tractor to power the combination implement is expressed by an equation of the same form as Equation 3.12.

$$\left(hp_{PTO\ equiv}\right)_{Tcj} = \frac{HHT_{Tcj} Y_j S_j w_c e_j}{8.25} + \frac{S_j w_c ff_{Tcj}}{360 TER_{Tcj}} . \qquad (3.33)$$

Where:

$\left(hp_{PTO\ equiv}\right)_{Tcj}$ = equivalent PTO hp required of the tractor to power combination implement c in operation j;

w_c = theoretical width of combination implement c, ft.

For all practical purposes, the width of both implements in a combination operation would be the same. So that, w_i and w_c are equal. Therefore, the tractor horsepower required in operation j would be calculated as follows:

$$\left(hp_{PTO\ equiv}\right)_{Ticj} = \left(hp_{PTO\ equiv}\right)_{Tij} + \left(hp_{PTO\ equiv}\right)_{Tcj} . \qquad (3.34)$$

Equation 3.34 expanded and simplified;

$$\left(hp_{PTO\ equiv}\right)_{Ticj} = \frac{\left(HHT_{Tij} + HHT_{Tcj}\right) Y_j S_j w_i e_j}{8.25} +$$

$$\frac{S_j w_i}{360}\left(\frac{ff_{Tij}}{TER_{Tij}} + \frac{ff_{Tcj}}{TER_{Tcj}}\right) . \qquad (3.35)$$

Where:

$\left(hp_{PTO\ equiv}\right)_{Ticj}$ = equivalent PTO hp required of the tractor in operation j to power implement i and combination implement c.

Tractor costs incurred in each operation must now be divided among the implements used in that operation. Tractor fixed costs and fuel costs will still be prorated on the basis of energy requirements. Therefore, Equation 3.11 still holds for dividing fixed costs. However, in the fuel efficiency equation for tractors, Equation 3.13, PTO equivalent horsepower must be determined from Equation 3.35.

$$FE_{Ticj} = F_{1,f_T} \frac{\left(hp_{PTO\ equiv}\right)_{Ticj}}{hp_T} + F_{2,f_T} -$$

$$F_{3,f_T}\left(F_{4,f_T} \frac{\left(hp_{PTO\ equiv}\right)_{Ticj}}{hp_T} + F_{5,f_T}\right)^{\frac{1}{2}} . \qquad (3.36)$$

Where:

FE_{Ticj} = fuel efficiency for tractor powering implements in combination operation j, $\frac{gal}{hp\text{-}hr}$.

The cost of fuel charged to implement i can still be determined by an equation similar to Equation 3.14.

$$FUEL_{Ti} = \sum_{j=1}^{m} \left(FE_{Ticj} E_{Ticj} p_{f_T}\right)\left(\frac{E_{Tij}}{E_{Ticj}}\right) ,$$

$$= \sum_{j=1}^{m} FE_{Ticj} E_{Tij} p_{f_T} . \quad (3.37)$$

The other areas of tractor cost will simply be divided equally among the implements involved. Letting the sum of the remaining tractor variable costs charged to implement i be denoted by $COST_{Ti}$, we have

$$COST_{Ti} = \sum_{j=1}^{m} \frac{8.25A_{ij}}{S_j w_i e_j N_j} \left[\left(O_{1,f_T} hp_T + O_{2,f_T}\right) o_{f_T} + rm_T p_T hp_T + l_T\right] . \quad (3.38)$$

Where:

$COST_{Ti}$ = tractor costs charged to implement i regarding oil, repair and maintenance, and labor;

N_j = number of different implements in operation j,

= 1 if operation j is not a combination operation,

= 2 if operation j is a combination operation.

Timeliness costs must also be shared by the implements in a field operation. The same method as used to determine $COST_{Ti}$ will be used. That is,

$$TIME_i = \sum_{j=1}^{m} \frac{8.25A_{ij}}{S_j w_i e_j N_j} \left(K_j A_{ij} Y_j V_j\right) . \qquad (3.39)$$

At this point it should also be mentioned that in a given operation it is possible to have more than one implement unit or tractor. For example, in the first tillage operation of the season when power requirements are great there may be two tractors, each pulling one unit of a given implement. In a later tillage operation, as long as the power requirements of the implements do not exceed the capacity of the tractor, these same two units may be hitched behind a single tractor. It is necessary to take this into consideration in the annual operating cost of the implement. For this work the only area affected will be the labor costs. Now, the cost of implement labor is given by:

$$L_i = \sum_{j=1}^{m} \frac{8.25A_{ij} l_i I_i}{S_j w_i e_j} . \qquad (3.40)$$

Where:

l_i = labor rate for each unit of implement i, \$/hr;

I_i = number of units of implement i.

The cost of tractor labor charged to implement i is now determined from

$$L_{Ti} = \sum_{j=1}^{m} \frac{8.25 A_{ij} l_T T_j}{S_j w_i e_j N_j} . \tag{3.41}$$

Where:

l_T = labor rate for each tractor, \$/hr;

T_j = number of tractor units in operation j.

3.4 Annual Cost Equation

The total annual cost equation for implement i can now be given by making use of all of the preceding information. In order to present the equation in a simplified form let Z_{Ticj} be defined as follows:

$$Z_{Ticj} = \frac{(hp_{PTO\ equiv})_{Ticj}}{w_i} , \tag{3.42}$$

$$= \frac{(HHT_{Tij} + HHT_{Tcj}) Y_j S_j e_j}{8.25} + \frac{S_j}{360} \left(\frac{ff_{Tij}}{TER_{Tij}} + \frac{ff_{Tcj}}{TER_{Tcj}} \right) . \tag{3.43}$$

And let;

$$Z_{Aij} = \frac{(hp_{PTO\ equiv})_{Aij}}{w_i},$$

$$= \frac{HHT_{Aij}Y_jS_je_j}{8.25} + \frac{S_jff_{Aij}}{360TER_{Aij}} . \qquad (3.44)$$

Then the expression for the annual operating cost of implement i, AC_i, is as follows:

$$AC_i = FC\%_i p_i w_i + \sum_{k=1}^{a_i} FC\%_{ki} p_{ki} w_i +$$

$$\frac{E_{Ti}}{E_{TOT}} FC\%_T p_T hp_T +$$

$$\sum_{j=1}^{m} \left(F_{1,f_T} \frac{Z_{Ticj} w_i}{hp_T} + F_{2,f_T} - F_{3,f_T} \left(F_{4,f_T} \frac{Z_{Ticj} w_i}{hp_T} + \right.\right.$$

$$\left.\left. F_{5,f_T} \right)^{\frac{1}{2}} \right) E_{Tij} p_{f_T} + \sum_{j=1}^{m} \left(F_{1,f_{Ai}} \frac{Z_{Aij} w_i}{hp_{Ai}} + F_{2,f_{Ai}} - \right.$$

$$\left. F_{3,f_{Ai}} \left(F_{4,f_{Ai}} \frac{Z_{Aij}}{hp_{Ai}} + F_{5,f_{Ai}} \right)^{\frac{1}{2}} \right) E_{Aij} p_{f_{Ai}} + \sum_{j=1}^{m} \frac{8.25A_{ij}}{S_j w_i e_j}$$

$$\left(\left(0_{1,f_{Ai}} hp_{Ai} + 0_{2,f_{Ai}}\right) o_{f_{Ai}} + 1_i I_i + rm_i p_i w_i\right) +$$

$$\sum_{k=1}^{a_i} \sum_{j=1}^{m} \frac{8.25 A_{kij}}{S_j w_i e_j} rm_{ki} p_{ki} w_i + \sum_{j=1}^{m} \frac{8.25 A_{ij}}{S_j w_i e_j N_j}$$

$$\left(\left(0_{1,f_T} hp_T + 0_{2,f_T}\right) o_{f_T} + 1_T T_j + rm_T p_T hp_T +\right.$$

$$\left. K_j A_{ij} Y_j V_j\right) . \qquad (3.45)$$

CHAPTER 4

METHOD OF OPTIMIZATION

Now that an expression for the annual cost of a farm implement has been developed, it is necessary to find the tractor horsepower level and w_i's which minimize the total annual cost of the farm machine system. Although several methods are no doubt available which can be used to solve for the values of hp_T and w_i's which minimize the total annual cost, calculus and two search techniques were the optimization methods chosen.

4.1 Implement Width

For a given hp_T, w_i must be found which minimizes AC_i. If differential calculus is used as Hunt did, the following calculations result.

$$\frac{dAC_i}{dw_i} = 0$$

$$= FC\%_i p_i + \sum_{k=1}^{a_i} FC\%_{ki} p_{ki} + \sum_{j=1}^{m} \left(F_{1,f_T} \frac{Z_{Ticj}}{hp_T} - F_{3,f_T} \right.$$

$$\left(\frac{1}{2}\right) \left(\left(F_{4,f_T} \frac{Z_{Ticj} w_i}{hp_T} + F_{5,f_T} \right)^{-\frac{1}{2}} \right) \left(F_{4,f_T} \frac{Z_{Ticj}}{hp_T} \right) E_{Tij} P_{f_T} -$$

$$\frac{1}{w_i^2} \sum_{j=1}^{m} \frac{8.25 A_{ij}}{S_j e_j} \left(O_{2,f_{Ai}} + 1_i I_i \right) - \frac{1}{w_i^2} \sum_{j=1}^{m} \frac{8.25 A_{ij}}{S_j e_j N_j}$$

$$\left(\left(O_{1,f_T} hp_T + O_{2,f_T}\right) o_{f_T} + l_T T_j + \right.$$

$$\left. rm_T p_T hp_T + K_j A_{ij} Y_j V_j\right) . \qquad (4.01)$$

It should be noted that since,

$$hp_{Ai} = \frac{\dfrac{HHT_{Aij} Y_j S_j e_j w_i}{8.25} + \dfrac{S_j w_i}{360}\left(\dfrac{ff_{Aij}}{TER_{Aij}}\right)}{(\%L)_T} ,$$

the fuel terms and one oil term for auxiliary engines drop out of the first derivative. Let:

$$C_1 = FC\%_i p_i + \sum_{k=1}^{a_i} FC\%_{ki} p_{ki} ,$$

$$C_2 = \sum_{j=1}^{m} F_{1,f_T} \frac{Z_{Ticj}}{hp_T} ,$$

$$C_3 = \sum_{j=1}^{m} \frac{8.25 A_{ij}}{S_j e_j} \left(O_{2,f_{Ai}} o_{f_{Ai}} + l_i T_i\right) ,$$

$$C_4 = \sum_{j=1}^{m} \frac{8.25_{Aij}}{S_j e_j N_j} \left(\left(O_{1,f_T} hp_T + O_{2,f_T}\right) o_{f_T} + l_T T_j + \right.$$

$$\left. rm_T p_T hp_T + K_j A_{ij} Y_j V_j\right) .$$

Then:

$$0 = C_1 + C_2 - \frac{1}{2} \sum_{j=1}^{m} \left(\left(F_{3,f_T} \left(F_{4,f_T} \frac{Z_{Tij} w_i}{hp_T} + F_{5,f_T} \right)^{-\frac{1}{2}} \right) \right.$$

$$\left. F_{4,f_T} \frac{Z_{Ticj}}{hp_T} E_{Tij} p_{f_T} \right) - \frac{C_3}{w_i^2} - \frac{C_4}{w_i^2} . \qquad (4.02)$$

Multiplying both sides of Equation 4.02 by w_i^2:

$$0 = C_1 w_i^2 + C_2 w_i^2 - \frac{w_i^2}{2} \sum_{j=1}^{m} \left(F_{3,f_T} \left(F_{4,f_T} \frac{Z_{Ticj} w_i}{hp_T} + \right. \right.$$

$$\left. \left. F_{5,f_T} \right)^{-\frac{1}{2}} \left(\frac{Z_{Ticj}}{hp_T} F_{4,f_T} E_{Tij} p_{f_T} \right) \right) - C_3 - C_4 . \qquad (4.03)$$

As can be seen, it is no longer a simple matter to solve for w_i. Another method that might be used is to find the roots of Equation 4.02 with a search technique, or a search technique might just as well be used on the annual cost equation to find that value of w_i which minimizes it. This latter method of solution was the method chosen. The search technique used is the Fibonacci search (3, 14).

4.2 Tractor Horsepower

Before any optimization of Equation 3.45 can occur a horsepower level of the tractor must be given, since an optimum w_i is found for a given hp_T. In order to reduce the computational effort in determining each of the optimum w_i's it is necessary to have a good estimate of the optimum horsepower level at the outset. With Hunt's original program an estimate of the optimum horsepower level was determined by the programmer. A search, based on equal increments of horsepower levels above and below the original estimate, was then used to locate the optimum hp_T. Since a programmer would need quite a background of knowledge to consistently estimate a horsepower level which would be close to the optimum solution, an improvement could be made by developing a calculational method to estimate the initial horsepower level.

The total cost of the farm machine system is the sum of the annual costs of all implements;

$$TAC = \sum_{i=1}^{n} AC_i \quad . \tag{4.04}$$

So, an estimate of the optimum tractor horsepower could be obtained by using differential calculus if TAC was expressed as a function of hp_T. With the use of Equation 2.10 and Equation 3.42, the tractor horsepower required to power implement i and combination implement c for operation j is:

$$hp_T = \frac{\left(hp_{PTO\ equiv}\right)_{Ticj}}{(\%L)_T} \ , \tag{4.05}$$

$$= \frac{Z_{Ticj} w_i}{(\%L)_T} \ . \tag{4.06}$$

Solving for w_i:

$$w_i = \frac{hp_T(\%L)_T}{Z_{Ticj}} . \tag{4.07}$$

For a given horsepower level, the maximum w_i that can be powered by hp_T in all operations in which implement i is used is where the denominator has its largest value. That is,

$$w_{i,max} = \frac{hp_T(\%L)_T}{Z_{Ticj,max}} . \tag{4.08}$$

Remembering that

$$hp_{Ai} = \frac{\frac{HHT_{Aij}S_jY_je_jw_i}{8.25} + \frac{S_jw_i}{360}\left(\frac{ff_{Aij}}{TER_{Aij}}\right)}{(\%L)_{Ai}} ,$$

the annual cost equation can be rewritten with w_i replaced by the expression for $w_{i,max}$. Let this annual cost be denoted by AC_i'. Then,

$$TAC = \sum_{i=1}^{n} AC_i' \tag{4.09}$$

and the derivative of TAC with respect to hp_T would be as follows:

$$\frac{d(TAC)}{dhp_T} = \frac{d\left(\sum_{i=1}^{n} AC_i'\right)}{dhp_T} , \tag{4.10}$$

$$= \sum_{i=1}^{n} \frac{d\left(AC_i'\right)}{dhp_T} , \tag{4.11}$$

$$\doteq \sum_{i=1}^{n} \left\{ FC\%_i p_i \frac{(\%L)_T}{Z_{Ticj,max}} + \sum_{k=1}^{a_i} FC\%_{ki} p_{ki} \frac{(\%L)_T}{Z_{Ticj,max}} + \right.$$

$$\frac{E_{Ti}}{E_{TOT}} FC\%_T p_T - \frac{1}{hp_T^2} \sum_{j=1}^{m} \frac{8.25 A_{ij} Z_{Ticj,max}}{S_j e_j (\%L)_T} \left(0_{2,f_{Ai}}\, o_{f_{Ai}} + 1_i I_i \right) -$$

$$\left. \frac{1}{hp_T^2} \sum_{j=1}^{m} \frac{8.25 A_{ij} Z_{Ticj,max}}{S_j e_j N_j (\%L)_T} \left(0_{2,f_T}\, o_{f_T} + 1_T T_j + K_j A_{ij} Y_j V_j \right) \right\} . \tag{4.12}$$

Noting that

$$E_{FO} = \sum_{i=1}^{n} E_{Ti} ,$$

and solving for hp_T:

$$hp_T = \sqrt{\frac{\displaystyle\sum_{i=1}^{n} \sum_{j=1}^{m} \frac{8.25 A_{ij} Z_{Ticj,max}}{S_j e_j (\%L)_T} \left\{ 0_{2,f_{Ai}}\, o_{f_{Ai}} + 1_i I_i + \frac{0_{2,f_T}\, o_{f_T} + 1_T T_j + K_j A_{ij} Y_j V_j}{N_j} \right\}}{\displaystyle\sum_{i=1}^{n} \left\{ FC\%_i p_i \frac{(\%L)_T}{Z_{Ticj,max}} + \sum_{k=1}^{a_i} FC\%_{ki} p_{ki} \frac{(\%L)_T}{Z_{Ticj,max}} \right\} + \frac{E_{FO}}{E_{TOT}} FC\%_T p_T}} \tag{4.13}$$

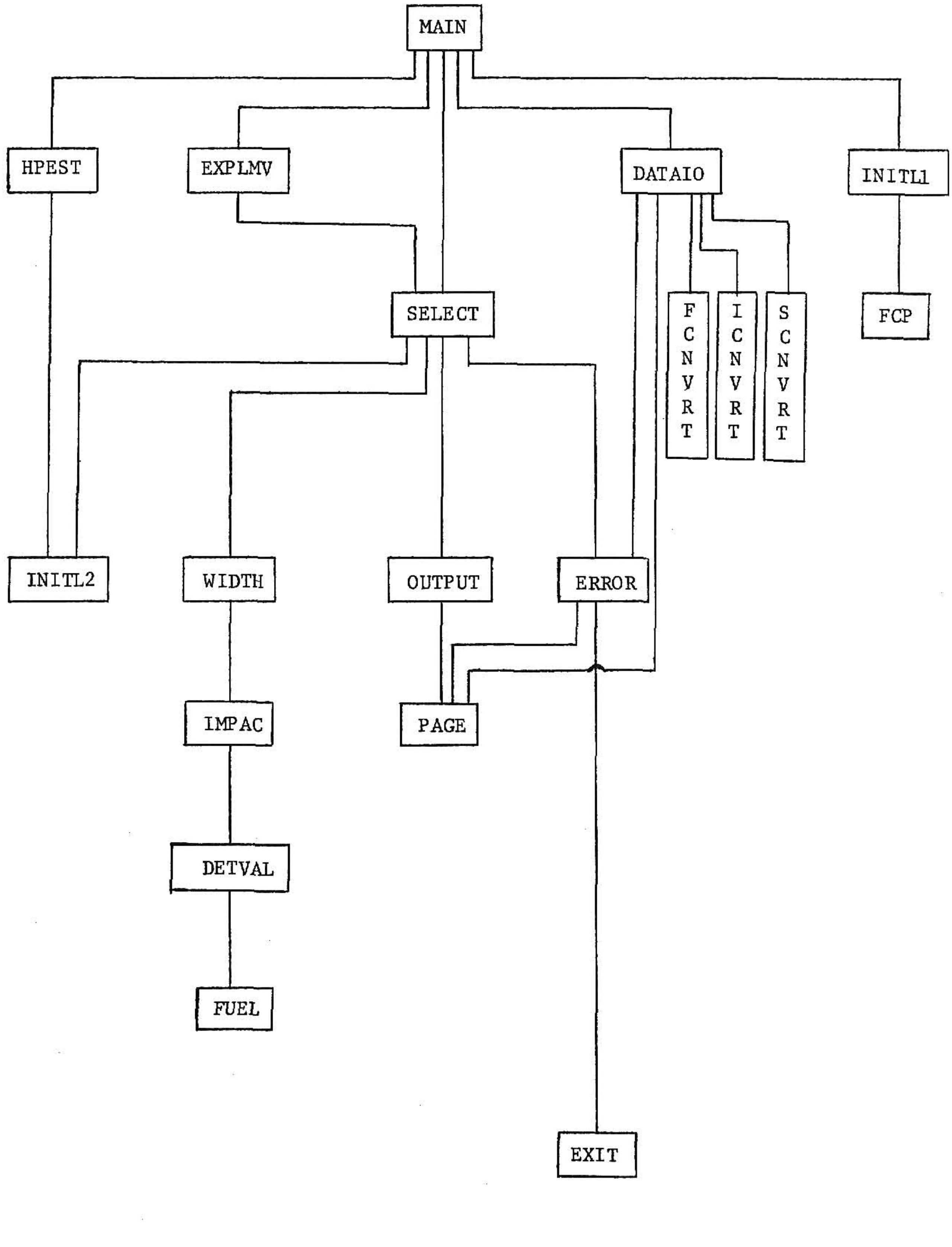
The first estimate of tractor horsepower can be obtained from Equation 4.13. The next step in finding the optimum solutions for hp_T and w_i is to bracket hp_T. That is, find two values of hp_T so that the optimum horsepower lies between them. Once the optimum hp_T is bracketed, the Fibonacci search can also be used to determine the value of the optimum hp_T. A Hooke and Jeeves pattern search will be used to bracket hp_T (9).

4.3 Computer Program

A computer program is used to perform the calculations which have been presented. The present program has grown from a machinery selection program obtained from Hunt (7). Hunt's program has been revised and expanded so that implement costs are based on Equation 3.45. The program also optimizes self-propelled implements by minimizing Equation 3.45. However, hp_T is replaced by the horsepower of the self-propelled implement's engine. The program, written in FORTRAN IV, consists of a main program and 17 user written subroutines. Figure 4.1 shows the lines of communication between MAIN and the subroutines. For a description of MAIN and each of the subroutines see the source listing in Appendix VI.

Input data for all of the variables used in Equation 3.45, except for the variables which are solved for, that is, hp_T and implement w_i's, are required by the program. Appendix I contains a list of input variables along with a brief description of each. Suggested sources to obtain input data for a farm machine system are the following:

Figure 4.1. Flow chart indicating communication lines amoung subroutines.



1) farm machinery manager,
2) implement dealers and valuation guides (11),
3) Agricultural Engineers Yearbook (4), and
4) extension publications (12).

Appendix I also contains a set of data sheets used to record the information which describes a farm machine system to be analyzed. Farm machine systems having 50 implements and 50 field operations can be optimized by the program. Information for 50 processing and 50 transportation operations is also accepted by the program. This capacity is somewhat greater than the capacity of the program obtained from Hunt. With the original program, a farm machine system was limited to 25 implements, 25 field operations, 10 processing operations, and 10 transportation operations.

Several data cards which contain information regarding input data codes and tractor drawbar performance predictor values must precede any farm machine system data. Tractor drawbar information is presently obtained from curves presented in the Agricultural Engineers Yearbook. Information represented by the curves concerns ground surface conditions and the method of implement attachment. Curves are given for concrete, firm, tilled, and soft soil conditions and for mounted, semi-mounted, or towed equipment. The information used in the program is based on the optimum points of the curves. For instance, the optimum value for TER_{Tij} on firm soil is approximately 0.791. Additional information obtained from these curves is that a 9.3% travel reduction can be expected and that for a towed implement the tractor can be expected to pull

0.4 pounds at the drawbar for each pound of rear wheel tractor weight (4). Information from the curve for concrete is not used in the program. See Appendix II.

Based on two example farm systems analyzed with the program, it appears that the greatest difficulty in preparing input data is in determining the input values for force factors, energy requirements, field efficiencies, timeliness factors, and ground speeds. Unless it is known otherwise, perhaps the safest approach is to take somewhat of a pessimistic view when using published information such as that given in the Agricultural Engineers Yearbook. For the most part, this was done for the examples analyzed by using the largest given force factors and energy requirements, and the smallest field efficiencies and ground speeds. General information for the farm systems analyzed along with an example of coded data sheets can be found in Appendix III.

An indication of Hunt's timeliness factors being unsatisfactory occurs when the resulting hours of operation are greater than desired by the machinery manager. If this is the case, the timeliness factor for that particular operation could be increased until the hours of operation are reduced to a desirable value. Further, by effective use of the timeliness factors the operation hours could be forced to values which would allow for operations to occur according to some predetermined schedule. In this way the capacity of the equipment selected would be sufficient to perform the needed operations in whatever number of good working days are available. Equipment selection on this basis is suggested by Constien (2).

A variable which may present some misunderstanding is w_i. It should be remembered that

w_i = theoretical width of implement i, ft.

For some implements there may be some difficulty in understanding what w_i should be. For instance, a baler may actually have a pickup width of approximately 4 feet. However, in the field the baler may be picking up a windrow collected over a width of 12 feet. So w_i as far as the program calculations are concerned is 12 feet. This is the reason for setting WMAX equal to 10 feet for the baler in operations 15 and 18 in Example Farm No. 1. See data sheets in Appendix III and computer printout listing in Appendix IV.

For reliable results combination implement identification numbers should be assigned according to their draft and/or energy requirements. That is, the implement with the greatest power requirement should have the lowest identification number while the implement with the lower power requirement should have the larger number. For instance, in Example Farm No. 2, Appendix IV, the undercutter requires 500 pounds per foot while the treader requires 100 pounds per foot in operations 7, 8, 33, and 34. Hence, it is correct to identify the undercutter and treader with identification numbers 10 and 11 respectively. Failure to observe this procedure may result in an optimum width which may require more tractor horsepower than what is available. Incorrect width selection will be indicated in the information recorded on the computer printout for each horsepower level. For no operation should the required horsepower exceed the amount available.

It should also be noted that the purchase prices for tractor horsepower and implement width, p_T and p_i respectively, are usually not constant over the range of sizes available. While purchase prices affect fixed cost and repair and maintenance cost calculations, it is not known at this point how sensitive the optimum solutions are to purchase prices. However, it is felt that the greatest errors would occur for tractors or implements when fixed costs and/or repair and maintenance costs are a major portion of the annual cost. If an optimum solution corresponds to a purchase price which is quite different from the purchase price used in obtaining the solution, the purchase price should be adjusted to correspond to the solution obtained and another analysis made with the new price.

Output information for each horsepower level tested by the program includes six pages of information. Sheet I gives the trial horsepower level of the tractor, the resulting annual operation costs, dollars invested in equipment, and the number of hours of work required to accomplish all field operations in the system. Information regarding optimum implement sizes, power levels for self-propelled implements and auxiliary engines, and purchase prices for all implements is also given. The amount of investment is the sum of implement purchase prices and the tractor purchase price.

Sheet II contains a breakdown of the system annual costs by implement. The annual cost of each implement is broken down into the areas of interest, i.e. fixed costs, and labor, fuel and oil, repair and maintenance, and timeliness costs. It should be noted that the total cost of operation given on this sheet does not necessarily equal the system annual cost given on Sheet I since custom costs are not given here.

General information regarding individual field operations is given on Sheet III. Information for each field operation includes the number of tractors required, the annual cost of operation, custom costs for operations performed by custom operators, combination implement widths and number of combination implements required for combination operations, and the number of hours of work required.

Sheet IV presents a breakdown of the system annual cost by operation. The annual cost of operation for each field operation is broken down into the areas of interest, i.e. fixed costs, labor, fuel and oil, etc. In addition, custom costs are presented for any operations which are performed by a custom operator. It should be noted that for custom operations a timeliness cost is also calculated based on an implement width equal to WMAX described in the input variable list given in Appendix I.

Sheet V presents fuel and oil consumption information for each field operation. Information is given for tractors, self-propelled implements, and auxiliary engines. Consumption rates as well as amounts consumed annually for each operation are given.

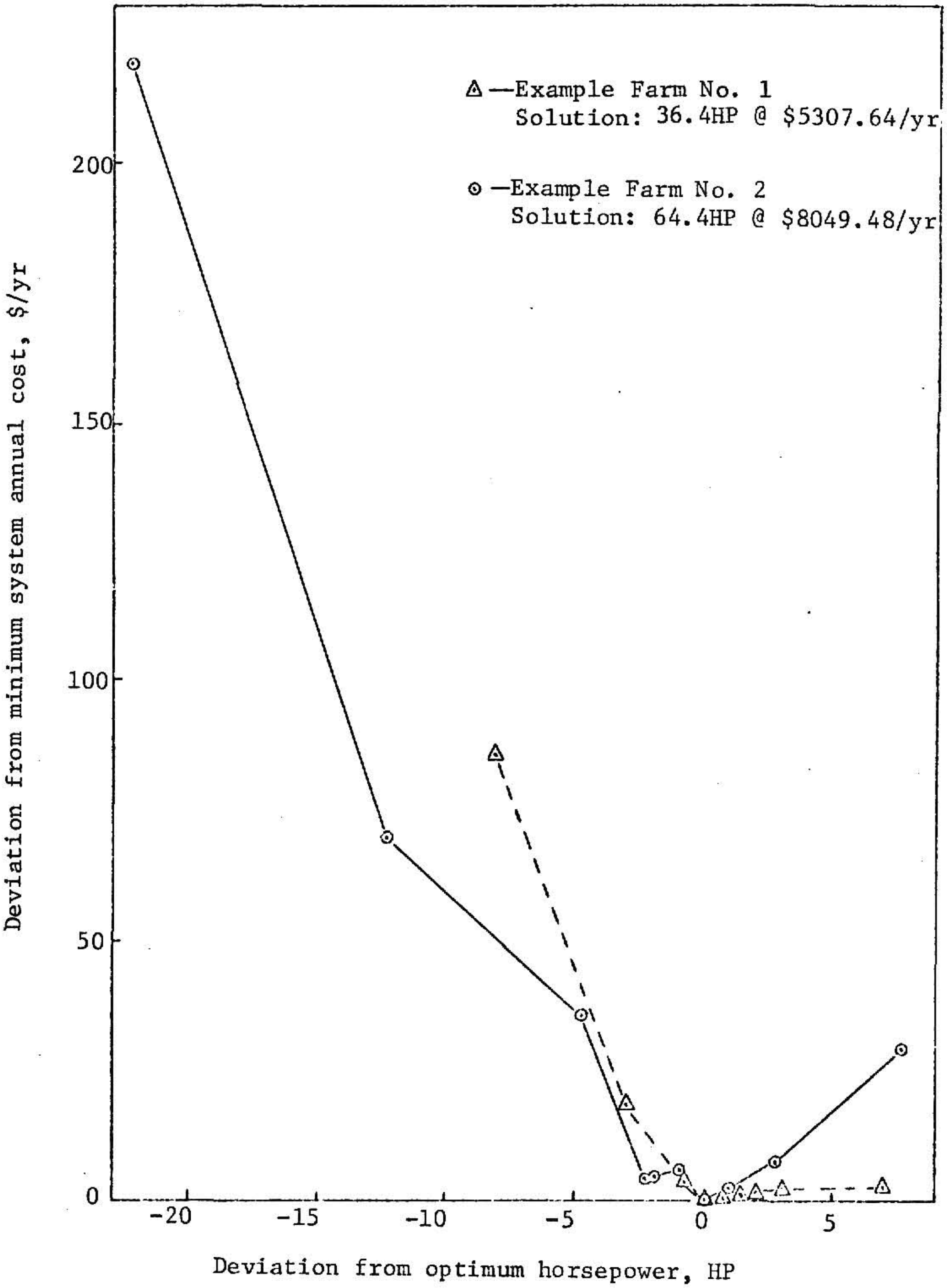
Information concerning tractor drawbar performance for each operation that requires tractor power is given on Sheet VI. This information indicates the loading of the tractor and also the amount of tractor weight required to perform each field operation satisfactorily. Total tractor weight is based on the typical tractor weight distribution of rear weight being approximately 75% of the total weight (4).

Results of the computer analysis for the two examples are presented in Appendix V. According to the program, the optimum tractor horsepower for Example Farm No. 1 and Farm No. 2 is 36.4 and 64.4 horsepower respectively. A plot of the observed system annual costs as related to tractor horsepower can be found in Figure 4.2. An execution time of 0.047 hrs. was required to reach both optimum solutions on the IBM 360 computer.

Since only two curves are available at this time no specific conclusion can be made concerning the shape of such curves. Plots of results from the analyses of other data may be quite different. However, an observation that can be made from the plot of Example Farm No. 2 is that the system annual cost as a function of tractor horsepower is not smooth and may have multiple local minima. At least this is indicated near the optimum solution. Therefore, it may be unwise to continue to use the Fibonacci method to locate the optimum solution. However, if errors are made with Fibonacci's method, as long as they occur near the "true" optimum solution, no errors of any consequence will be made in terms of dollars if the slope of the curve above and below the optimum horsepower is not steep. Perhaps the optimum solution could just as well be found by reducing the number of horsepower levels tested near the optimum solution, making a plot of horsepower versus system annual costs, and selecting a feasible horsepower level near the lowest point in the curve.

In order to test the validity of the optimization method presented in this work and the calculations made by the program, a comparison is

Figure 4.2. Observed horsepower versus system annual cost.



made between data presented in a letter to Kansas Farm Management Association # 2 and resulting optimum solutions for the two examples. In the letter dated May 26, 1971, the Cooperative Extension Service of Kansas State University reported that the remaining investment as of January 1, 1970 for farms averaging 285 crop acres was $39.42 per acre (10). In order to make a meaningful comparison, assume that the reported investment represents an average investment, that is, that the amount will not vary greatly from year to year. Practically speaking, this is possible since a farm will usually have new and partially depreciated equipment at the start of a new year. Rarely would one find a farm machine system in which all of the equipment was purchased in the same year. So, assuming that the average investment for a farm operating with equipment suggested by the program is 50% of the calculated investment, the average investment per crop acre for Example Farm No. 1, I_1, would be;

$$I_1 = (0.5)(\$16,394.50)/180 \text{ crop acres},$$

$$= \$45.54/\text{acre}.$$

Similarly, for Example Farm No. 2;

$$I_2 = (0.5)(\$20,109.05)/391 \text{ crop acres},$$

$$= \$25.74/\text{acre}.$$

Considering machinery costs for the example farms to be the system annual cost less any labor, timeliness, and custom costs, machinery costs per acre for Example Farm No. 1, MC_1, would be;

$$MC_1 = (\$5,307.64 - \$2,560.38)/180 \text{ crop acres},$$

$$= \$15.26/\text{acre}.$$

And,

$$MC_2 = (\$8{,}049.48 - \$3{,}419.45)/391 \text{ crop acres},$$
$$= \$11.84/\text{acre}.$$

This information is summarized in Table 4.1.

TABLE 4.1

Comparison of Farm Management Information and Optimum Solutions

	Data Sources		
		Example Farms	
Compared Data	Farm Management*	No. 1	No. 2
Crop acres	0 - 400, 285 average	180	391
Per acre			
investment	$39.42	$45.54	$25.74
machinery cost	$20.04	$15.26	$11.84

*Source: Kepley, L.R., Frederick, H., and Collins, B.D., "Machinery Investments", letter to Kansas Farm Management Association # 2, Cooperative Extension Service of Kansas State University, May 26, 1971.

According to the information presented in Table 4.1, the program appears to select equipment and calculate costs which are reasonable. However, making any conclusion concerning the validity of the program may be premature at this point. A conclusion should not be made before several analyses of existing farm machine systems are made. Should any major discrepancies exist, reason or reasons should be found and appropriate corrective measures taken if necessary. This would be an adequate validation procedure and is recommended before the program is used for production purposes.

Future use of the program once it has been validated could be made by any organization which is in need of economic analyses of farm machine systems. Organizations such as lending agencies, farm equipment distributors or manufacturers, extension programs, etc. could use the program to provide information which would aid farmers in the decision making involved with the purchasing of equipment. Of course no farmer is expected to base his decision entirely on the results of the analysis, but rather use the results to obtain a better "feeling" for the possible economic gains or losses as affected by the equipment purchased and the crops planted.

Researchers may find the program a useful tool in studying the effect of parameters such as field efficiency, purchase prices, and fuel costs on the overall system annual cost. Questions such as the following might be answered. Can a significant number of dollars be saved by increasing field efficiency from 75 to 90 percent? What effect does travel speed have on the cost of a field operation?

CHAPTER 5

SUMMARY

Farming as a business is becoming quite competitive. With a decrease in labor input and an increase in machinery input compounded by rising machinery purchase prices, farm managers must assume better management of their machinery systems if they are to make ends meet. A computer program was written by Donnell Hunt to make an economic analysis of a farm machine system. The program may be used to aid farm machinery managers, since implement widths and tractor horsepower are selected which minimize the total annual operating cost. This program was obtained from Hunt and several revisions have been made which have made it more general in its use.

With the original program it was only possible to select a fuel type for the entire farm machine system. For instance, if a diesel tractor was desired, all other engines in the system were considered to be diesel. This restriction has been removed and it is now possible to select a fuel type for every engine whether it be tractor, auxiliary implement engine, or the engine of a self-propelled implement.

Restrictions regarding power requirements have also been relaxed. Horsepower computations are now calculated on input data indicating draft requirements in pounds per foot of implement width and on data indicating energy required in terms of horsepower-hours per ton of material processed. Energy requirements, rather than draft requirements, are more suited for harvesting equipment such as forage harvesters and balers.

Required drawbar horsepower is influenced by soil conditions, travel speed, tractor weight, and method of implement attachment. Drawbar horsepower calculations within the program have been revised so that information presented in the Agricultural Engineers Yearbook for predicting optimum tractor drawbar performance is utilized. Apparently, Hunt has also added this capability to his original program (8). However, it is not known whether the information used by Hunt is the same as that used here.

General improvements have also been made to the program. Optimization techniques used in management science are used to locate the optimum tractor horsepower and implement sizes. Specifically, the Fibonacci search and Hooke and Jeeves pattern search are used. The program has also been redesigned as a set of subroutines, each performing a logical portion of the selection process. A computational method has been incorporated to determine the initial starting point in the search for the optimum tractor horsepower. Information obtained from the program has been increased to better aid the farm machinery manager in the decisions he must make. Preliminary tests indicate that the solutions obtained from the program are reasonable, although, no general conclusions can be made at this point.

Finally, the written material presented in this work serves as a formal presentation of the basic concepts and calculations used in the program. It is suggested that any subsequent changes in the program also be made here, since a person unfamiliar with the program can use this material to obtain an understanding of the mathematical equations on which the resulting program solutions are based.

Walter W. Hinz has stated that programs still need to be developed to allow flexibility of input data and to project alternatives (5). It is felt that the contribution made here has advanced Hunt's machinery selection program a step closer to that goal.

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APPENDIX I

Input variable list for

a. alphabetic input data codes,

b. information concerning predictor values for tractor drawbar performance, and

c. information concerning the farm machine system.

Data form for machinery selection program.

INPUT VARIABLE LIST FOR ALPHABETIC INPUT DATA CODES

Card Type 1/1

Variable Name	Description	Code	Card Columns	Field Length
AFCODE(1)	Code for gasoline	G	1	1
AFCODE(2)	Code for diesel fuel	D	2	1
AFCODE(3)	Code for LP gas	L	3	1
AFCODE(4)	"Dummy" fuel code	"blank"	4	1
ICODE(1)	Integral method of implement attachment	I	5	1
ICODE(2)	Semi-integral method of implement attachment	S	6	1
ICODE(3)	Towed method of implement attachment	T	7	1
ICODE(4)	"Dummy" method of implement attachment	"blank"	8	1
NSCODE(1)	Firm soil surface condition	F	9	1
NSCODE(2)	Tilled soil surface condition	T	10	1
NSCODE(3)	Soft soil surface condition	S	11	1
NSCODE(4)	"Dummy" soil surface condition	"blank"	12	1

INPUT VARIABLE LIST FOR INFORMATION CONCERNING PREDICTOR VALUES FOR TRACTOR DRAWBAR PERFORMANCE

Card Type 1/2

Variable Name	Description	Card Columns	Field Length
DTOAHP	Drawbar horsepower to axle horsepower ratio	1 - 6	6
TREDUC	Percent travel reduction	7 - 12	6
TRATIO	$\frac{\text{Actual travel speed}}{\text{No load travel speed}}$	13 - 18	6

Card Type 2/2

Variable Name	Description	Card Columns	Field Length
DBPRTW	Drawbar pull to rear tractor weight ratio	1 - 6	6
RWNLS	$\frac{\text{(Rear tractor weight)(No load travel speed)}}{\text{375 (Axle horsepower)}}$	7 - 12	6

INPUT VARIABLE LIST FOR INFORMATION CONCERNING THE FARM MACHINE SYSTEM

Identification and Tractor Information - - Card Type 1/1

Variable Name	Description	Card Columns	Field Length
NM1, NM2, NM3, NM4, NM5	Identification name	1 - 20	20
PURTR	Purchase price of tractor, $ per maximum PTO horsepower	21 - 25	5
HPPER	Largest horsepower obtainable in a single, usable tractor or the largest horsepower tractor desired	26 - 30	5
ESTHPL	If implement sizes are to be selected for a given tractor horsepower, set ESTHPL equal to that horsepower. Otherwise, leave blank.	31 - 35	5
RMTR	Tractor repair and maintenance costs, decimal of purchase price per hour of use	36 - 42	7
DLTAHP	Tractor horsepower stepsize for Hooke and Jeeves Pattern Search	43 - 47	5
XLIFET	Estimated service life of tractors	48 - 52	5
TRDNTT	Expected trade-in age of tractors	53 - 57	5
XLFTR	Maximum load factor permitted on tractors, decimal	58 - 62	5
TFTYPE	Fuel type for the tractor, G-gasoline, D-diesel fuel, L-LP gas	63	1

Number of Operations and Fuel and Oil Price Information - - Card Type 1/1

Variable Name	Description	Card Columns	Field Length
NMBRPR	Number of processing operations in farm machine system; (right justified, no decimal point)	1 - 4	4
NMBRTR	Number of transport operations in farm machine system; (right justified, no decimal point)	5 - 8	4
NMBRIM	Number of implements in farm machine system; (right justified, no decimal point)	9 - 12	4
NMBROP	Number of field operations required; (right justified, no decimal point)	13 - 16	4
C	If a machinery manager feels that it is inconvenient for him to have operations done by custom operators he can estimate this inconvenience with a dollar cost. If it is desirable to have no operations done by a custom operator let C = 99999.	17 - 21	5
OPRICE(1)	Oil price for gasoline engines, $ per gallon	22 - 26	5
OPRICE(2)	Oil price for diesel engines, $ per gallon	27 - 31	5
OPRICE(3)	Oil price for LP gas engines, $ per gallon	32 - 36	5
FPRICE(1)	Fuel price of gasoline, $ per gallon	37 - 41	5
FPRICE(2)	Fuel price of diesel fuel, $ per gallon	42 - 46	5
FPRICE(3)	Fuel price of LP gas, $ per gallon	47 - 51	5

Process Operations Information - - Card Type 1/1

Variable Name	Description	Card Columns	Field Length
NPR1, NPR2, NPR3, NPR4, NPR5	Name of process activity	1 - 20	20
G	Tractor energy required, $\frac{\text{hp-hr}}{\text{ton}}$	21 - 27	7
TONSPR	Amount of material processed annually, tons/yr	28 - 34	7

Transport Operations Information - - Card Type 1/1

Variable Name	Description	Card Columns	Field Length
NTR1, NTR2, NTR3, NTR4, NTR5	Name of transport activity	1 - 20	20
DISTR	One-way transport distance, miles	21 - 27	7
TONSTR	Amount of material transported annually, tons/yr	28 - 34	7

Field Operations Information - - Card Type 1/5

Variable Name	Description	Card Columns	Field Length
XINDEX	Identification number of field operation	1 - 3	3
NOP1, NOP2, NOP3	Name of field operation	4 - 15	12
ACRESO	Annual operation acreage, acres/yr	16 - 21	6
NSOIL	Soil surface condition; F-firm, T-tilled, S-soft	22	1
SPEED	Travel speed, mph	28 - 33	6
EFFIC	Field efficiency	34 - 39	6
FFACTR	Force factor, lbs/ft	40 - 45	6
HPHRTI	Energy requirement of implement, $\frac{\text{hp-hr}}{\text{ton}}$	46 - 51	6
COMBID	A combination operation occurs when two different implement types are powered at the same time. For such operations, COMBID contains the operation number of the other operation	52 - 57	6
TPOWRD	Use 1.0 if implement is tractor powered. Otherwise, leave blank.	58 - 63	6
SPLFTR	Load factor for self-propelled implement, decimal	64 - 69	6
SFTYPE	Fuel type for self-propelled implement; G-gasoline, D-diesel fuel, L-LP gas	70	1

Field Operations Information - - Card Type 2/5

Variable Name	Description	Card Columns	Field Length
XINDEX	Identification number of field operation	1 - 3	3
AUXENG	Use 1.0 if implement has auxiliary engine. Otherwise, leave blank.	4 - 9	6
XFTYPE	Fuel type for auxiliary engine; G-gasoline, D-diesel fuel, L-LP gas	10	1
AXMXHP	Maximum horsepower of auxiliary engine permitted, hp	16 - 21	6
AXLFTR	Load factor for auxiliary engine, decimal	22 - 27	6
FFCTRX	Force factor for auxiliary engine, lbs/ft	28 - 33	6
HPHRTX	Energy required of auxiliary engine, $\frac{\text{hp-hr}}{\text{ton}}$	34 - 39	6

Field Operations Information - - Card Type 3/5

Variable Name	Description	Card Columns	Field Length
XINDEX	Identification number of field operation	1 - 3	3
NMCH1, NMCH2, NMCH3	Implement name	4 - 15	12
XIMPL	Identification number of implement	16 - 21	6
IMPCLS	Method of implement attachment; I-fully mounted, S-semi-mounted, T-towed	22	1
WMAX	Largest implement width available or desired, ft	28 - 33	6
PURIO	Purchase price of implement, $/ft	34 - 39	6
XLIFEI	Estimated service life of implement, yrs	40 - 45	6
TRDNTI	Expected trade-in age of implement, yrs	46 - 51	6
RMI	Implement repair and maintenance costs, decimal of purchase price per hour of use	52 - 57	6
TIMLI	Timeliness factor for this operation, decimal/hr	58 - 63	6
CROPA	Annual crop acreage, acres/yr. Need not agree with the annual operation acreage. For instance, if the same implement were used for the second and third operation on 40 acres of wheat ground, this could be considered as one operation with ACRESO = 80 acres but only 40 crop acres.	64 - 69	6
YIELD	Yield of crop, bushels, tons, etc. per acre	70 - 75	6

Field Operations Information - - Card Type 4/5

Variable Name	Description	Card Columns	Field Length
XINDEX	Identification number of field operation	1 - 3	3
VALUE	Gross value of crop; $ per bushel, ton, etc.	4 - 9	6
XTIMES	Use 1.0 for all operations except for combination operations use 2.0	10 - 15	6
E	Feasible number of implement units hooked side by side behind one tractor. Use 100.0 if implement is self-propelled	16 - 21	6
XLABOR	Price of tractor operator labor, $/hr	22 - 27	6
XNOPS	Price of implement operator labor, $/hr	28 - 33	6
ATTACH	Identification number of attachment used in this operation	34 - 39	6
ACTOTA	Annual acreage for this attachment, acres/yr	40 - 45	6
PURA	Purchase price of attachment, $/ft	46 - 51	6
XLIFEA	Estimated service life of attachment, yrs	52 - 57	6
TRDNTA	Expected trade-in age of attachment, yrs	58 - 63	6
RMA	Attachment repair and maintenance costs, decimal of purchase price per hour of use	64 - 69	6
XNDCTR	Use 1.0 for operations using self-propelled implements. For operations using the tractor use 1.0, except for combination operations, use 1.0 for the operation in which the implement is directly behind the tractor and leave blank for the other operation.	70 - 75	6

Field Operations Information - - Card Type 5/5

Variable Name	Description	Card Columns	Field Length
XINDEX	Identification number of field operation	1 - 3	3
CUSTOM	Custom rate for this operation, $/acre	4 - 9	6
BASUSD	Identification number of implement for which the attachment was purchased	10 - 15	6

DATA FORM FOR MACHINERY SELECTION PROGRAM

Identification and Tractor Information

Sheet 1/1

Identification name ______________________________

Purchase price of tractor, $ per maximum PTO horsepower ________

Largest horsepower obtainable in a single, usable tractor or the largest horsepower tractor desired ________

Tractor horsepower for which implement widths should be selected. Or leave blank if both tractor horsepower and implement widths should be selected ________

Tractor repair and maintenance costs, decimal of purchase price per hour of use ________

Tractor horsepower stepsize for Hooke and Jeeves Method ________

Estimated service life of tractors, years ________

Expected trade-in age for tractors, years ________

Maximum load factor permitted on tractors, decimal ________

Fuel type for the tractor, G-gasoline, D-diesel fuel, L-LP gas ________

Number of Operations and Fuel and Oil Price Information

Sheet 1/1

Number of processing operations in machinery system	________
Number of transport operations in machinery system	________
Number of field implement types needed	________
Number of field operations required	________
Charge made against custom operation for inconvenience, $	________
Oil price for gasoline engines, $ per gallon	________
Oil price for diesel engines, $ per gallon	________
Oil price for LP-gas engines, $ per gallon	________
Fuel price of gasoline, $ per gallon	________
Fuel price of diesel fuel, $ per gallon	________
Fuel price of LP-gas, $ per gallon	________

Process Operations Information

Sheet 1/1

Number and Name of process activity	Tractor energy required, hp-hr/ton	Amount of material processed, tons/yr

Transport Operations Information

Sheet 1/1

Number and Name of transport activity	One-way transport distance, miles	Amount of material transported, tons/yr

Field Operations Information

Sheet 1/5

Identification number of field operation	Name of field operation	Annual operation acreage, acres/yr	Soil surface condition; F-firm, T-tilled, S-soft	Travel speed, mph	Field efficiency	Force factor, lbs/ft	$\frac{\text{hp-hr}}{\text{ton}}$ for implement	Number of operation combined with	Is implement tractor powered? (1-yes, blank-no)	Load factor for self-propelled implement, decimal	Fuel type (for self-propelled implement; G, D, or L)

Field Operations Information

Sheet 2/5

Identification number of field operation	Implement have auxiliary engine? (1-yes, blank-no)	Fuel type for auxiliary engine; G, D, or L	Maximum size auxiliary engine permitted, hp	Load factor for auxiliary engine, decimal	Force factor for auxiliary engine, lbs/ft	$\frac{hp\text{-}hr}{ton}$ for auxiliary engine

Field Operations Information

Sheet 3/5

Identification number of field operation	Implement name	Identification number of implement	Method of implement attachment; T, S, T	Maximum available single-implement width, ft	Purchase price, $/ft	Estimated service life, yrs	Expected trade-in age, yrs	Repair and maintenance costs, decimal of purchase price per hour of use	Timeliness factor, decimal/hr	Annual crop acreage, acres/yr	Yield of crop, bushels, tons, etc. per acre

Field Operations Information

Sheet 4/5

Identification number of field operation	Gross value of crop; $ per bushel, ton, etc.	Number of different implements in operation	Number of implements feasible behind one tractor	Price of tractor operator labor, $/hr	Price of implement operator labor, $/hr	Implement attachment number	Annual acreage for attachment, acres/yr	Purchase price of attachment, $/ft	Estimated service life of attachment, years	Expected trade-in age of attachment, years	Repair and maintenance costs, decimal of purchase price per hour of use	Print tractor performance? (1-yes, blank-no)

Field Operations Information

Sheet 5/5

Identification number of field operation	Custom rate, $/acre	Number of implement attachment was purchased for

APPENDIX II

Listing of input data cards for

a. alphabetic codes, and

b. tractor drawbar performance predictor values.

Input data card listing produced by the program for

a. alphabetic codes, and

b. tractor drawbar performance predictor values.

```
                 LISTING OF ALPHABETIC INPUT DATA CODES

                            GUIDE TO CARD COLUMNS
       10        20        30        40        50        60        70        80
*********|*********|*********|*********|*********|*********|*********|*********|
GDL IST FTS


             LISTING OF TRACTOR DRAWBAR PERFORMANCE PREDICTOR VALUES

                            GUIDE TO CARD COLUMNS
       10        20        30        40        50        60        70        80
*********|*********|*********|*********|*********|*********|*********|*********|
.791  9.3   .907                                                               1
.646  10.6  .894                                                               2
.533  15.   .85                                                                3
.508  1.708                                                                    4
.442  1.875                                                                    5
.4    2.063                                                                    6
.436  1.74                                                                     7
.382  1.848                                                                    8
.364  2.065                                                                    9
.282  2.265                                                                   10
.255  2.435                                                                   11
.227  2.565                                                                   12
```

PAGE 1

INPUT VALUES FOR CODES:

```
      FUEL
****************
G  GASOLINE
D  DIESEL
L  LP GAS
   BLANK

   IMPLEMENT
****************
I  INTEGRAL
S  SEMI-INTEGRAL
T  TOWED
   BLANK

      SOIL
****************
F  FIRM
T  TILLED
S  SOFT
   BLANK
```

PREDICTOR VALUES

FOR

TRACTOR DRAWBAR PERFORMANCE

SOIL	DBHP / AHP	% TRAVEL REDUCTION	TRAVEL RATIO	IMPLEMENT CODE	P / RWS	(RWS)(NLIS) / (AHP)(375)
F	0.791	9.300	0.907	I	0.508	1.708
				S	0.442	1.875
				T	0.400	2.063
T	0.646	10.600	0.894	I	0.436	1.740
				S	0.382	1.849
				T	0.364	2.065
S	0.533	15.000	0.850	I	0.282	2.265
				S	0.255	2.435
				T	0.227	2.565

APPENDIX III

General information for

a. Example Farm No. 1, and

b. Example Farm No. 2.

Coded data form for machinery selection program using Example Farm No. 1 information.

Example Farm Number 1

General information regarding implements and field operations.

A. Implements

1. baler
2. combine

    a. attachments

        1. platform
        2. corn head

3. cultivator
4. disk
5. drill
6. harrow
7. mower
8. planter
9. plow
10. rake

B. Field operations for crop enterprises

1. Corn - 100 acres - yields 80 bu/acre @ $1.48/bu

    a. Order of operations
        1. plow 40 acres and disk 60 acres
        2. disk
        3. disk
        4. harrow
        5. plant
        6. cultivate
        7. cultivate
        8. harvest
        9. haul grain to storage

2. Oats - 40 acres - yields 30 bu/acre @ $.80/bu - yields

    1 ton straw/acre @ $12.50/ton

    a. Order of operations
        1. disk
        2. disk
        3. harrow
        4. drill
        5. combine
        6. haul grain to storage
        7. mow

8. rake
9. bale
10. haul bales to stack

3. Alfalfa - 40 acres - yields three cuttings, 1.67 tons/cutting per acre @ $18.00/ton

   a. Order of operations per cutting
      1. mow and rake combined
      2. bale
      3. haul bales to stack

Example Farm Number 2

General information regarding implements and field operations.

A. Implement list

1. Baler
2. Binder
3. Combine
4. Drill
5. Disk
6. Harrow
7. Spring tooth
8. Sprayer
9. Swather
10. Undercutter
11. Treader
12. Cultivator
13. Rotary Hoe

B. Field operations for crop enterprises

1. Alfalfa - 50 acres - three cuttings, yields .67 ton/cutting per acre @ $18.00/ton

    a. Order of operations per cutting
        1. Swath
        2. Bale
        3. Haul bales

    b. Order of annual field operations
        1. Spring tooth
        2. Harrow

2. Alfalfa - 7 acres - yields 2 ton/acre @ $18.00/ton

    a. Order of operations
        1. Undercut
        2. Disk
        3. Undercut and tread combined
        4. Disk
        5. Harrow
        6. Harrow
        7. Drill

3. Forage sorghum - 35 acres - yields 2 tons/acre @ $12.00/ton

    a. Order of operations
        1. Undercut
        2. Disk
        3. Disk
        4. Spray - 18 acres
        5. Drill
        6. Rotary hoe - 20 acres

7. Swath - 10 acres
8. Bale - 10 acres
9. Haul bales
10. Bind - 25 acres
11. Haul bundles

4. Hay - 10 acres - yields .5 ton/acre @ $5.20/ton

   a. Order of operations
      1. Swath
      2. Bale
      3. Haul bales

5. Grain sorghum - 70 acres - yields 31 bu/acre @ $2.00/bu

   a. Order or operations
      1. Undercut
      2. Disk
      3. Disk
      4. Spray - 35 acres
      5. Drill
      6. Cultivate
      7. Cultivate
      8. Combine

6. Sudan - 16 acres - yields 2 ton/acre @ $12.00/ton

   a. Order of operations
      1. Undercut
      2. Disk
      3. Disk
      4. Spray - 8 acres
      5. Drill
      6. Swath - 8 acres
      7. Bale - 8 acres
      8. Haul bales

7. Wheat - 210 acres - yields 18 bu/acre @ $1.80/bu

   a. Order of operations
      1. Undercut
      2. Undercut and tread combined
      3. Spray - 105 acres
      4. Disk
      5. Drill
      6. Combine

DATA FORM FOR MACHINERY SELECTION PROGRAM

Identification and Tractor Information

Sheet 1/1

Identification name	EXAMPLE FARM No. 1
Purchase price of tractor, $ per maximum PTO horsepower	80
Largest horsepower obtainable in a single, usable tractor or the largest horsepower tractor desired	65
Tractor horsepower for which implement widths should be selected. Or leave blank if both tractor horsepower and implement widths should be selected	
Tractor repair and maintenance costs, decimal of purchase price per hour of use	0.0001
Tractor horsepower stepsize for Hooke and Jeeves Method	5
Estimated service life of tractors, years	12
Expected trade-in age for tractors, years	12
Maximum load factor permitted on tractors, decimal	0.85
Fuel type for the tractor, G-gasoline, D-diesel fuel, L-LP gas	G

Number of Operations and Fuel and Oil Price Information

Sheet 1/1

Number of processing operations in machinery system	2
Number of transport operations in machinery system	6
Number of field implement types needed	10
Number of field operations required	18
Charge made against custom operation for inconvenience, $	99999
Oil price for gasoline engines, $ per gallon	1.36
Oil price for diesel engines, $ per gallon	
Oil price for LP-gas engines, $ per gallon	
Fuel price of gasoline, $ per gallon	0.17
Fuel price of diesel fuel, $ per gallon	
Fuel price of LP-gas, $ per gallon	

Process Operations Information

Sheet 1/1

Number and Name of process activity	Tractor energy required, $\frac{hp\text{-}hr}{ton}$	Amount of material processed, tons/yr
1 GRIND CORN	5.5	240
2 LOAD MANURE	0.2	200

Transport Operations Information

Sheet 1/1

Number and Name of transport activity	One-way transport distance, miles	Amount of material transported, tons/yr
1 HAUL CORN	0.5	240
2 " OATS	0.5	34
3 " ALFALFA	2.0	200
4 " FERTILIZER	0.5	5
5 " MANURE	0.5	200
6 " STRAW	0.5	40

Field Operations Information

Sheet 1/5

Identification number of field operation	Name of field operation	Annual operation acreage, acres/yr	Soil surface condition; F-firm, T-tilled, S-soft	Travel speed, mph	Field efficiency	Force factor, lbs/ft	hp-hr/ton for implement	Number of operation combined with	Is implement tractor powered? (1-yes, blank-no)	Load factor for self-propelled implement, decimal	Fuel type for self-propelled implement; G, D, or L
1	PLOW CORN S	40	F	3.5	.7	650			1		
2	DISK CORN S	60	F	3.0	.7	400			1		
3	DISK CORN T	200	T	3.0	.7	400			1		
4	HARROW CORN	100	S	3.0	.7	60			1		
5	PLANT CORN	100	T	3.0	.7	240			1		
6	CULTIVATE CORN	200	T	2.5	.7	80			1		
7	PICK CORN	100	F	2.0	.6	480				.8	G
8	DISK OAT S	40	F	3.0	.7	400			1		
9	DISK OAT T	40	T	3.0	.7	400			1		
10	HARROW OAT	40	S	3.0	.7	60			1		
11	DRILL OAT	40	T	2.5	.65	100			1		
12	COMBINE OATS	40	F	2.0	.65	460				.8	G
13	MOW OATS	40	F	5.0	.75	80			1		
14	RAKE OATS	40	F	4.0	.7	70			1		
15	BALE OATS	40	F	3.5	.6	110			1		
16	M&R ALFALFA	120	F	4.0	.7	80		17	1		
17	R&M ALFALFA	120	F	4.0	.7	70		16	1		
18	BALE ALFALFA	120	F	3.5	.6	110			1		

Field Operations Information

Sheet 2/5

Identification number of field operation	Implement have auxiliary engine? (1-yes, blank-no)	Fuel type for auxiliary engine; G, D, or L	Maximum size auxiliary engine permitted, hp	Load factor for auxiliary engine, decimal	Force factor for auxiliary engine, lbs/ft	$\frac{hp\text{-}hr}{ton}$ for auxiliary engine
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15	1	G	20	.7		2.5
16						
17						
18	1	G	20	.7		2.5

Field Operations Information

Sheet 3/5

Identification number of field operation	Implement name	Identification number of implement	Method of implement attachment; I, S, T	Maximum available single-implement width, ft	Purchase price, $/ft	Estimated service life, yrs	Expected trade-in age, yrs	Repair and maintenance costs, decimal of purchase price per hour of use	Timeliness factor, decimal/hr	Annual crop acreage, acres/yr	Yield of crop, bushels, tons, etc. per acre
1	PLOW	9	T	6	150	15	15	.00048	.00005	40	80
2	DISK	4	T	12	125	15	15	.00048	.00005	60	80
3	DISK	4	T	12	125	15	15	.00048	.00005	100	80
4	HARROW	6	T	14	16	15	15	.00048	.00005	100	80
5	PLANTER	8	I	10	80	10	10	.00048	.0003	100	80
6	CULTIVATOR	3	I	10	65	15	15	.00048	.0003	100	80
7	COMBINE	2		14	480	12	12	.0003	.0003	100	80
8	DISK	4	T	12	125	15	15	.00048	.00005	40	1.9
9	DISK	4	T	12	125	15	15	.00048	.00005	40	1.9
10	HARROW	6	T	14	16	15	15	.00048	.00005	40	1.9
11	DRILL	5	T	13	65	20	20	.00084	.0003	40	1.9
12	COMBINE	2		14	480	12	12	.0003	.0003	40	30
13	MOWER	7	S	10	40	15	15	.0006	.0001	40	1
14	RAKE	10	T	10	50	20	20	.0004	.0005	40	1
15	BALER	1	T	10	217	10	10	.00032	.0005	40	1
16	MOWER	7	S	10	40	15	15	.0006	.0001	120	1.67
17	RAKE	10	T	10	50	20	20	.0004	.0005	120	1.67
18	BALER	1	T	10	217	10	10	.00032	.0005	120	1.67

Field Operations Information

Sheet 4/5

Identification number of field operation	Gross value of crop; $ per bushel, ton, etc.	Number of different implements in operation	Number of implements feasible behind one tractor	Price of tractor operator labor, $/hr	Price of implement operator labor, $/hr	Implement attachment number	Annual acreage for attachment, acres/yr	Purchase price of attachment, $/ft	Estimated service life of attachment, years	Expected trade-in age of attachment, years	Repair and maintenance costs, decimal of purchase price per hour of use	First tractor [illegible] (1-yes, blank-no)
1	1.48	1	1	2								1
2	1.48	1	1	2								1
3	1.48	1	1	2								1
4	1.48	1	1	2								1
5	1.48	1	1	2								1
6	1.48	1	1	2								1
7	1.48	1	100		2	2	100	400	12	12	.0003	1
8	19.20	1	1	2								1
9	19.20	1	1	2								1
10	19.20	1	1	2								1
11	19.20	1	1	2								1
12	.80	1	100		2	1	40	40	12	12	.0003	1
13	12.50	1	1	2								1
14	12.50	1	1	2								1
15	12.50	1	1	2								1
16	18.00	2	1	2								1
17	18.00	2	1	2								
18	18.00	1	1	2								1

Field Operations Information

Sheet 5/5

Identification number of field operation	Custom rate, $/acre	Number of implement attachment was purchased for
1	3.61	
2	1.53	
3	1.53	
4	.91	
5	2.63	
6	1.67	
7	9.60	2
8	1.53	
9	1.53	
10	.91	
11	1.67	
12	3.90	2
13	1.50	
14	1.12	
15	3.40	
16	2.62	
17		
18	5.70	

APPENDIX IV

Listing of input data cards for Example Farm No. 1.

Input data card listing produced by the program for

a. Example Farm No. 1, and

b. Example Farm No. 2.

LISTING OF FARM MACHINE SYSTEM DATA CARDS FOR EXAMPLE FARM NO. 1


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                                  GUIDE TO CARD COLUMNS
        10        20        30        40        50        60        70        80
*********|*********|*********|*********|*********|*********|*********|*********|
EXAMPLE FARM NO. 1 80.  65.        .0001  5.   12.  12.  .85  G
  2   6  10  18999991.36            .17
GRIND CORN          5.5     240.
LOAD MANURE         .2      200.
HAUL CORN           .5      240.
HAUL OATS           .5      34.
HAUL ALFALFA        2.      200.
HAUL FERTILIZER     .5      5.
HAUL MANURE         .5      200.
HAUL STRAW          .5      40.
 1.PLOW CORN S 40.  F       3.5    .7     650.              1.                  1
 1.                                                                             2
 1.PLOW        9.   T       6.     150.   15.    15.    .00048.0000540.   80.   3
 1.1.48  1.    1.   2.                                                    1.    4
 1.1.61                                                                         5
 2.DISK CORN S 60.  F       3.     .7     400.              1.                  1
 2.                                                                             2
 2.DISK        4.   T       12.    125.   15.    15.    .00048.0000560.   80.   3
 2.1.48  1.    1.   2.                                                    1.    4
 2.1.53                                                                         5
 3.DISK CORN T 200. T       3.     .7     400.              1.                  1
 3.                                                                             2
 3.DISK        4.   T       12.    125.   15.    15.    .00048.00005100.  80.   3
 3.1.48  1.    1.   2.                                                    1.    4
 3.1.53                                                                         5
 4.HARROW CORN 100. S       3.     .7     60.               1.                  1
 4.                                                                             2
 4.HARROW      6.   T       14.    16.    15.    15.    .00048.00005100.  60.   3
 4.1.48  1.    1.   2.                                                    1.    4
 4..91                                                                          5
 5.PLANT CORN  100. T       3.     .7     240.              1.                  1
 5.                                                                             2
 5.PLANTER     8.   I       10.    80.    10.    10.    .00048.0003 100.  80.   3
 5.1.48  1.    1.   2.                                                    1.    4
 5.2.63                                                                         5
 6.CULTIVATE C 200. T       2.5    .7     80.               1.                  1
 6.                                                                             2
 6.CULTIVATOR  3.   I       10.    65.    15.    15.    .00048.0003 100.  80.   3
 6.1.43  1.    1.   2.                                                    1.    4
 6.1.67                                                                         5
 7.PICK CORN   100. F       2.     .6     480.                    .8      G     1
 7.                                                                             2
 7.COMBINE     2.           14.    490.   12.    12.    .0003 .0003 100.  80.   3
 7.1.48  1.    100.         2.     2.     100.   400.   12.   12.   .0003 1.    4
 7.9.6   2.                                                                     5
 8.DISK OAT S  40.  F       3.     .7     400.              1.                  1
 8.                                                                             2
 8.DISK        4.   T       12.    125.   15.    15.    .00048.0000540.   1.9   3
 8.19.2  1.    1.   2.                                                    1.    4
 8.1.53                                                                         5
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                              GUIDE TO CARD COLUMNS
        10        20        30        40        50        60        70        80
*********|*********|*********|*********|*********|*********|*********|*********|
 9.DISK OAT T  40.     T     3.    .7    400.                 1.                1
9.                                                                             2
 9.DISK         4.     T     12.   125.  15.    15.   .00048.0000540.   1.9    3
 9.19.2  1.     1.     2.                                               1.     4
 9.1.53                                                                        5
10.HARROW OAT  40.     S     3.    .7    60.                  1.               1
10.                                                                            2
10.HARROW       6.     T     14.   16.   15.    15.   .00048.0000540.   1.9    3
10.19.2  1.     1.     2.                                               1.     4
10..91                                                                         5
11.DRILL OAT   40.     T     2.5   .65   100.                 1.               1
11.                                                                            2
11.DRILL        5.     T     13.   65.   20.    20.   .00084.0003 40.   1.9    3
11.19.2  1.     1.     2.                                               1.     4
11.1.67                                                                        5
12.COMBINE OATS40.     F     2.    .65   460.                       .8  G      1
12.                                                                            2
12.COMBINE      2.           14.   480.  12.    12.   .0003 .0003 40.   30.    3
12..8    1.     100.         2.    1.    40.    40.   12.   12.   .0003 1.     4
12.3.9   2.                                                                    5
13.MOW OATS    40.     F     5.    .75   80.                  1.               1
13.                                                                            2
13.MOWER        7.     S     10.   40.   15.    15.   .0006 .0001 40.   1.     3
13.12.5  1.     1.     2.                                               1.     4
13.1.5                                                                         5
14.RAKE OATS   40.     F     4.    .7    70.                  1.               1
14.                                                                            2
14.RAKE        10.     T     10.   50.   20.    20.   .0004 .0005 40.   1.     3
14.12.5  1.     1.     2.                                               1.     4
14.1.12                                                                        5
15.BALE OATS   40.     F     3.5   .6    110.                 1.               1
15.1.    G     20.     .7          2.5                                         2
15.BALER        1.     T     10.   217.  10.    10.   .00032.0005 40.   1.     3
15.12.5  1.     1.     2.                                               1.     4
15.3.4                                                                         5
16.M & R ALFALF120.    F     4.    .7    80.          17.   1.                 1
16.                                                                            2
16.MOWER        7.     S     10.   40.   15.    15.   .0006 .0001 120.  1.67   3
16.18.   2.     1.     2.                                               1.     4
16.2.62                                                                        5
17.R & M ALFALF120.    F     4.    .7    70.          16.   1.                 1
17.                                                                            2
17.RAKE        10.     T     10.   50.   20.    20.   .0004 .0005 120.  1.67   3
17.18.   2.     1.     2.                                                      4
17.                                                                            5
18.BALE ALFALFA120.    F     3.5   .6    110.                 1.               1
18.1.    G     20.     .7          2.5                                         2
18.BALER        1.     T     10.   217.  10.    10.   .00032.0005 120.  1.67   3
18.18.   1.     1.     2.                                               1.     4
18.5.7                                                                         5
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EXAMPLE FARM NO. 1

Input Data Card Listing Produced by the Program

INPUT VALUES

NO. OF PROCESSING OPS.= 2 NO. OF TRANSPORT OPS.= 6 NO. OF FIELD OPS. = 18 NO. OF IMPLS. = 10

$/HP	LARGEST TRACTOR	EST. HP	TRACTOR REP.RATE	HP STEPSIZE	CUSTOM INCONV.$	TRACTOR LIFE	TRADE IN TIME	LOAD FACTOR	FUEL TYPE	FUEL $/GAL	OIL $/GAL
80.	65.	0.	0.000100	5.0	99999.	12.	12.	0.85	G	0.17	1.36

PROCESSING OPERATIONS

NAME	ENERGY, HP-HRS/TON	TONS/YR
GRIND CORN	5.50	240.
LOAD MANURE	0.20	200.

TRANSPORT OPERATIONS

NAME	ONE-WAY DIST.,MILES	TONS/YR
HAUL CORN	0.50	240.
HAUL OATS	0.50	34.
HAUL ALFALFA	2.00	200.
HAUL FERTILIZER	0.50	5.
HAUL MANURE	0.50	200.
HAUL STRAW	0.50	40.

ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

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XINDEX	OPERATION	ACRESO	NSOIL	SPEED	EFFIC	FFACTR	HPHRTI	COMBID	TPOWRD	SPLFTR	SFTYPE	FPRICE	OPRICE
1.	PLOW CORN S	40.00	F	3.50	0.70	650.00	0.0	0.0	1.00	0.0	G	0.17	1.36
2.	DISK CORN S	60.00	F	3.00	0.70	400.00	0.0	0.0	1.00	0.0	G	0.17	1.36
3.	DISK CORN T	200.00	T	3.00	0.70	400.00	0.0	0.0	1.00	0.0	G	0.17	1.36
4.	HARROW CORN	100.00	S	3.00	0.70	60.00	0.0	0.0	1.00	0.0	G	0.17	1.36
5.	PLANT CORN	100.00	T	3.00	0.70	240.00	0.0	0.0	1.00	0.0	G	0.17	1.36
6.	CULTIVATE C	200.00	T	2.50	0.70	80.00	0.0	0.0	1.00	0.0	G	0.17	1.36
7.	PICK CORN	100.00	F	2.00	0.60	480.00	0.0	0.0	0.0	0.80	G	0.17	1.36
8.	DISK OAT S	40.00	F	3.00	0.70	400.00	0.0	0.0	1.00	0.0	G	0.17	1.36
9.	DISK OAT T	40.00	T	3.00	0.70	400.00	0.0	0.0	1.00	0.0	G	0.17	1.36
10.	HARROW OAT	40.00	S	3.00	0.70	60.00	0.0	0.0	1.00	0.0	G	0.17	1.36
11.	DRILL OAT	40.00	T	2.50	0.65	100.00	0.0	0.0	1.00	0.0	G	0.17	1.36
12.	COMBINE OATS	40.00	F	2.00	0.65	460.00	0.0	0.0	0.0	0.80	G	0.17	1.36
13.	MOW OATS	40.00	F	5.00	0.75	80.00	0.0	0.0	1.00	0.0	G	0.17	1.36
14.	RAKE OATS	40.00	F	4.00	0.70	70.00	0.0	0.0	1.00	0.0	G	0.17	1.36
15.	BALE OATS	40.00	F	3.50	0.60	110.00	0.0	0.0	1.00	0.0	G	0.17	1.36
16.	M & R ALFALF	120.00	F	4.00	0.70	80.00	0.0	17.00	1.00	0.0	G	0.17	1.36
17.	R & M ALFALF	120.00	F	4.00	0.70	70.00	0.0	15.00	1.00	0.0	G	0.17	1.36
18.	BALE ALFALFA	120.00	F	3.50	0.60	110.00	0.0	0.0	1.00	0.0	G	0.17	1.36

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XINDEX	OPERATION	AUXENG	XFTYPE	FPRICE	OPRICE	AXMXHP	AXLFTR	FFCTRX	HPHRTX
1.	PLOW CORN S	0.0		0.0	0.0	0.0	0.0	0.0	0.0
2.	DISK CORN S	0.0		0.0	0.0	0.0	0.0	0.0	0.0
3.	DISK CORN T	0.0		0.0	0.0	0.0	0.0	0.0	0.0
4.	HARROW CORN	0.0		0.0	0.0	0.0	0.0	0.0	0.0
5.	PLANT CORN	0.0		0.0	0.0	0.0	0.0	0.0	0.0
6.	CULTIVATE C	0.0		0.0	0.0	0.0	0.0	0.0	0.0
7.	PICK CORN	0.0		0.0	0.0	0.0	0.0	0.0	0.0
8.	DISK OAT S	0.0		0.0	0.0	0.0	0.0	0.0	0.0
9.	DISK OAT T	0.0		0.0	0.0	0.0	0.0	0.0	0.0
10.	HARROW OAT	0.0		0.0	0.0	0.0	0.0	0.0	0.0
11.	DRILL OAT	0.0		0.0	0.0	0.0	0.0	0.0	0.0
12.	COMBINE OATS	0.0		0.0	0.0	0.0	0.0	0.0	0.0
13.	MOW OATS	0.0		0.0	0.0	0.0	0.0	0.0	0.0
14.	RAKE OATS	0.0		0.0	0.0	0.0	0.0	0.0	0.0
15.	BALE OATS	1.00	G	0.17	1.36	20.00	0.70	0.0	2.50
16.	M & R ALFALF	0.0		0.0	0.0	0.0	0.0	0.0	0.0
17.	R & M ALFALF	0.0		0.0	0.0	0.0	0.0	0.0	0.0
18.	BALE ALFALFA	1.00	G	0.17	1.36	20.00	0.70	0.0	2.50

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XINDEX	IMPL.,	NUMBER	IMPCLS	WMAX	PURIO	XLIFE	TRDNTI	RMI	TIMLI	CPOPA	YIELD	VALUE	XTIMES
1.	PLOW	9.0	T	6.0	150.0	15.0	15.0	0.000480	0.000050	40.0	80.0	1.5	1.0
2.	DISK	4.0	T	12.0	125.0	15.0	15.0	0.000480	0.000050	60.0	80.0	1.5	1.0
3.	DISK	4.0	T	12.0	125.0	15.0	15.0	0.000480	0.000050	100.0	80.0	1.5	1.0
4.	HARROW	6.0	T	14.0	16.0	15.0	15.0	0.000480	0.000050	100.0	80.0	1.5	1.0
5.	PLANTER	8.0	I	10.0	90.0	10.0	10.0	0.000480	0.000300	100.0	80.0	1.5	1.0
6.	CULTIVATOR	3.0	I	10.0	65.0	15.0	15.0	0.000480	0.000300	100.0	80.0	1.5	1.0
7.	COMBINE	2.0		14.0	490.0	12.0	12.0	0.000300	0.000300	100.0	80.0	1.5	1.0
8.	DISK	4.0	T	12.0	125.0	15.0	15.0	0.000480	0.000050	40.0	1.9	19.2	1.0
9.	DISK	4.0	T	12.0	125.0	15.0	15.0	0.000480	0.000050	40.0	1.9	19.2	1.0
10.	HARROW	6.0	T	14.0	16.0	15.0	15.0	0.000480	0.000050	40.0	1.9	19.2	1.0
11.	DRILL	5.0	T	13.0	65.0	20.0	20.0	0.000840	0.000300	40.0	1.9	19.2	1.0
12.	COMBINE	2.0		14.0	480.0	12.0	12.0	0.000300	0.000300	40.0	30.0	0.8	1.0
13.	MOWER	7.0	S	10.0	40.0	15.0	15.0	0.000600	0.000100	40.0	1.0	12.5	1.0
14.	RAKE	10.0	T	10.0	50.0	20.0	20.0	0.000400	0.000500	40.0	1.0	12.5	1.0
15.	BALER	1.0	T	10.0	217.0	10.0	10.0	0.000320	0.000500	40.0	1.0	12.5	1.0
16.	MOWER	7.0	S	10.0	40.0	15.0	15.0	0.000600	0.000100	120.0	1.7	18.0	2.0
17.	RAKE	10.0	T	10.0	50.0	20.0	20.0	0.000400	0.000500	120.0	1.7	18.0	2.0
18.	BALER	1.0	T	10.0	217.0	10.0	10.0	0.000320	0.000500	120.0	1.7	18.0	1.0

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XINDEX	E	XLABOR	XNOPS	ATTACH	ACTOTA	PURA	XLIFEA	TRONTA	RMA	XNDCTR	CUSTOM	BASUSD
1.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	3.61	0.0
2.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.53	0.0
3.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.53	0.0
4.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.91	0.0
5.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.63	0.0
6.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.67	0.0
7.	100.0	0.0	2.00	2.00	100.00	400.00	12.00	12.00	0.000300	1.00	9.60	2.00
8.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.53	0.0
9.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.53	0.0
10.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.91	0.0
11.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.67	0.0
12.	100.0	0.0	2.00	1.00	40.00	40.00	12.00	12.00	0.000300	1.00	3.90	2.00
13.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.50	0.0
14.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.12	0.0
15.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	3.40	0.0
16.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.62	0.0
17.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	5.70	0.0

EXAMPLE FARM NO. 2

Input Data Card Listing Produced by the Program

INPUT VALUES

NO. OF PROCESSING OPS.= 1 NO. OF TRANSPORT OPS.= 4 NO. OF FIELD OPS. = 40 NO. OF IMPLS. = 13

$/HP	LARGEST TRACTOR	EST. HP	TRACTOR REP.RATE	HP STEPSIZE	CUSTOM INCONV.$	TRACTOR LIFE	TRADE IN TIME	LOAD FACTOR	FUEL TYPE	FUEL $/GAL	OIL $/GAL
85.	84.	0.	0.000100	10.0	99999.	12.	13.	0.85	D	0.15	1.36

PROCESSING OPERATIONS

NAME	ENERGY, HP-HRS/TON	TONS/YR
GRIND MILO	10.00	30.

TRANSPORT OPERATIONS

NAME	ONE-WAY DIST.,MILES	TONS/YR
HAUL ALFALFA	0.50	100.
HAUL FEED	0.50	86.
HAUL HAY	0.50	5.
HAUL FERTILIZER	40.00	2.

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XINDEX	OPERATION	ACRESO	NSOIL	SPEED	EFFIC	FFACTR	HPHRTI	COMBID	TPOWRD	SPLFTR	SFTYPE	FPRICE	OPRICE
1.	SWATH ALFALF	150.00	F	3.00	0.55	190.00	0.0	0.0	0.0	0.80	G	0.17	1.36
2.	BALE ALFALFA	150.00	F	3.50	0.60	110.00	2.50	0.0	1.00	0.0	D	0.15	1.36
3.	SPRNG TOTH A	50.00	F	3.00	0.70	310.00	0.0	0.0	1.00	0.0	D	0.15	1.36
4.	HARROW ALFAL	50.00	T	3.00	0.70	60.00	0.0	0.0	1.00	0.0	D	0.15	1.36
5.	UNDERCUT ALF	7.00	F	3.00	0.70	500.00	0.0	0.0	1.00	0.0	D	0.15	1.36
6.	DISK ALFALFA	7.00	T	3.00	0.70	400.00	0.0	0.0	1.00	0.0	D	0.15	1.36
7.	UNDERCUT ALF	7.00	T	3.00	0.70	500.00	0.0	8.00	1.00	0.0	D	0.15	1.36
8.	TREAD ALFALF	7.00	T	3.00	0.70	100.00	0.0	7.00	1.00	0.0	D	0.15	1.36
9.	DISK ALFALFA	7.00	T	3.00	0.70	400.00	0.0	0.0	1.00	0.0	D	0.15	1.36
10.	HARROW ALFAL	14.00	T	3.00	0.70	60.00	0.0	0.0	1.00	0.0	D	0.15	1.36
11.	DRILL ALFALF	7.00	T	2.50	0.65	100.00	0.0	0.0	1.00	0.0	D	0.15	1.36
12.	UNDERCUT FD	35.00	F	3.00	0.70	500.00	0.0	0.0	1.00	0.0	D	0.15	1.36
13.	DISK FEED	70.00	T	3.00	0.70	400.00	0.0	0.0	1.00	0.0	D	0.15	1.36
14.	SPRAY FEED	18.00	T	3.00	0.50	80.00	0.0	0.0	1.00	0.0	D	0.15	1.36
15.	DRILL FEED	35.00	T	2.50	0.65	100.00	0.0	0.0	1.00	0.0	D	0.15	1.36
16.	SWATH FEED	10.00	F	3.00	0.55	190.00	0.0	0.0	0.0	0.80	G	0.17	1.36
17.	BALE FEED	10.00	F	1.50	0.60	110.00	2.50	0.0	1.00	0.0	D	0.15	1.36
18.	BIND FEED	25.00	F	2.00	0.55	150.00	2.00	0.0	1.00	0.0	D	0.15	1.36
19.	SWATH HAY	10.00	F	3.00	0.55	190.00	0.0	0.0	0.0	0.80	G	0.17	1.36
20.	BALE HAY	10.00	F	3.00	0.60	110.00	2.50	0.0	1.00	0.0	D	0.15	1.36
21.	UNDERCUT MIL	70.00	F	3.00	0.70	500.00	0.0	0.0	1.00	0.0	D	0.15	1.36
22.	DISK MILO	140.00	T	3.00	0.70	400.00	0.0	0.0	1.00	0.0	D	0.15	1.36
23.	SPRAY MILO	35.00	T	3.00	0.55	80.00	0.0	0.0	1.00	0.0	D	0.15	1.36
24.	DRILL MILO	70.00	T	2.50	0.65	100.00	0.0	0.0	1.00	0.0	D	0.15	1.36
25.	COMBINE MILO	70.00	F	2.00	0.65	460.00	0.0	0.0	0.0	0.80	G	0.17	1.36
26.	UNDERCT SUDN	16.00	F	3.00	0.70	500.00	0.0	0.0	1.00	0.0	D	0.15	1.36
27.	DISK SUDAN	32.00	T	3.00	0.70	400.00	0.0	0.0	1.00	0.0	D	0.15	1.36
28.	SPRAY SUDAN	8.00	T	3.00	0.50	80.00	0.0	0.0	1.00	0.0	D	0.15	1.36
29.	DRILL SUDAN	16.00	T	2.50	0.65	100.00	0.0	0.0	1.00	0.0	D	0.15	1.36
30.	SWATH SUDAN	8.00	F	3.00	0.55	190.00	0.0	0.0	0.0	0.80	G	0.17	1.36
31.	BALE SUDAN	8.00	F	1.50	0.60	110.00	2.50	0.0	1.00	0.0	D	0.15	1.36
32.	UNDERCT WHT	210.00	F	3.00	0.70	500.00	0.0	0.0	1.00	0.0	D	0.15	1.36
33.	UNDERCT WHT	210.00	T	3.00	0.70	500.00	0.0	34.00	1.00	0.0	D	0.15	1.36
34.	TREAD WHEAT	210.00	T	3.00	0.70	100.00	0.0	33.00	1.00	0.0	D	0.15	1.36
35.	SPRAY WHEAT	105.00	T	3.00	0.50	80.00	0.0	0.0	1.00	0.0	D	0.15	1.36
36.	DISK WHEAT	210.00	T	3.00	0.70	400.00	0.0	0.0	1.00	0.0	D	0.15	1.36
37.	DRILL WHEAT	210.00	T	2.50	0.65	100.00	0.0	0.0	1.00	0.0	D	0.15	1.36
38.	COMBINE WHT	210.00	F	2.00	0.65	460.00	0.0	0.0	0.0	0.80	G	0.17	1.36
39.	CULTIVATE ML	140.00	T	2.50	0.70	80.00	0.0	0.0	1.00	0.0	D	0.15	1.36
40.	HOE FEED	20.00	F	5.00	0.70	100.00	0.0	0.0	1.00	0.0	D	0.15	1.36

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XINDEX	OPERATION	AUXENG	XFTYPE	FPRICE	OPRICE	AXMXHP	AXLFTR	FFCTRX	HPHRTX
1.	SWATH ALFALF	0.0		0.0	0.0	0.0	0.0	0.0	0.0
2.	BALE ALFALFA	0.0		0.0	0.0	0.0	0.0	0.0	0.0
3.	SPRNG TOTH A	0.0		0.0	0.0	0.0	0.0	0.0	0.0
4.	HARROW ALFAL	0.0		0.0	0.0	0.0	0.0	0.0	0.0
5.	UNDERCUT ALF	0.0		0.0	0.0	0.0	0.0	0.0	0.0
6.	DISK ALFALFA	0.0		0.0	0.0	0.0	0.0	0.0	0.0
7.	UNDERCUT ALF	0.0		0.0	0.0	0.0	0.0	0.0	0.0
8.	TREAD ALFALF	0.0		0.0	0.0	0.0	0.0	0.0	0.0
9.	DISK ALFALFA	0.0		0.0	0.0	0.0	0.0	0.0	0.0
10.	HARROW ALFAL	0.0		0.0	0.0	0.0	0.0	0.0	0.0
11.	DRILL ALFALF	0.0		0.0	0.0	0.0	0.0	0.0	0.0
12.	UNDERCUT FD	0.0		0.0	0.0	0.0	0.0	0.0	0.0
13.	DISK FEED	0.0		0.0	0.0	0.0	0.0	0.0	0.0
14.	SPRAY FEED	0.0		0.0	0.0	0.0	0.0	0.0	0.0
15.	DRILL FEED	0.0		0.0	0.0	0.0	0.0	0.0	0.0
16.	SWATH FEED	0.0		0.0	0.0	0.0	0.0	0.0	0.0
17.	BALE FEED	0.0		0.0	0.0	0.0	0.0	0.0	0.0
18.	BIND FEED	0.0		0.0	0.0	0.0	0.0	0.0	0.0
19.	SWATH HAY	0.0		0.0	0.0	0.0	0.0	0.0	0.0
20.	BALE HAY	0.0		0.0	0.0	0.0	0.0	0.0	0.0
21.	UNDERCUT MIL	0.0		0.0	0.0	0.0	0.0	0.0	0.0
22.	DISK MILO	0.0		0.0	0.0	0.0	0.0	0.0	0.0
23.	SPRAY MILO	0.0		0.0	0.0	0.0	0.0	0.0	0.0
24.	DRILL MILO	0.0		0.0	0.0	0.0	0.0	0.0	0.0
25.	COMBINE MILO	0.0		0.0	0.0	0.0	0.0	0.0	0.0
26.	UNDERCT SUDN	0.0		0.0	0.0	0.0	0.0	0.0	0.0
27.	DISK SUDAN	0.0		0.0	0.0	0.0	0.0	0.0	0.0
28.	SPRAY SUDAN	0.0		0.0	0.0	0.0	0.0	0.0	0.0
29.	DRILL SUDAN	0.0		0.0	0.0	0.0	0.0	0.0	0.0
30.	SWATH SUDAN	0.0		0.0	0.0	0.0	0.0	0.0	0.0
31.	BALE SUDAN	0.0		0.0	0.0	0.0	0.0	0.0	0.0
32.	UNDERCT WHT	0.0		0.0	0.0	0.0	0.0	0.0	0.0
33.	UNDERCT WHT	0.0		0.0	0.0	0.0	0.0	0.0	0.0
34.	TREAD WHEAT	0.0		0.0	0.0	0.0	0.0	0.0	0.0
35.	SPRAY WHEAT	0.0		0.0	0.0	0.0	0.0	0.0	0.0
36.	DISK WHEAT	0.0		0.0	0.0	0.0	0.0	0.0	0.0
37.	DRILL WHEAT	0.0		0.0	0.0	0.0	0.0	0.0	0.0
38.	COMBINE WHT	0.0		0.0	0.0	0.0	0.0	0.0	0.0
39.	CULTIVATE ML	0.0		0.0	0.0	0.0	0.0	0.0	0.0
40.	HOE FEED	0.0		0.0	0.0	0.0	0.0	0.0	0.0

XINDEX	IMPL..	NUMBER	IMPCLS	WMAX	PURIO	XLIFEI	TRDNTI	RMI	TIMLI	CROPA	YIELD	VALUE	XTIMES
1.	SWATHER	9.0		14.0	385.0	12.0	15.0	0.000400	0.000500	50.0	2.0	18.0	1.0
2.	BALER	1.0	T	14.0	155.0	10.0	12.0	0.000320	0.000500	150.0	0.7	18.0	1.0
3.	SPRING TOOTH	7.0	T	13.0	20.0	15.0	20.0	0.000480	0.000050	50.0	2.0	18.0	1.0
4.	HARROW	6.0	T	14.0	16.0	15.0	20.0	0.000480	0.000050	50.0	2.0	18.0	1.0
5.	UNDERCUTTER	10.0	T	15.0	85.0	15.0	20.0	0.000480	0.000050	7.0	2.0	19.0	1.0
6.	DISK	5.0	T	12.0	125.0	15.0	20.0	0.000480	0.000050	7.0	2.0	18.0	1.0
7.	UNDERCUTTER	10.0	T	15.0	85.0	15.0	20.0	0.000480	0.000050	7.0	2.0	18.0	2.0
8.	TREADER	11.0	T	7.5	30.0	10.0	15.0	0.000480	0.000050	7.0	2.0	18.0	2.0
9.	DISK	5.0	T	12.0	125.0	15.0	20.0	0.000480	0.000050	7.0	2.0	18.0	1.0
10.	HARROW	6.0	T	14.0	16.0	15.0	20.0	0.000480	0.000050	7.0	2.0	18.0	1.0
11.	DRILL	4.0	T	13.0	65.0	20.0	25.0	0.000840	0.000300	7.0	2.0	18.0	1.0
12.	UNDERCUTTER	10.0	T	15.0	85.0	15.0	20.0	0.000480	0.000050	35.0	2.0	12.0	1.0
13.	DISK	5.0	T	12.0	125.0	15.0	20.0	0.000480	0.000050	35.0	2.0	12.0	1.0
14.	SPRAYER	8.0	T	18.0	22.0	12.0	20.0	0.000400	0.000300	18.0	2.0	12.0	1.0
15.	DRILL	4.0	T	13.0	65.0	20.0	25.0	0.000840	0.000300	35.0	2.0	12.0	1.0
16.	SWATHER	9.0		14.0	385.0	12.0	15.0	0.000400	0.000500	10.0	2.0	12.0	1.0
17.	BALER	1.0	T	14.0	155.0	10.0	12.0	0.000320	0.000500	10.0	2.0	12.0	1.0
18.	BINDER	2.0	T	10.0	80.0	12.0	20.0	0.000300	0.000100	25.0	2.0	12.0	1.0
19.	SWATHER	9.0		14.0	385.0	12.0	15.0	0.000400	0.000500	10.0	0.5	5.2	1.0
20.	BALER	1.0	T	14.0	155.0	10.0	12.0	0.000320	0.000500	10.0	0.5	5.2	1.0
21.	UNDERCUTTER	10.0	T	15.0	85.0	15.0	20.0	0.000480	0.000050	70.0	31.0	2.0	1.0
22.	DISK	5.0	T	12.0	125.0	15.0	20.0	0.000480	0.000050	70.0	31.0	2.0	1.0
23.	SPRAYER	8.0	T	18.0	22.0	12.0	20.0	0.000400	0.000300	35.0	31.0	2.0	1.0
24.	DRILL	4.0	T	13.0	65.0	20.0	25.0	0.000840	0.000300	70.0	31.0	2.0	1.0
25.	COMBINE	3.0		14.0	520.0	12.0	15.0	0.000300	0.000300	70.0	31.0	2.0	1.0
26.	UNDERCUTTER	10.0	T	15.0	85.0	15.0	20.0	0.000480	0.000050	16.0	2.0	12.0	1.0
27.	DISK	5.0	T	12.0	125.0	15.0	20.0	0.000480	0.000050	16.0	2.0	12.0	1.0
28.	SPRAYER	8.0	T	18.0	22.0	12.0	20.0	0.000400	0.000300	8.0	2.0	12.0	1.0
29.	DRILL	4.0	T	13.0	65.0	20.0	25.0	0.000840	0.000300	16.0	2.0	12.0	1.0
30.	SWATHER	9.0		14.0	385.0	12.0	15.0	0.000400	0.000500	8.0	2.0	12.0	1.0
31.	BALER	1.0	T	14.0	155.0	10.0	12.0	0.000320	0.000500	8.0	2.0	12.0	1.0
32.	UNDERCUTTER	10.0	T	15.0	85.0	15.0	20.0	0.000480	0.000050	210.0	18.0	1.8	1.0
33.	UNDERCUTTER	10.0	T	15.0	85.0	15.0	20.0	0.000480	0.000050	210.0	18.0	1.8	2.0
34.	TREADER	11.0	T	7.5	30.0	10.0	15.0	0.000480	0.000050	210.0	18.0	1.8	2.0
35.	SPRAYER	8.0	T	18.0	22.0	12.0	20.0	0.000400	0.000300	105.0	18.0	1.8	1.0
36.	DISK	5.0	T	12.0	125.0	15.0	20.0	0.000480	0.000050	210.0	18.0	1.8	1.0
37.	DRILL	4.0	T	13.0	65.0	20.0	25.0	0.000840	0.000300	210.0	18.0	1.8	1.0
38.	COMBINE	3.0		14.0	520.0	12.0	15.0	0.000300	0.000300	210.0	18.0	1.8	1.0
39.	CULTIVATOR	12.0	T	10.0	65.0	15.0	20.0	0.000480	0.000300	70.0	31.0	2.0	1.0
40.	ROTARY HOE	13.0	T	12.0	20.0	10.0	15.0	0.000300	0.000300	20.0	2.0	12.0	1.0

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XINDEX	E	XLABOR	XNOPS	ATTACH	ACTOTA	PURA	XLIFEA	TRDNTA	RMA	XNDCTR	CUSTOM	BASUSD
1.	100.0	0.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.60	0.0
2.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.25	0.0
3.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.21	0.0
4.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.91	0.0
5.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.20	0.0
6.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.53	0.0
7.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	3.04	0.0
8.	2.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.53	0.0
10.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.91	0.0
11.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.60	0.0
12.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.20	0.0
13.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.53	0.0
14.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.98	0.0
15.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.69	0.0
16.	100.0	0.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.60	0.0
17.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	3.40	0.0
18.	1.0	2.00	2.00	0.0	0.0	0.0	0.0	0.0	0.0	1.00	3.20	0.0
19.	100.0	0.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.60	0.0
20.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.70	0.0
21.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.20	0.0
22.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.53	0.0
23.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.98	0.0
24.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.69	0.0
25.	100.0	0.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	1.00	4.16	0.0
26.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.20	0.0
27.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.53	0.0
28.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.98	0.0
29.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.69	0.0
30.	100.0	0.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.60	0.0
31.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	3.40	0.0
32.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.20	0.0
33.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	3.04	0.0
34.	2.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.98	0.0
36.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.53	0.0
37.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.60	0.0
38.	100.0	0.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	1.00	3.76	0.0
39.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.67	0.0
40.	1.0	2.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.00	0.84	0.0

APPENDIX V

Information produced by the program for the optimum horsepower level of

a. Example Farm No. 1, and

b. Example Farm No. 2.

EXAMPLE FARM NO. 1

Information Produced by the Program for

the Optimum Horsepower Level

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SYSTEM ANNUAL COSTS	FACTORY RATED TRACTOR PTO HP	NO. OF TRACTORS	SYSTEM HOURS	INVESTMENT
$ 5307.64	36.38	1.	730.4	$ 16394.50

IMPLEMENT	OPTIMUM SIZE	NO. REQ'D	POWER LEVELS SELF-PROPELLED	AUXENG	PURCHASE PRICE
BALER	9.1	1.	0.0	13.8	1965.39
COMBINE	7.9	1.	33.2	0.0	7237.80
CULTIVATOR	9.5	1.	0.0	0.0	619.36
DISK	5.5	1.	0.0	0.0	692.42
DRILL	9.6	1.	0.0	0.0	623.04
HARROW	13.6	1.	0.0	0.0	217.46
MOWER	9.5	1.	0.0	0.0	381.14
PLANTER	9.5	1.	0.0	0.0	761.35
PLOW	3.4	1.	0.0	0.0	509.87
RAKE	9.5	1.	0.0	0.0	476.43
TRACTORS					2910.26

INVESTMENT INCLUDING TRACTORS = $ 16394.50

BREAKDOWN OF IMPLEMENT ANNUAL COSTS

IMPLEMENT	FIXED COST IMPLEMENT	FIXED COST TRACTOR	LABOR	TIMELINESS	FUEL	OIL	REPAIR & MAINTENANCE IMPLEMENT	REPAIR & MAINTENANCE TRACTOR	TOTAL
BALER	294.81	23.91	138.80	98.22	50.01	1.76	43.65	20.20	671.35
COMBINE	552.28	0.0	239.31	319.70	71.98	1.66	221.10	0.0	1406.02
CULTIVATOR	74.32	22.81	197.90	351.47	38.99	1.42	29.42	28.80	745.13
DISK	83.09	183.45	482.27	103.23	145.22	3.47	80.14	70.18	1151.03
DRILL	65.42	6.14	42.37	9.27	9.21	0.30	11.09	6.17	149.98
HARROW	26.10	14.52	80.93	17.96	18.99	0.58	4.22	11.78	175.09
MOWER	45.74	14.66	55.58	7.15	15.01	0.40	10.60	8.09	157.22
PLANTER	114.20	34.22	82.56	146.63	26.02	0.59	15.09	12.01	431.32
PLOW	61.18	30.27	79.25	9.38	23.82	0.57	9.70	11.53	225.72
RAKE	50.03	13.04	61.84	36.55	14.45	0.44	9.43	9.00	194.79
COLUMN TOTALS	1367.16	343.01	1460.82	1099.56	413.72	11.21	434.43	177.75	5307.64

FIELD OPERATION INFORMATION

OPERATION	TRACTORS NEEDED	COST OF OPERATION	CUSTOM COST	COMBINATION W	NO. OF COMB.IMPS.	ANNUAL HOURS REQ'D
PLOW CORN S	1.00	225.72	0.0	0.0	0.	39.6
DISK CORN S	1.00	193.92	0.0	0.0	0.	42.6
DISK CORN T	1.00	708.80	0.0	0.0	0.	141.8
HARROW CORN	1.00	129.34	0.0	0.0	0.	28.9
PLANT CORN	1.00	431.32	0.0	0.0	0.	41.3
CULTIVATE C	1.00	745.13	0.0	0.0	0.	99.0
PICK CORN	0.0	1084.96	0.0	0.0	0.	87.4
DISK OAT S	1.00	121.27	0.0	0.0	0.	28.4
DISK OAT T	1.00	127.04	0.0	0.0	0.	23.4
HARROW OAT	1.00	45.74	0.0	0.0	0.	11.6
DRILL OAT	1.00	149.98	0.0	0.0	0.	21.2
COMBINE OATS	0.0	321.07	0.0	0.0	0.	32.3
MOW OATS	1.00	43.18	0.0	0.0	0.	9.2
RAKE OATS	1.00	54.90	0.0	0.0	0.	12.4
BALE OATS	1.00	147.10	0.0	0.0	0.	17.4
M & R ALFALF	1.00	253.93	0.0	9.5	1.	37.1
BALE ALFALFA	1.00	524.25	0.0	0.0	0.	52.1

SYSTEM HOURS = 730.4

BREAKDOWN OF OPERATION COSTS

OPERATION	FIXED COST IMPLEMENTS	FIXED COST TRACTOR	LABOR	TIMELINESS	FUEL	OIL	REPAIR & MAINTENANCE IMPLEMENTS	REPAIR & MAINTENANCE TRACTOR	CUSTOM	TOTAL
PLOW CORN S	61.18	30.27	79.25	9.38	23.82	0.57	9.70	11.53	0.0	225.72
DISK CORN S	14.66	27.95	85.11	15.11	23.95	0.61	14.14	12.38	0.0	193.92
DISK CORN T	48.88	114.06	283.69	83.97	87.75	2.04	47.14	41.28	0.0	708.80
HARROW CORN	18.64	10.37	57.81	17.11	13.57	0.42	3.02	8.41	0.0	129.34
PLANT CORN	114.20	34.22	82.56	146.63	26.02	0.59	15.09	12.01	0.0	431.32
CULTIVATE C	74.32	22.81	197.90	351.47	38.99	1.42	29.42	28.80	0.0	745.13
PICK CORN	364.14	0.0	174.78	310.40	52.93	1.21	181.50	0.0	0.0	1084.96
DISK OAT S	9.78	18.63	56.74	2.07	15.97	0.41	9.43	8.26	0.0	121.27
DISK OAT T	9.78	22.81	56.74	2.07	17.55	0.41	9.43	8.26	0.0	127.04
HARROW OAT	7.46	4.15	23.12	0.84	5.43	0.17	1.21	3.36	0.0	45.74
DRILL OAT	65.42	6.14	42.37	9.27	9.21	0.30	11.09	6.17	0.0	149.98
COMBINE OATS	188.14	0.0	64.53	9.29	19.06	0.45	39.60	0.0	0.0	321.07
MOW OATS	11.43	3.48	18.47	0.46	4.40	0.13	2.11	2.69	0.0	43.18
RAKE OATS	12.51	3.26	24.74	3.09	5.17	0.18	2.36	3.60	0.0	54.90
BALE OATS	73.70	5.98	34.70	4.34	11.98	0.44	10.91	5.05	0.0	147.10
M & R ALFALF	71.82	20.96	74.21	40.15	19.89	0.53	15.56	10.80	0.0	253.93
BALE ALFALFA	221.11	17.93	104.10	93.88	38.03	1.32	32.74	15.15	0.0	524.25
COLUMN TOTALS	1367.16	343.01	1460.82	1099.56	413.72	11.21	434.43	177.75	0.0	5307.64

FUEL AND OIL CONSUMPTION PER OPERATION

OPERATION	FUEL: HP-HR/GAL TRACTOR, SP	FUEL: HP-HR/GAL AUX ENG	FUEL: GALLONS USED GASOLINE	FUEL: GALLONS USED DIESEL	FUEL: GALLONS USED LP GAS	OIL: GAL/HR TRACTOR, SP	OIL: GAL/HR AUX ENG	OIL: GALLONS USED GASOLINE	OIL: GALLONS USED DIESEL	OIL: GALLONS USED LP GAS
PLOW CORN S	9.03	0.0	140.14	0.0	0.0	0.01	0.0	0.42	0.0	0.0
DISK CORN S	8.29	0.0	140.90	0.0	0.0	0.01	0.0	0.45	0.0	0.0
DISK CORN T	9.24	0.0	516.15	0.0	0.0	0.01	0.0	1.50	0.0	0.0
HARROW CORN	5.43	0.0	79.81	0.0	0.0	0.01	0.0	0.31	0.0	0.0
PLANT CORN	9.35	0.0	153.07	0.0	0.0	0.01	0.0	0.44	0.0	0.0
CULTIVATE C	4.16	0.0	229.36	0.0	0.0	0.01	0.0	1.05	0.0	0.0
PICK CORN	9.31	0.0	311.32	0.0	0.0	0.01	0.0	0.89	0.0	0.0
DISK OAT S	8.29	0.0	93.94	0.0	0.0	0.01	0.0	0.30	0.0	0.0
DISK OAT T	9.24	0.0	103.23	0.0	0.0	0.01	0.0	0.30	0.0	0.0
HARROW OAT	5.43	0.0	31.92	0.0	0.0	0.01	0.0	0.12	0.0	0.0
DRILL OAT	4.74	0.0	54.17	0.0	0.0	0.01	0.0	0.22	0.0	0.0
COMBINE OATS	9.15	0.0	112.09	0.0	0.0	0.01	0.0	0.33	0.0	0.0
MOW OATS	5.61	0.0	25.90	0.0	0.0	0.01	0.0	0.10	0.0	0.0
RAKE OATS	4.48	0.0	30.42	0.0	0.0	0.01	0.0	0.13	0.0	0.0
BALE OATS	5.29	6.15	70.50	0.0	0.0	0.01	0.01	0.32	0.0	0.0
M & R ALFALF	7.49	0.0	62.40	0.0	0.0	0.01	0.0	0.20	0.0	0.0
R & M ALFALF	7.49	0.0	54.60	0.0	0.0	0.01	0.0	0.20	0.0	0.0
BALE ALFALFA	5.29	8.74	223.70	0.0	0.0	0.01	0.01	0.97	0.0	0.0
COLUMN TOTALS	---------	---------	2433.66	0.0	0.0	---------	---------	8.24	0.0	0.0

INFORMATION CONCERNING

FACTORS AFFECTING

OPTIMUM TRACTOR PERFORMANCE

FACTORY RATED TRACTOR PTO HP	AVAILABLE TRACTOR PTO HP, USING 85.0% OF THE FACTORY RATING
36.38	30.92

REQUIRED

OPERATION	FACTORY RATED TRACTOR PTO HP	PTO HP	DB HP	NO LOAD SPEED,MPH	TOTAL PULL,LBS	TOTAL REAR WT,LBS	TOTAL TRACTOR WT,LBS
PLOW CORN S	31.95	0.0	20.62	3.86	2209.4	5523.6	7364.8
DISK CORN S	27.46	0.0	17.73	3.31	2215.7	5539.3	7385.8
DISK CORN T	33.63	0.0	17.73	3.36	2215.7	6087.2	8116.2
HARROW CORN	15.00	0.0	6.52	3.53	815.5	3592.4	4789.8
PLANT CORN	34.66	0.0	18.27	3.36	2284.0	5238.6	6984.8
CULTIVATE C	9.64	0.0	5.08	2.80	762.3	1748.4	2331.2
DISK OAT S	27.46	0.0	17.73	3.31	2215.7	5539.3	7385.8
DISK OAT T	33.63	0.0	17.73	3.36	2215.7	6087.2	8116.2
HARROW OAT	15.00	0.0	6.52	3.53	815.5	3592.4	4789.8
DRILL OAT	12.12	0.0	6.39	2.80	958.5	2633.3	3511.1
MOW OATS	15.75	0.0	10.16	5.51	762.3	1724.6	2299.5
RAKE OATS	11.02	0.0	7.11	4.41	667.0	1667.5	2223.3
BALE OATS	14.41	0.0	9.30	3.86	996.3	2490.7	3320.9
M & R ALFALF	23.62	0.0	15.25	4.41	1429.3	3392.1	4522.8
BALE ALFALFA	14.41	0.0	9.30	3.86	996.3	2490.7	3320.9

EXAMPLE FARM NO. 2

Information Produced by the Program for
the Optimum Horsepower Level

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SYSTEM ANNUAL COSTS	FACTORY RATED TRACTOR PTO HP	NO. OF TRACTORS	SYSTEM HOURS	INVESTMENT
$ 8049.48	64.35	1.	1204.0	$ 20109.05

IMPLEMENT	OPTIMUM SIZE	NO. REQ'D	POWER LEVELS SELF-PROPELLED	AUXENG	PURCHASE PRICE
BALER	10.7	1.	0.0	0.0	1663.04
BINDER	9.1	1.	0.0	0.0	724.57
COMBINE	9.8	1.	39.6	0.0	5101.86
DRILL	12.6	1.	0.0	0.0	820.34
DISK	10.3	1.	0.0	0.0	1286.43
HARROW	13.6	1.	0.0	0.0	217.46
SPRING TOOTH	12.6	1.	0.0	0.0	252.41
SPRAYER	17.7	1.	0.0	0.0	388.84
SWATHER	6.9	1.	17.3	0.0	2655.52
UNDERCUTTER	6.7	1.	0.0	0.0	572.48
TREADER	6.7	1.	0.0	0.0	202.05
CULTIVATOR	9.5	1.	0.0	0.0	619.36
ROTARY HOE	6.7	1.	0.0	0.0	135.00
TRACTORS					5469.70

INVESTMENT INCLUDING TRACTORS = $ 20109.05

BREAKDOWN OF IMPLEMENT ANNUAL COSTS

IMPLEMENT	FIXED COST IMPLEMENT	FIXED COST TRACTOR	LABOR	TIMELINESS	FUEL	OIL	REPAIR & MAINTENANCE IMPLEMENT	REPAIR & MAINTENANCE TRACTOR	TOTAL
BALER	249.46	32.75	149.15	51.41	30.99	1.95	39.69	40.79	596.18
BINDER	97.82	7.50	82.81	1.24	7.81	0.54	4.50	11.32	213.55
COMBINE	688.75	0.0	362.22	336.21	131.09	2.69	277.20	0.0	1798.17
DRILL	86.14	46.50	271.94	213.60	49.62	3.56	93.69	74.37	839.42
DISK	154.37	238.13	355.77	40.29	130.43	4.66	109.84	97.30	1130.79
HARROW	26.10	4.91	37.00	1.35	5.75	0.48	1.93	10.12	87.64
SPRING TOOTH	30.29	16.17	31.13	1.40	9.55	0.41	1.89	8.51	99.35
SPRAYER	52.49	23.30	101.33	40.66	21.73	1.33	7.88	27.71	276.44
SWATHER	358.49	0.0	258.07	99.38	40.68	1.49	137.06	0.0	895.17
UNDERCUTTER	68.70	314.94	520.88	72.48	188.68	6.82	88.96	142.45	1403.91
TREADER	30.31	27.72	126.58	20.86	15.21	1.66	12.28	34.62	269.23
CULTIVATOR	74.32	14.31	138.53	90.18	18.09	1.81	20.59	37.89	395.72
ROTARY HOE	20.25	2.09	13.97	1.01	2.35	0.18	0.28	3.82	43.94
COLUMN TOTALS	1937.48	728.31	2449.37	970.09	651.98	27.57	795.79	488.90	8049.48

FIELD OPERATION INFORMATION

OPERATION	TRACTORS NEEDED	COST OF OPERATION	CUSTOM COST	COMBINATION W	NO. OF COMB.IMPS.	ANNUAL HOURS REQ'D
SWATH ALFALF	0.0	768.47	0.0	0.0	0.	108.7
BALE ALFALFA	1.00	480.95	0.0	0.0	0.	54.9
SPRNG TOTH A	1.00	99.35	0.0	0.0	0.	15.6
HARROW ALFAL	1.00	68.71	0.0	0.0	0.	14.5
UNDERCUT ALF	1.00	18.53	0.0	0.0	0.	4.1
DISK ALFALFA	1.00	16.41	0.0	0.0	0.	2.7
UNDERCUT ALF	1.00	22.23	0.0	6.7	1.	4.1
DISK ALFALFA	1.00	16.41	0.0	0.0	0.	2.7
HARROW ALFAL	1.00	18.93	0.0	0.0	0.	4.0
DRILL ALFALF	1.00	13.17	0.0	0.0	0.	2.8
UNDERCUT FD	1.00	93.25	0.0	0.0	0.	20.4
DISK FEED	1.00	164.93	0.0	0.0	0.	26.7
SPRAY FEED	1.00	26.68	0.0	0.0	0.	5.6
DRILL FEED	1.00	68.35	0.0	0.0	0.	14.1
SWATH FEED	0.0	45.58	0.0	0.0	0.	7.2
BALE FEED	1.00	47.07	0.0	0.0	0.	8.5
BIND FEED	1.00	213.55	0.0	0.0	0.	20.7
SWATH HAY	0.0	44.80	0.0	0.0	0.	7.2
BALE HAY	1.00	30.66	0.0	0.0	0.	4.3
UNDERCUT MIL	1.00	193.65	0.0	0.0	0.	40.8
DISK MILO	1.00	339.22	0.0	0.0	0.	53.4
SPRAY MILO	1.00	53.33	0.0	0.0	0.	9.9
DRILL MILO	1.00	166.27	0.0	0.0	0.	28.2
COMBINE MILO	0.0	424.44	0.0	0.0	0.	45.3
UNDERCT SUDN	1.00	42.42	0.0	0.0	0.	9.3
DISK SUDAN	1.00	75.12	0.0	0.0	0.	12.2
SPRAY SUDAN	1.00	11.68	0.0	0.0	0.	2.5
DRILL SUDAN	1.00	30.37	0.0	0.0	0.	6.4
SWATH SUDAN	0.0	36.32	0.0	0.0	0.	5.8
BALE SUDAN	1.00	37.49	0.0	0.0	0.	6.8
UNDERCT WHT	1.00	596.03	0.0	0.0	0.	122.5
UNDERCT WHT	1.00	707.03	0.0	6.7	1.	122.5
SPRAY WHEAT	1.00	184.75	0.0	0.0	0.	32.7
DISK WHEAT	1.00	518.70	0.0	0.0	0.	80.2
DRILL WHEAT	1.00	561.26	0.0	0.0	0.	84.5
COMBINE WHT	0.0	1373.73	0.0	0.0	0.	135.8
CULTIVATE ML	1.00	395.72	0.0	0.0	0.	69.5
HOE FEED	1.00	43.94	0.0	0.0	0.	7.0

SYSTEM HOURS =1204.0

BREAKDOWN OF OPERATION COSTS

OPERATION	FIXED COST IMPLEMENTS	FIXED COST TRACTOR	LABOR	TIMELINESS	FUEL	OIL	REPAIR & MAINTENANCE IMPLEMENTS	REPAIR & MAINTENANCE TRACTOR	CUSTOM	TOTAL
SWATH ALFALF	302.10	0.0	217.47	97.86	34.28	1.25	115.50	0.0	0.0	768.47
BALE ALFALFA	210.22	26.42	109.85	49.68	24.09	1.44	29.23	30.04	0.0	480.95
SPRNG TOTH A	30.29	16.17	31.13	1.40	9.55	0.41	1.89	8.51	0.0	99.35
HARROW ALFAL	20.39	3.83	28.91	1.30	4.49	0.38	1.51	7.91	0.0	68.71
UNDERCUT ALF	0.87	3.65	8.17	0.05	2.33	0.11	1.12	2.23	0.0	18.53
DISK ALFALFA	2.32	3.58	5.34	0.03	1.96	0.07	1.65	1.46	0.0	16.41
UNDERCUT ALF	1.84	5.37	8.17	0.05	2.94	0.11	1.52	2.23	0.0	22.23
DISK ALFALFA	2.32	3.58	5.34	0.03	1.96	0.07	1.65	1.46	0.0	16.41
HARROW ALFAL	5.71	1.07	8.09	0.05	1.26	0.11	0.42	2.21	0.0	18.93
DRILL ALFALF	1.78	0.96	5.63	0.21	1.03	0.07	1.94	1.54	0.0	13.17
UNDERCUT FD	4.33	18.26	40.83	0.86	11.66	0.53	5.61	11.17	0.0	93.25
DISK FEED	23.19	35.77	53.44	1.12	19.59	0.70	16.50	14.62	0.0	164.93
SPRAY FEED	5.69	2.58	11.20	0.73	2.40	0.15	0.87	3.06	0.0	26.68
DRILL FEED	8.92	4.82	28.16	3.55	5.14	0.37	9.70	7.70	0.0	68.35
SWATH FEED	20.14	0.0	14.50	0.87	2.29	0.08	7.70	0.0	0.0	45.58
BALE FEED	14.01	2.60	17.09	1.03	2.90	0.22	4.55	4.67	0.0	47.07
BIND FEED	97.82	7.50	82.31	1.24	7.31	0.54	4.50	11.32	0.0	213.55
SWATH HAY	20.14	0.0	14.50	0.09	2.29	0.08	7.70	0.0	0.0	44.80
BALE HAY	14.01	1.65	8.54	0.06	1.67	0.11	2.27	2.34	0.0	30.66
UNDERCUT MIL	8.66	36.52	81.66	8.86	23.32	1.07	11.22	22.33	0.0	193.65
DISK MILO	46.38	71.54	106.88	11.60	39.18	1.40	33.00	29.23	0.0	339.22
SPRAY MILO	11.07	4.55	19.80	6.45	4.25	0.26	1.54	5.42	0.0	53.33
DRILL MILO	17.64	9.63	56.32	36.66	10.28	0.74	19.40	15.40	0.0	166.27
COMBINE MILO	172.19	0.0	90.56	58.95	32.77	0.67	69.30	0.0	0.0	424.44
UNDERCT SUDN	1.98	8.35	18.67	0.18	5.33	0.24	2.56	5.10	0.0	42.42
DISK SUDAN	10.60	16.35	24.43	0.23	8.96	0.32	7.54	6.68	0.0	75.12
SPRAY SUDAN	2.53	1.14	4.98	0.14	1.07	0.07	0.39	1.36	0.0	11.68
DRILL SUDAN	4.08	2.20	12.87	0.74	2.35	0.17	4.44	3.52	0.0	30.37
SWATH SUDAN	16.11	0.0	11.60	0.56	1.83	0.07	6.16	0.0	0.0	36.32
BALE SUDAN	11.21	2.08	13.67	0.66	2.32	0.18	3.64	3.74	0.0	37.49
UNDERCT WHT	25.99	109.55	244.98	41.67	69.97	3.21	33.66	67.00	0.0	596.03
UNDERCT WHT	55.32	160.97	244.98	41.67	88.33	3.21	45.54	67.00	0.0	707.03
SPRAY WHEAT	33.20	15.02	65.35	33.35	14.02	0.86	5.08	17.87	0.0	184.75
DISK WHEAT	69.57	107.31	160.33	27.27	58.78	2.10	49.50	43.85	0.0	518.70
DRILL WHEAT	53.52	28.39	168.95	172.43	30.83	2.21	58.21	46.21	0.0	561.26
COMBINE WHT	516.56	0.0	271.67	277.26	98.32	2.02	207.90	0.0	0.0	1373.73
CULTIVATE ML	74.32	14.31	138.53	90.18	18.09	1.81	20.59	37.89	0.0	395.72
HOE FEED	20.25	2.09	13.97	1.01	2.35	0.18	0.28	3.82	0.0	43.94
COLUMN TOTALS	1937.48	728.31	2449.36	970.09	651.98	27.57	795.79	488.90	0.0	8049.48

FUEL AND OIL CONSUMPTION PER OPERATION

	FUEL					OIL				
	HP-HR/GAL		GALLONS USED			GAL/HR		GALLONS USED		
OPERATION	TRACTOR, SP	AUX ENG	GASOLINE	DIESEL	LP GAS	TRACTOR, SP	AUX ENG	GASOLINE	DIESEL	LP GAS
SWATH ALFALF	9.31	0.0	201.65	0.0	0.0	0.01	0.0	0.92	0.0	0.0
BALE ALFALFA	7.68	0.0	0.0	160.59	0.0	0.02	0.0	0.0	1.06	0.0
SPRNG TOTH A	11.85	0.0	0.0	63.69	0.0	0.02	0.0	0.0	0.30	0.0
HARROW ALFAL	5.97	0.0	0.0	29.95	0.0	0.02	0.0	0.0	0.28	0.0
UNDERCUT ALF	10.96	0.0	0.0	15.55	0.0	0.02	0.0	0.0	0.08	0.0
DISK ALFALFA	12.78	0.0	0.0	13.06	0.0	0.02	0.0	0.0	0.05	0.0
UNDERCUT ALF	12.76	0.0	0.0	16.36	0.0	0.02	0.0	0.0	0.04	0.0
TREAD ALFALF	12.76	0.0	0.0	3.27	0.0	0.02	0.0	0.0	0.04	0.0
DISK ALFALFA	12.78	0.0	0.0	13.06	0.0	0.02	0.0	0.0	0.05	0.0
HARROW ALFAL	5.97	0.0	0.0	8.39	0.0	0.02	0.0	0.0	0.08	0.0
DRILL ALFALF	6.56	0.0	0.0	6.85	0.0	0.02	0.0	0.0	0.05	0.0
UNDERCUT FD	10.96	0.0	0.0	77.74	0.0	0.02	0.0	0.0	0.39	0.0
DISK FEED	12.78	0.0	0.0	130.61	0.0	0.02	0.0	0.0	0.51	0.0
SPRAY FEED	7.50	0.0	0.0	16.02	0.0	0.02	0.0	0.0	0.11	0.0
DRILL FEED	6.56	0.0	0.0	34.25	0.0	0.02	0.0	0.0	0.27	0.0
SWATH FEED	9.31	0.0	13.44	0.0	0.0	0.01	0.0	0.06	0.0	0.0
BALE FEED	6.27	0.0	0.0	19.35	0.0	0.02	0.0	0.0	0.16	0.0
BIND FEED	6.72	0.0	0.0	52.09	0.0	0.02	0.0	0.0	0.40	0.0
SWATH HAY	9.31	0.0	13.44	0.0	0.0	0.01	0.0	0.06	0.0	0.0
BALE HAY	6.92	0.0	0.0	11.16	0.0	0.02	0.0	0.0	0.08	0.0
UNDERCUT MIL	10.96	0.0	0.0	155.48	0.0	0.02	0.0	0.0	0.79	0.0
DISK MILO	12.78	0.0	0.0	261.23	0.0	0.02	0.0	0.0	1.03	0.0
SPRAY MILO	7.50	0.0	0.0	28.31	0.0	0.02	0.0	0.0	0.19	0.0
DRILL MILO	6.56	0.0	0.0	68.51	0.0	0.02	0.0	0.0	0.54	0.0
COMBINE MILO	9.31	0.0	192.78	0.0	0.0	0.01	0.0	0.49	0.0	0.0
UNDERCT SUDN	10.96	0.0	0.0	35.54	0.0	0.02	0.0	0.0	0.18	0.0
DISK SUDAN	12.78	0.0	0.0	59.71	0.0	0.02	0.0	0.0	0.24	0.0
SPRAY SUDAN	7.50	0.0	0.0	7.12	0.0	0.02	0.0	0.0	0.05	0.0
DRILL SUDAN	6.56	0.0	0.0	15.66	0.0	0.02	0.0	0.0	0.12	0.0
SWATH SUDAN	9.31	0.0	10.75	0.0	0.0	0.01	0.0	0.05	0.0	0.0
BALE SUDAN	6.27	0.0	0.0	15.48	0.0	0.02	0.0	0.0	0.13	0.0
UNDERCT WHT	10.96	0.0	0.0	466.44	0.0	0.02	0.0	0.0	2.36	0.0
UNDERCT WHT	12.76	0.0	0.0	490.75	0.0	0.02	0.0	0.0	1.18	0.0
TREAD WHEAT	12.76	0.0	0.0	98.15	0.0	0.02	0.0	0.0	1.18	0.0
SPRAY WHEAT	7.50	0.0	0.0	93.44	0.0	0.02	0.0	0.0	0.63	0.0
DISK WHEAT	12.78	0.0	0.0	391.84	0.0	0.02	0.0	0.0	1.54	0.0
DRILL WHEAT	6.56	0.0	0.0	205.53	0.0	0.02	0.0	0.0	1.63	0.0
COMBINE WHT	9.31	0.0	578.34	0.0	0.0	0.01	0.0	1.48	0.0	0.0
CULTIVATE ML	5.54	0.0	0.0	120.57	0.0	0.02	0.0	0.0	1.33	0.0
HOE FEED	6.23	0.0	0.0	15.64	0.0	0.02	0.0	0.0	0.13	0.0
COLUMN TOTALS	---------	---------	1010.41	3201.40	0.0	---------	---------	3.07	17.20	0.0

INFORMATION CONCERNING

FACTORS AFFECTING

OPTIMUM TRACTOR PERFORMANCE

FACTORY RATED TRACTOR PTO HP	AVAILABLE TRACTOR PTO HP, USING 85.0% OF THE FACTORY RATING
64.35	54.70

		REQUIRED					
OPERATION	FACTORY RATED TRACTOR PTO HP	PTO HP	DB HP	NO LOAD SPEED,MPH	TOTAL PULL,LBS	TOTAL REAR WT,LBS	TOTAL TRACTOR WT,LBS
BALE ALFALFA	22.45	4.57	11.02	3.86	1180.2	2950.6	3934.1
SPRNG TOTH A	48.49	0.0	31.30	3.31	3912.4	9781.0	13041.3
HARROW ALFAL	12.38	0.0	6.52	3.36	815.5	2240.3	2987.1
UNDERCUT ALF	41.74	0.0	26.94	3.31	3367.6	8418.9	11225.2
DISK ALFALFA	62.47	0.0	32.93	3.36	4116.6	11309.3	15079.1
UNDERCUT ALF	61.33	0.0	32.33	3.36	4041.1	11101.8	14802.4
DISK ALFALFA	62.47	0.0	32.93	3.36	4116.6	11309.3	15079.1
HARROW ALFAL	12.38	0.0	6.52	3.36	815.5	2240.3	2987.1
DRILL ALFALF	15.96	0.0	8.41	2.80	1262.1	3467.2	4622.9
UNDERCUT FD	41.74	0.0	26.94	3.31	3367.6	8418.9	11225.2
DISK FEED	62.47	0.0	32.93	3.36	4116.6	11309.3	15079.1
SPRAY FEED	21.46	0.0	11.31	3.36	1414.0	3884.6	5179.4
DRILL FEED	15.96	0.0	8.41	2.80	1262.1	3467.2	4622.9
BALE FEED	14.20	5.85	4.72	1.65	1180.2	2950.6	3934.1
BIND FEED	16.91	4.83	7.25	2.21	1358.6	3396.4	4528.5
BALE HAY	18.07	2.93	9.44	3.31	1180.2	2950.6	3934.1
UNDERCUT MIL	41.74	0.0	26.94	3.31	3367.6	8418.9	11225.2
DISK MILO	62.47	0.0	32.93	3.36	4116.6	11309.3	15079.1
SPRAY MILO	21.46	0.0	11.31	3.36	1414.0	3884.6	5179.4
DRILL MILO	15.96	0.0	8.41	2.80	1262.1	3467.2	4622.9
UNDERCT SUDN	41.74	0.0	26.94	3.31	3367.6	8418.9	11225.2
DISK SUDAN	62.47	0.0	32.93	3.36	4116.6	11309.3	15079.1
SPRAY SUDAN	21.46	0.0	11.31	3.36	1414.0	3884.6	5179.4
DRILL SUDAN	15.96	0.0	8.41	2.80	1262.1	3467.2	4622.9
BALE SUDAN	14.20	5.85	4.72	1.65	1180.2	2950.6	3934.1
UNDERCT WHT	41.74	0.0	26.94	3.31	3367.6	8418.9	11225.2
UNDERCT WHT	61.33	0.0	32.33	3.36	4041.1	11101.8	14802.4
SPRAY WHEAT	21.46	0.0	11.31	3.36	1414.0	3884.6	5179.4
DISK WHEAT	62.47	0.0	32.93	3.36	4116.6	11309.3	15079.1
DRILL WHEAT	15.96	0.0	8.41	2.80	1262.1	3467.2	4622.9
CULTIVATE ML	9.64	0.0	5.08	2.80	762.3	2094.2	2792.3
HOE FEED	13.94	0.0	9.00	5.51	675.0	1687.5	2250.0

APPENDIX VI

Listing of the machinery selection program.

```
C***********************************************************************
C***********************************************************************
C     FARM MACHINERY SELECTION PROGRAM - FORTRAN IV - JANUARY 1973
C     INDUSTRIAL ENGINEERING DEPARTMENT, KANSAS STATE UNIVERSITY
C
C
C     THIS PROGRAM IS AN EXTENSION OF
C     MACHINERY SELECTION PROGRAM - FORTRAN IV - JUNE 1968
C     AGRICULTURAL ENGINEERING DEPARTMENT, UNIVERSITY OF ILLINOIS
C***********************************************************************
C***********************************************************************
C
C
C     ALL COMMENTS THAT APPEAR IN QUOTATION MARKS WERE OBTAINED FROM AN
C     ARTICLE WRITTEN BY DONNELL HUNT.  THE TITLE OF THE ARTICLE WAS
C     'A FORTRAN PROGRAM FOR SELECTING FARM EQUIPMENT'.  THE ARTICLE
C     WAS PUBLISHED IN
C     AGRICULTURAL ENGINEERING(VOL. 48, NO. 6, PP. 332-335, JUNE 1967),
C     -----------------------
C     THE JOURNAL OF THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS,
C     ST. JOSEPH, MICHIGAN.
C
C
C     REFERENCES
C
C     1.  HUNT, DONNELL R.  FARM POWER AND MACHINERY MANAGEMENT.  IOWA
C         STATE UNIVERSITY PRESS (4TH EDITION) 1964.
C
C***********************************************************************
C
C
C     CONCERNING THE PROGRAM
C     **********************
C
C
C          'THIS PROGRAM ASSUMES THAT THE ENTERPRISES AND MACHINERY
C     ACTIVITIES ON A FARM ARE KNOWN AND UNCHANGING DURING EQUIPMENT
C     LIFE.'
C
C          'IMPLEMENT SIZE AND POWER LEVEL, ARE THE UNKNOWN VARIABLES
C     FOR WHICH SOLUTIONS ARE SOUGHT' WITH THIS PROGRAM.
C
C          'ALWAYS THE MINIMUM NUMBER OF POWER UNITS IN THE LARGEST
C     SIZES PERMITTED BY THE PROGRAM WILL BE SELECTED.'
C
C          'IN THIS ANALYSIS EACH FIELD OPERATION IS CONSIDERED TO BE
C     PERFORMED BY A BASE IMPLEMENT THAT MAY OR MAY NOT HAVE ATTACHMENTS
C     OR THAT MAY OR MAY NOT BE USED IN COMBINATION WITH OTHER
C     IMPLEMENTS.'
C
C          'TIMELINESS COSTS ARE USED IN SELECTING THE OPTIMUM SIZE AND
C     IN DETERMINING THE SYSTEM COSTS BUT ARE SUBTRACTED WHEN COMPARING
C     WITH CUSTOM COSTS.  THEY ARE COMPUTED BY USING THE FACTORS IN
C     TABLE 14.2 (1).'
C
C
C     TABLE 14.2
C
```

```
C     TIMELINESS FACTORS
C     ----------------------------------------
C
C     OPERATION                              K VALUE
C     ----------------------------------------
C
C     SEEDING                                .00030
C     TILLAGE                                .00005
C     CULTIVATION                            .00020
C     GRAIN HARVESTING                       .00030
C     HAY HARVESTING                         .00050
C     GREEN FORAGE HARVESTING                .00010
C     ----------------------------------------
C
C
C * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
C     CONCERNING INPUT TO THE PROGRAM
C     *******************************
C
C
C
C          IF AN IMPLEMENT IS NOT TRACTOR POWERED IT IS CONSIDERED
C     TO BE SELF-PROPELLED.
C
C          'REPAIR AND MAINTENANCE COSTS ARE DERIVED FOR THE BASE
C     IMPLEMENT, THE COMBINATION IMPLEMENT, THE ATTACHMENT, AND THE
C     TRACTOR.  THEY ARE COMPUTED AS A DECIMAL QUANTITY OF THE PURCHASE
C     PRICE PER HOUR OF USE AND ARE DEVELOPED FROM DATA IN THE
C     AGRICULTURAL ENGINEER'S YEARBOOK.'
C     ------------------------------
C
C          'THIS SELECTION PROCESS REQUIRES GROSS ENERGY FIGURES THAT
C     INCLUDE ROLLING RESISTANCE AND SLOPE ENERGY REQUIREMENTS.'
C
C          'THE TERM FORCE FACTOR IS USED HERE TO INDICATE GROSS ENERGY
C     REQUIREMENTS OF FIELD OPERATIONS.  THESE FORCE FACTORS HAVE UNITS
C     OF POUNDS OF FORCE PER FOOT OF EFFECTIVE WIDTH OF AN IMPLEMENT.
C     THEY ARE BASED ON PUBLISHED DRAFT AND POWER REQUIREMENTS WITH
C     THE AUXILIARY ROLLING RESISTANCES OF THE TRACTOR, IMPLEMENT, AND
C     TRAILING WAGONS, IF ANY, INCLUDED.  ANY TABLE OF FORCE FACTORS
C     COULD REPRESENT ONLY GENERAL VALUES.  THE FORCE FACTORS MUST BE
C     CAREFULLY EVALUATED FOR THE SPECIFIC FARM SITUATION.'
C
C          'EACH CROP ENTERPRISE MUST HAVE ITS OWN ENTRY.  DISKING FOR
C     CORN, FOR EXAMPLE, IS LISTED AS A SEPARATE ACTIVITY FROM DISKING
C     FOR SOYBEANS.  THIS DIFFERENTIATION IS NECESSARY TO DISCRIMINATE
C     THE RESPECTIVE TIMELINESS, LABOR, AND REPAIR COSTS AND TO PERMIT
C     DISTINCTION, IF ANY, BETWEEN THE RESPECTIVE FORCE FACTORS.  THIS
C     IMPLEMENT WOULD, HOWEVER, BE IDENTIFIED BY THE SAME IDENTIFICATION
C     NUMBER IN BOTH THE CORN AND SOYBEAN ENTRIES.'
C
C***********************************************************************
C***********************************************************************
C
C
C                 *****MAIN*****
C
```

```
C
C                 CONTROLS SEARCH FOR OPTIMUM TRACTOR HORSEPOWER
C
C
C                 COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                 FUELS, AND SOILS
C
       COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
C                 COMMON AREA OF SCALAR VARIABLES
C
       COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCRDR, NM1,
      1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
      2PURTR, RMTR, SMNRGD, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRDNTT,
      3XLFTR, XLIFET
C
C
C                 COMMON AREA OF ARRAY VARIABLES
C
       COMMON ACIMP(50), ACIMP1(50), ACIMP2(50), ACIMP3(50), ACIMP4(50),
      1ACIMP5(50), ACIMP6(50), ACIMP7(50), ACIMP8(50), ACRESD(50),
      2ACTOTA(50), ATTACH(50), AUXENG(50), AXHPLV(50), AXLFTR(50),
      3AXMXHP(50), BASUSD(50), CNTRCT(50), COMBID(50), COSTI(50),
      4COST2(50), COST3(50), COST4(50), COST5(50), COST6(50), COST7(50),
      5COST8(50), COSTID(50), CROPA(50), CUSTOM(50), CU(50), DDPRTW(4,4),
      6DISTR(50), DTOAHP(4), E(50), EFFIC(50), FCPCTA(50), FCPCTC(50),
      7FCPCTI(50), FEFFIC(50), FEFICX(50), FFACTR(50), FFCTRX(50),
      8FFCTRC(50), FPRICE( 4), FTYPE(50), FUELC(50,4), G(50)
       COMMON HP(50), HPHRTC(50), HPHRTI(50), HPHRTX(50), IMPCLS(50),
      1NCCODE(50), NMCH1(50), NMCH2(50), NMCH3(50), NMCHJ1(50),
      2NMCHJ2(50), NMCHJ3(50), NOP1(50), NOP2(50), NOP3(50), NPR1(50),
      3NPR2(50), NPR3(50), NPR4(50), NPR5(50), NSOIL(50), NTR1(50),
      4NTR2(50), NTR3(50), NTR4(50), NTR5(50)
       COMMON OCSMPA(50), OCSMPT(50), OIL(50,4), OPRICE( 4), PP(50),
      1PURA(50), PURI(50), PURID(50), PURIC(50), Q(50), QA(50), RMA(50),
      2RMI(50), RMIC(50), RNATCH(50), RWNLS(4,4), SFTYPE(50), SNRGDI(50),
      3SNRGOC(50), SNRGP(50), SNRGT(50), SPDFF(50), SPEED(50), SPHP(50),
      4SPLFTR(50), SUMAC(50), SUMACC(50), TIMLI(50), TIMPMX(50),
      5TONSPR(50), TONSTR(50), TPOWRD(50), TRATIO(4), TREDUC(4),
      6TRDNTA(50), TRDNTI(50), VALUE(50), W(50), WC(50), WMAX(50), WS(50)
       COMMON XIMPL(50), XINDEX(50), X(50), XFTYPE(50), XLABOR(50),
      1XLIFEA(50), XLIFEI(50), XNDCTR(50), XNIMPS(50), XNIMPC(50),
      2XNOPS(50), XNTRSN(50), XTIMES(50), YIELD(50), Z(50)
C
C
C                 IDENTIFY I/O UNITS
C
       NCRDR = 5
       NPRNTR = 6
C
C
C                 READ IN DATA
C
       IOCNT = 0
       KPAGE = 0
  1000 CALL DATAIO(IOCNT)
       IOCNT = 1
```

```
C
C
C                   INITIALIZE VARIABLES AND IF ESTHPL EQUALS 0.0
C                   CALCULATE AN ESTIMATE OF THE HORSEPOWER LEVEL NEEDED
C
      CALL INITL1
      IF ( ESTHPL .EQ. 0.0 ) GO TO 60
      OHP = ESTHPL
      CALL SELECT ( OHP, OFNHP, OFNTRS, &1000, &599 )
   60 DO 83 I = 1, NMBROP
   83 CNTRCT( I ) = 1.0
      CALL HPEST ( BSHPN )
C
C
C                   USE HOOKE & JEEVES PATTERN SEARCH TO FIND THE
C                   INTERVAL OF UNCERTAINTY FOR TRACTOR HORSEPOWER
C
C                   LOWER LIMIT ON HORSEPOWER IS 1.0 HP.
C
      CALL SELECT ( BSHPN, FNBHPN, FXNTRS, &1000,  &87 )
   87 HP = BSHPN
      FNHP = FNBHPN
      FNTRS = FXNTRS
      CALL EXPLMV ( HP, FNHP, FNTRS, &1000, &69 )
   69 IF ( FNHP .GE. FNBHPN ) GO TO 80
   70 BSHPO = BSHPN
      BSHPN = HP
      FNBHPN = FNHP
      FXNTRS = FNTRS
      HP = BSHPN * 2. - BSHPO
      IF ( HP .LT. 1.0 ) HP = 1.0
      CALL SELECT ( HP, FNHP, FNTRS, &1000, &72 )
   72 IF ( FNHP .GE. FNBHPN ) GO TO 81
      GO TO 70
   80 HP1 = HP + DLTAHP
      HP2 = HP - DLTAHP
      IF ( HP2 .LT. 1.0 ) HP2 = 1.0
      GO TO 85
   81 HP1 = HP
      HP2 = BSHPO
   85 IF ( HP1 .LE. HP2 ) GO TO 86
      HPLOW = HP2
      HPHIGH = HP1
      GO TO 88
   86 HPLOW = HP1
      HPHIGH = HP2
   88 HPRNGE = HPHIGH - HPLOW
      IF ( HPRNGE .GT. 1.0 ) GO TO 90
      WRITE(NPRNTR,89)
   89 FORMAT(1H1,///52H  SOLUTION REACHED, HPRNGE LESS THAN OR EQUAL TO
     11.0 )
      GO TO 1000
C
C
C                   USE FIBONACCI METHOD TO FIND TRACTOR HORSEPOWER WHICH
C                   YIELDS THE LEAST COST FARM MACHINE SYSTEM
C
C                   INTERVAL OF UNCERTAINTY REMAINING AFTER SEARCH IS
```

```
C                    1.0 HORSEPOWER
C
   90 N = 1
      F0 = 1.0
      F1 = 1.0
      FN = 1.0
   91 IF ( 1.0/FN .LE. 1.0/HPRNGE ) GO TO 92
      FN = F0 + F1
      F0 = F1
      F1 = FN
      N = N + 1
      GO TO 91
   92 HP1 = F0 * HPRNGE / FN  + HPLOW
      HP2 = HPLOW + HPHIGH - HP1
      CALL SELECT(HP1, FNHP1, FNTRS1, &1000, &93 )
   93 CALL SELECT ( HP2, FNHP2, FNTRS2, &1000, &94 )
   94 IF ( N .LE. 2 ) GO TO 97
      DO 95 I = 3, N
      IF ( FNHP1 .GE. FNHP2 ) GO TO 96
      HPLOW = HP2
      HP2 = HP1
      FNHP2 = FNHP1
      HP1 = HPLOW + HPHIGH - HP2
      CALL SELECT ( HP1, FNHP1, FNTRS1, &1000, &95 )
   96 HPHIGH = HP1
      HP1 = HP2
      FNHP1 = FNHP2
      HP2 = HPLOW + HPHIGH - HP1
      CALL SELECT ( HP2, FNHP2, FNTRS2, &1000, &95 )
   95 CONTINUE
   97 IF ( FNHP1 .GE. FNHP2 ) GO TO 98
      OHP = HP1
      OFNHP = FNHP1
      OFNTRS = FNTRS1
      GO TO 599
   98 OHP = HP2
      OFNHP = FNHP2
      OFNTRS = FNTRS2
  599 WRITE(NPRNTR,600)
  600 FORMAT (1H-, 16X, 90H    IMPLEMENT SIZES, POWER LEVEL, AND OPERATI
     1ON COSTS FOR THE LEAST COST SYSTEM                             // )
      WRITE(NPRNTR,601) OFNHP, OHP, OFNTRS
  601 FORMAT (    2X,          39H    TOTAL ANNUAL OPERATION COSTS ARE $
     1   F10.2, 1H, 27H     OPTIMUM POWER LEVEL IS F10.2,1H, 20H    TOTAL
     2TRACTORS =   F3.0 )
      GO TO 1000
      END
```

```
      SUBROUTINE DATAIO(IOCNT)
C
C
C                READS IN AND LISTS ALL INPUT DATA FOR A FARM MACHINE
C                SYSTEM.  ALSO CHECKS FOR CERTAIN ERRORS IN THE
C                DATA.
C
C
C                IOCNT -- INDICATES IF ALPHABETIC CODES AND TRACTOR
C                         DRAWBAR PREDICTOR VALUES SHOULD BE READ IN
C
C
C                COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
C                COMMON AREA OF SCALAR VARIABLES
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCRDR, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBPTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRDNTT,
     3XLFTR, XLIFET
C
C
C                COMMON AREA OF ARRAY VARIABLES
C
      COMMON ACIMP(50), ACIMP1(50), ACIMP2(50), ACIMP3(50), ACIMP4(50),
     1ACIMP5(50), ACIMP6(50), ACIMP7(50), ACIMP8(50), ACPESO(50),
     2ACTOTA(50), ATTACH(50), AUXENG(50), AXHPLV(50), AXLFTR(50),
     3AXMXHP(50), BASUSD(50), CNTRCT(50), COMBID(50), COST1(50),
     4COST2(50), COST3(50), COST4(50), COST5(50), COST6(50), COST7(50),
     5COST8(50), COSTIO(50), CROPA(50), CUSTOM(50), CU(50), DBPRTW(4,4),
     6DISTR(50), DTOAHP(4), E(50), EFFIC(50), FCPCTA(50), FCPCTC(50),
     7FCPCTI(50), FEFFIC(50), FFFICX(50), FFACTR(50), FFCTRX(50),
     8FFCTRC(50), FPRICE( 4), FTYPE(50), FUELC(50,4), G(50)
      COMMON HO(50), HPHRTC(50), HPHRTI(50), HPHRTX(50), IMPCLS(50),
     1NCCODE(50), NMCH1(50), NMCH2(50), NMCH3(50), NMCHJ1(50),
     2NMCHJ2(50), NMCHJ3(50), NOP1(50), NOP2(50), NOP3(50), NPR1(50),
     3NPR2(50), NPR3(50), NPR4(50), NPR5(50), NSOIL(50), NTR1(50),
     4NTR2(50), NTR3(50), NTR4(50), NTR5(50)
      COMMON OCSMPA(50), OCSMPT(50), OIL(50,4), OPRICE( 4), PP(50),
     1PURA(50), PURI(50), PURIO(50), PURIC(50), Q(50), QA(50), RMA(50),
     2RMI(50), RMIC(50), RNATCH(50), RWNLS(4,4), SFTYPE(50), SNRGOI(50),
     3SNRGOC(50), SNRGP(50), SNRGT(50), SPDFF(50), SPEED(50), SPHP(50),
     4SPLFTR(50), SUMAC(50), SUMACC(50), TIMLI(50), TIMPMX(50),
     5TONSPR(50), TONSTR(50), TPOWRD(50), TRATIO(4), TREDUC(4),
     6TRDNTA(50), TRDNTI(50), VALUE(50), W(50), WC(50), WMAX(50), WS(50)
      COMMON XIMPL(50), XINDEX(50), X(50), XFTYPE(50), XLABOR(50),
     1XLIFEA(50), XLIFEI(50), XNOCTR(50), XNIMPS(50), XNIMPC(50),
     2XNOPS(50), XNTRSN(50), XTIMES(50), YIELD(50), Z(50)
C
C
C                CHECK IF ALPHABETIC CODES AND TRACTOR DRAWBAR
C                PREDICTOR INFORMATION MUST BE READ IN.
C
      IF( IOCNT .NE. 0 ) GO TO 1000
```

```
C
C
C                 READ FUEL, IMPLEMENT, AND SOIL CODES
C
      READ(NCRDR,2000) AFCODE(1), AFCODE(2), AFCODE(3), AFCODE(4),
     1ICODE(1), ICODE(2), ICODE(3), ICODE(4), NSCODE(1), NSCODE(2),
     2NSCODE(3), NSCODE(4)
 2000 FORMAT(12A1)
C
C
C                 PRINT OUT FUEL, IMPLEMENT, AND SOIL CODES
C
      CALL PAGE
      WRITE(NPRNTR,2001) AFCODE(1), AFCODE(2), AFCODE(3), AFCODE(4),
     1ICODE(1), ICODE(2), ICODE(3), ICODE(4), NSCODE(1), NSCODE(2),
     2NSCODE(3), NSCODE(4)
 2001 FORMAT(1H ,23HINPUT VALUES FOR CODES:////11X,4HFUEL/5X,16(1H*)/
     15X,A1,2X,8HGASOLINE/5X,A1,2X,6HDIESEL/5X,A1,2X,6HLP GAS/5X,A1,2X,
     25HBLANK////8X,9HIMPLEMENT/5X, 16(1H*)/5X,A1,2X,
     38HINTEGRAL/5X,A1,2X,13HSEMI-INTEGRAL/5X,A1,2X,5HTOWED/5X,A1,2X,
     45HBLANK////11X,4HSOIL/5X,16(1H*)/5X,A1,2X,4HFIRM/5X,A1,2X,6HTILLED
     5/5X,A1,2X,4HSOFT,/5X,A1,2X,5HBLANK)
C
C
C                 READ TRACTOR PERFORMANCE PREDICTOR VALUES
C
      READ(NCRDR ,2003) (DTOAHP(I), TREDUC(I), TRATIO(I), I = 1,3)
 2003 FORMAT(3F6.0)
      DO 2005 I = 1, 3
      DO 2005 J = 1, 3
 2005 READ(NCRDR ,2010) DBPRTW(I,J), RWNLS(I,J)
 2010 FORMAT(2F6.0)
C
C
C                 PRINT OUT TRACTOR PERFORMANCE PREDICTOR VALUES
C
      CALL PAGE
      WRITE(NPRNTR, 2020)
 2020 FORMAT(1H ,55X,16HPREDICTOR VALUES//62X,3HFOR//50X,
     127HTRACTOR DRAWBAR PERFORMANCE///)
      WRITE(NPRNTR,2030)
 2030 FORMAT(40X,4HDBHP,37X,17HP      (RWS)(NLTS)/1H+,39X,4H____,3X,
     18H% TRAVEL,4X,6HTRAVEL,2X,9HIMPLEMENT,4X,3H___,4X,11(1H_)/
     232X,4HSOIL,4X,3HAHP,3X,9HREDUCTION,4X,5HRATIO,3X,4HCODE, 9X,3HRWS,
     34X,10H(AHP)(375)/)
      DO 2045 I = 1, 3
      WRITE(NPRNTR,2040)NSCODE(I),DTOAHP(I), TREDUC(I), TRATIO(I),
     1ICODE(1), DBPRTW(I,1), RWNLS(I,1)
 2040 FORMAT(35X,A1,F8.3,4X,F7.3,2X,F7.3,6X,A1,6X,F6.3,8X,F6.3)
 2045 WRITE(NPRNTR,2050)( ICODE(J), DBPRTW(I,J), RWNLS(I,J), J = 2, 3)
 2050 FORMAT(70X,A1,6X,F6.3,8X,F6.3)
C
C
C                 READ IN FARM MACHINE SYSTEM DATA
C
C                 READ IN CONSTANTS
C
 1000 READ(NCRDR,100) NM1, NM2, NM3, NM4, NM5, PURTR, HPPER, ESTHPL,
```

```
     1 RMTR, DLTAHP, XLIFET, TRDNTT, XLFTR, TFTYPE, NMBRPR,
     2NMBRTR, NMBRIM, NMBROP, C, OPRICE(1), OPRICE(2), OPRICE(3),
     3FPRICE(1), FPRICE(2), FPRICE(3)
      IF ( PURTR .LE. 0.0 ) CALL ERROR (1, I20, ERCNT )
  100 FORMAT (5A4, 3F5.0, F7.0 , 4F5.0,A1 / 4I4, 7F5.0 )
C
C
C                 READ IN SUBSCRIPTED ARRAYS FOR PROCESSING OPERATIONS
C
C
      READ(NCPDR,200)(NPR1(I), NPR2(I), NPR3(I), NPR4(I), NPR5(I),
     1G(I), TONSPR(I), I = 1,NMBRPR)
  200 FORMAT( 5A4, 2F7.0 )
C
C
C                 READ IN SUBSCRIPTED ARRAYS FOR TRANSPORT OPERATIONS
C
C
      READ(NCRDR,200) (NTR1(I), NTR2(I), NTR3(I), NTR4(I), NTR5(I),
     1DISTR(I), TONSTR(I), I = 1,NMBRTR)
C
C
C                 READ IN SUBSCRIPTED ARRAYS FOR FIELD OPERATIONS
C
      READ(NCRDR,400) (XINDEX(I), NOP1(I), NOP2(I), NDP3(I), ACRESO(I),
     1NSOIL(I), SPEED(I), EFFIC(I), FFACTR(I), HPHRTI(I), COMBID(I),
     2TPOWRD(I), SPLFTR(I), SFTYPE(I),
     3AUXENG(I), XFTYPE(I), AXMXHP(I), AXLFTR(I), FFCTRX(I), HPHRTX(I),
     4NMCH1(I), NMCH2(I), NMCH3(I), XIMPL(I), IMPCLS(I), WMAX(I),
     5PURIO(I), XLIFEI(I), TRDNTI(I), RMI(I), TIMLI(I), CROPA(I),
     6YIELD(I), VALUE(I), XTIMES(I),
     7E(I),XLABOR(I), XNOPS(I), ATTACH(I), ACTOTA(I), PURA(I),XLIFEA(I),
     8TRONTA(I), RMA(I), XNOCTR(I), CUSTOM(I), BASUSD(I), I = 1,NMBROP)
  400 FORMAT (F3.0,3A4,F6.0,A1,5X,7F6.0,A1,10X/3X,F6.0,A1,5X,4F6.0/
     13X,3A4,F6.0,A1,5X,8F6.0/3X,12F6.0/3X,2F6.0 )
C
C
C                 SET UP FUEL AND OIL PRICE ARRAYS
C
      FPRICE(4) = 0.0
      OPRICE(4) = 0.0
      DTOAHP(4) = 1.0
      TRATIO(4) = 1.0
      TREDUC(4) = 1.0
      DO 8 J = 1, 4
      DBPRTW(J,4) = 1.0
      RWNLS(J,4) = 1.0
      DBPRTW(4,J) = 1.0
    8 RWNLS(4,J) = 1.0
      CALL FCNVRT(TFTYPE)
      DO 40 I = 1, NMBROP
      IF ( TPOWRD(I) - 1.0 ) 30, 10, 20
   10 FTYPE(I) = TFTYPE
      GO TO 50
   20 CALL ERROR ( 5, I20, ERCNT )
      GO TO 1000
   30 CALL FCNVRT(SFTYPE(I))
      FTYPE(I) = SFTYPE(I)
```

```
   50 CALL FCNVRT(XFTYPE(I))
      CALL SCNVRT(NSOIL(I))
      CALL ICNVRT(IMPCLS(I))
   40 CONTINUE
C
C
C                 WRITE OUT FARM MACHINE SYSTEM INPUT DATA
C
      CALL PAGE
      WRITE(NPRNTR,494)
  494 FORMAT ( 1H , ///////////////////// 46X, 40H***   LEAST-COST MACHIN
     1ERY SYSTEM    ***       /// )
      WRITE(NPRNTR,496)
  496 FORMAT ( 61X, 9H FOR THE    ///)
      WRITE(NPRNTR,498) NM1, NM2, NM3, NM4, NM5
  498 FORMAT ( 52X, 5A4, 5H FARM )
      CALL PAGE
      WRITE(NPRNTR,1001)
 1001 FORMAT (1H , 26X, 13H INPUT VALUES/// )
      WRITE(NPRNTR,101) NMBRPR, NMBRTR, NMBROP, NMBRIM
  101 FORMAT( 1H-,23HNO. OF PROCESSING OPS.=, I3,4X,23HNO. OF TRANSPORT
     1OPS.=   ,I3,4X, 19HNO. OF FIELD OPS. = ,I3, 4X, 15HNO. OF IMPLS. =
     2, I3   )
      WRITE(NPRNTR,201)
  201 FORMAT(1H-,4H$/HP,3X,7HLARGEST, 3X,4HEST.,3X,7HTRACTOR,6X,
     12HHP, 6X, 6HCUSTOM,5X,7HTRACTOR,3X,5HTRADE,5X,4HLOAD,4X,
     24HFUEL,4X,4HFUEL,5X,3HOIL )
      WRITE(NPRNTR,1010)
 1010 FORMAT(1H ,7X,7HTRACTOR,4X,2HHP,3X,8HREP.RATE,3X,8HSTEPSIZE,3X,
     18HINCONV.$,4X,4HLIFE,4X,7HIN TIME,3X,6HFACTOR,3X,4HTYPE,3X,5H$/GAL
     2,3X,5H$/GAL )
      IFTYPE = TFTYPE
      WRITE(NPRNTR,1011) PURTR, HPPER, ESTHPL, RMTR, DLTAHP, C, XLIFET,
     1TRONTT, XLFTR, AFCODE(IFTYPE), FPRICE(IFTYPE), OPRICE(IFTYPE)
 1011 FORMAT(1H-,F4.0,F10.0,F7.0,F11.6,F7.1,F11.0,F10.0,
     1F11.0,F9.2,4X,A1,2X,2F9.2 )
      WRITE(NPRNTR,1013)
 1013 FORMAT(1H-, 10X, 21HPROCESSING OPERATIONS )
      WRITE(NPRNTR,1014)
 1014 FORMAT(1H-,6X,4HNAME,10X, 18HENERGY, HP-HRS/TON,3X,7HTONS/YR, / )
      WRITE(NPRNTR,1015)(NPR1(I),NPR2(I), NPR3(I), NPR4(I), NPR5(I),
     1G(I), TONSPR(I), I = 1,NMBRPR )
 1015 FORMAT(1H ,5A4,5X,F10.2,2X,F10.0 )
      WRITE(NPRNTR,1016)
 1016 FORMAT(1H-, 10X, 20HTRANSPORT OPERATIONS )
      WRITE(NPRNTR,1017)
 1017 FORMAT(1H-,6X,4HNAME,10X,19HONE-WAY DIST.,MILES,3X,7HTONS/YR,    /)
      WRITE(NPRNTR,1015) (NTR1(I), NTR2(I), NTR3(I), NTR4(I), NTR5(I),
     1DISTR(I), TONSTR(I), I = 1,NMBRTR)
      CALL PAGE
      WRITE(NPRNTR,1121)
 1121 FORMAT(1H ,7H XINDEX,2X,9HOPERATION,4X,6HACRESO,1X,5HNSOIL,2X,5HSP
     1EED,2X,5HEFFIC,1X,6HFFACTR,1X,6HHPHRTI,1X,6HCOMBID,1X,6HTPOWRD,1X,
     26HSPLFTR,1X,6HSFTYPE,1X,6HFPRICE,1X,6HOPRICE  / )
      DO 1122 I = 1, NMBROP
      IFTYPE = FTYPE(I)
 1122 WRITE(NPRNTR,401) XINDEX(I),NOP1(I), NOP2(I), NOP3(I), ACRESO(I),
     1NSCODE(NSOIL(I)), SPEED(I), EFFIC(I), FFACTR(I), HPHRTI(I),
```

```
     2COMBID(I), TPOWRD(I), SPLFTR(I), AFCODE(IFTYPE), FPRICE(IFTYPE),
     3OPRICE(IFTYPE)
  401 FORMAT(1H ,F5.0,3X,3A4,1X,F7.2,4X,A1,1X,7F7.2,4X,A1,1X,2F7.2)
      CALL PAGE
      WRITE(NPRNTR,402)
  402 FORMAT(1H ,7H XINDEX, 2X,9HOPERATION,5X,6HAUXENG,1X,6HXFTYPE,1X,
     16HFPRICE,1X,6HOPRICE,1X,6HAXMXHP,1X,6HAXLFTR,1X,6HFFCTRX,1X,6HHPHR
     2TX  / )
      DO 1126 I = 1, NMBROP
      IXTYPE = XFTYPE(I)
 1126 WRITE(NPRNTR,403) XINDEX(I),NOP1(I), NOP2(I), NOP3(I), AUXENG(I),
     1AFCODE(IXTYPE),FPRICE(IXTYPE),OPRICE(IXTYPE),AXMXHP(I),AXLFTR(I),
     2FFCTRX(I), HPHRTX(I)
  403 FORMAT(1H , F5.0,3X,3A4,1X,F7.2,4X,A1,1X,6F7.2)
      CALL PAGE
      WRITE(NPRNTR,114)
  114 FORMAT(4X,6HXINDEX,6X,13HIMPL., NUMBER,2X,6HIMPCLS,3X,4HWMAX,2X,
     15HPURIO,2X,6HXLIFEI,1X,6HTRDNTI,4X,3HRMI,5X,5HTIMLI,3X,5HCROPA,3X,
     25HYIELD,3X,5HVALUE,2X,6HXTIMES    / )
      WRITE(NPRNTR,501)(XINDEX(I),NMCH1(I),NMCH2(I), NMCH3(I), XIMPL(I),
     1ICODE(IMPCLS(I)), WMAX(I), PURIO(I), XLIFEI(I), TRDNTI(I),
     2RMI(I), TIMLI(I), CROPA(I), YIELD(I), VALUE(I), XTIMES(I), I = 1,
     3NMBROP )
  501 FORMAT(3X,F5.0,3X,3A4,F6.1,5X,A1,2X,4F7.1,2F10.6,F6.1,3F8.1    )
      CALL PAGE
      WRITE(NPRNTR,116)
  116 FORMAT(2X,6HXINDEX,5X, 1HE,3X,6HXLABOR,2X,5HXNOPS,2X,6HATTACH,1X,
     16HACTOTA,2X,4HPURA,2X,6HXLIFEA,1X,6HTRDNTA,4X,3HRMA,4X,6HXNDCTR,1X
     2,6HCUSTOM, 2X, 6HBASUSD   / )
      WRITE(NPRNTR,606)(XINDEX(I),E(I),XLABOR(I), XNOPS(I), ATTACH(I),
     1ACTOTA(I),PURA(I),XLIFEA(I),TRDNTA(I),RMA(I),XNDCTR(I), CUSTOM(I),
     2BASUSD(I), I = 1, NMBROP)
  606 FORMAT(1H ,F5.0,1X,F7.1,2X, 7F7.2, F10.6, 2F8.2, F7.2  )
C
C
C                  CHECK FOR DATA INPUT ERRORS
C
      ERCNT = 0.0
      CALL PAGE
      DO 3000 I = 1,NMBROP
      IF ( ATTACH(I) .LT. 0.0 ) CALL ERROR( 2,I,ERCNT )
      IF ( COMBID(I) .LT. 0.0 ) CALL ERROR( 3, I, ERCNT )
      IF ( AUXENG(I) .NE. 0.0 .AND. AUXENG(I) .NE. 1.0 ) CALL ERROR( 4,
     1I, ERCNT )
      IF ( TPOWRD(I) .NE. 0.0 .AND. TPOWRD(I) .NE. 1.0 ) CALL ERROR( 5,
     1I, ERCNT )
      IF ( XNDCTR(I) .NE. 0.0 .AND. XNDCTR(I) .NE. 1.0 ) CALL ERROR( 6,
     1I, ERCNT )
      IF ( ATTACH(I) .EQ. 0.0 ) GO TO 3010
      IF ( BASUSD(I) .LE. 0.0 ) CALL ERROR ( 8, I, ERCNT)
 3010 IF ( TPOWRD(I) .EQ. 1.0 ) GO TO 3000
      IF ( SPLFTR(I) .LE. 0.0 ) CALL ERROR ( 12, I, ERCNT )
 3000 CONTINUE
      IF ( ERCNT .GT. 0.0 ) GO TO 1000
      WRITE(NPRNTR,3020)
 3020 FORMAT(30H NO INPUT DATA ERRORS DETECTED   )
      RETURN
      END
```

```
      SUBROUTINE DETVAL ( I, HPMAX, XNTRS )
C
C
C                 DETERMINES VALUES FOR CERTAIN VARIABLES FOR A GIVEN
C                 IMPLEMENT WIDTH.
C
C
C                     I -- IMPLEMENT NUMBER
C                 HPMAX -- TOTAL TRACTOR HORSEPOWER AVAILABLE
C                 XNTRS -- NUMBER OF TRACTORS IN FARM SYSTEM
C
C
C                 COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                 FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
C                 COMMON AREA OF SCALAR VARIABLES
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCRDR, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRDNTT,
     3XLFTR, XLIFET
C
C
C                 COMMON AREA OF ARRAY VARIABLES
C
      COMMON ACIMP(50), ACIMP1(50), ACIMP2(50), ACIMP3(50), ACIMP4(50),
     1ACIMP5(50), ACIMP6(50), ACIMP7(50), ACIMP8(50), ACRESO(50),
     2ACTOTA(50), ATTACH(50), AUXENG(50), AXHPLV(50), AXLFTR(50),
     3AXMXHP(50), BASUSD(50), CNTRCT(50), COMBID(50), COST1(50),
     4COST2(50), COST3(50), COST4(50), COST5(50), COST6(50), COST7(50),
     5COST8(50), COSTID(50), CROPA(50), CUSTOM(50), CU(50), DBPPTW(4,4),
     6DISTR(50), DTOAHP(4), E(50), EFFIC(50), FCPCTA(50), FCPCTC(50),
     7FCPCTI(50), FEFFIC(50), FEFICX(50), FFACTR(50), FFCTRX(50),
     8FFCTRC(50), FPRICE( 4), FTYPE(50), FUELC(50,4), G(50)
      COMMON HO(50), HPHRTC(50), HPHRTI(50), HPHRTX(50), IMPCLS(50),
     1NCCODE(50), NMCH1(50), NMCH2(50), NMCH3(50), NMCHJ1(50),
     2NMCHJ2(50), NMCHJ3(50), NOP1(50), NOP2(50), NOP3(50), NPR1(50),
     3NPR2(50), NPR3(50), NPR4(50), NPR5(50), NSOIL(50), NTR1(50),
     4NTR2(50), NTR3(50), NTR4(50), NTR5(50)
      COMMON OCSMPA(50), OCSMPT(50), OIL(50,4), OPRICE( 4), PP(50),
     1PURA(50), PURI(50), PURIO(50), PURIC(50), Q(50), QA(50), RMA(50),
     2RMI(50), RMIC(50), RNATCH(50), RWNLS(4,4), SFTYPE(50), SNRGOI(50),
     3SNRGOC(50), SNRGP(50), SNRGT(50), SPDFF(50), SPEED(50), SPHP(50),
     4SPLFTR(50), SUMAC(50), SUMACC(50), TIMLI(50), TIMPMX(50),
     5TONSPR(50), TONSTR(50), TPOWRO(50), TRATIO(4), TREDUC(4),
     6TRONTA(50), TRONTI(50), VALUE(50), W(50), WC(50), WMAX(50), WS(50)
      COMMON XIMPL(50), XINDEX(50), X(50), XFTYPE(50), XLABOR(50),
     1XLIFEA(50), XLIFEI(50), XNOCTR(50), XNIMPS(50), XNIMPC(50),
     2XNOPS(50), XNTRSN(50), XTIMES(50), YIELD(50), Z(50)
C
C
C                 INITIALIZE
C
      SPHP(I) = 0.0
      XNIMPS(I) = 0.0
```

```
      AXHPLV(I) = 0.0
      NIMPS = 0
      IF ( WS(I) .NE. 0.0 ) NIMPS = W(I) / WS(I) + 0.99999
      XNIMPS(I) = NIMPS
      DO 100 K1 = 1, NMBROP
      IF ( X(I) .NE. XIMPL(K1) ) GO TO 100
      XNTRSN(K1) = 0.0
      Q(K1) = 0.0
      QA(K1) = 0.0
      FEFFIC(K1) = 0.0
      FEFICX(K1) = 0.0
      OCSMPT(K1) = 0.0
      OCSMPA(K1) = 0.0
      IF ( TPOWRD(K1) * CNTRCT(K1)  .EQ. 0.0 ) GO TO 100
C
C
C                 DETERMINE NUMBER OF TRACTORS TO BE USED IN OPERATION
C                 K1
C
   80 IF ( XNTRSN(K1) * TIMPMX(I) .GE. XNIMPS(I)) GO TO 100
      XNTRSN(K1) = XNTRSN(K1) + 1.0
      GO TO 80
  100 CONTINUE
C
C
C                 CALCULATE AMOUNT OF TRACTOR HORSEPOWER USED IN
C                 OPERATION K2 OR CALCULATE REQUIRED HORSEPOWER OF
C                 SELF-PROPELLED IMPLEMENT.
C
      DO 200 K2 = 1, NMBROP
      IF ( X(I) .NE. XIMPL(K2) ) GO TO 200
      IF ( TPOWRD(K2) .EQ. 0.0 ) GO TO 210
      Q(K2) = XNTRSN(K2) * HPMAX / XNTRS * CNTRCT(K2)
      GO TO 220
C
C
C                 CALCULATE SELF-PROPELLED HORSEPOWER
C
  210 SPHP1 = SPEED(K2) * W(I) / SPLFTR(K2) * (FFACTR(K2) /(360.0 *
     1DTOAHP(NSOIL(K2))) + HPHRTI(K2) * YIELD(K2) * EFFIC(K2) / 8.25 ) *
     2CNTRCT(K2)
      IF ( SPHP1 .GT. SPHP(I) ) SPHP(I) = SPHP1
  220 IF ( AUXENG(K2) * CNTRCT(K2) .NE. 1.0 ) GO TO 200
C
C
C                 CALCULATE AUXILIARY ENGINE HORSEPOWER
C
      AHP = W(I ) * SPEED(K2) * (FFCTRX(K2) / (360.0* DTOAHP(NSOIL(K2)))
     1+ HPHRTX(K2) * YIELD(K2) * EFFIC(K2) / 8.25 ) / AXLFTR(K2)
      IF ( AXHPLV(I) .LT. AHP ) AXHPLV(I) = AHP
  200 CONTINUE
C
C
C                 COMPUTE FUEL EFFICIENCY AND OIL CONSUMPTION
C
C
C          'THIS PROGRAM COMPUTES FUEL CONSUMPTION FOR EACH FIELD
C     OPERATION.  IT CONSIDERS THE DECREASE IN FUEL EFFICIENCY AS THE
```

```
C     PERCENTAGE LOAD ON THE POWER UNIT LESSENS.  THE AVERAGE VARIABLE-
C     LOAD FUEL EFFICIENCY OF 118 TRACTORS TESTED IN THE NEBRASKA
C     TRACTOR TESTS SINCE 1958 IS USED  |TABLE 2.2 IN HUNT (1)|.  A
C     PARABOLIC CURVE IS FITTED TO THE TEST DATA FOR EACH OF THE THREE
C     COMMON FUELS.  THE EQUATION FOR THIS CURVE IS EXPRESSED IN GALLONS
C     PER HORSEPOWER-HOUR AND IS A FUNCTION OF THE PERCENTAGE LOAD ON
C     THE POWER UNIT --WHETHER TRACTOR, SELF-PROPELLED, OR AUXILIARY
C     ENGINE.  EQUATIONS ARE GIVEN INDIVIDUALLY FOR GASOLINE, DIESEL,
C     AND LP-GAS.  THE FUEL MUST BE SELECTED AT THE BEGINNING OF THE
C     PROGRAM.'
C
C          'OIL CONSUMPTION BY POWER UNITS, A SMALL COST, IS INCLUDED
C     AS A FUNCTION OF THE POWER RATING OF THE ENGINE.  IT IS CONSIDERED
C     TO BE THE OIL CHANGE VOLUME DIVIDED BY THE RECOMMENDED OIL CHANGE
C     FREQUENCY |TABLE 2.3 (1) |.  A LEAST-SQUARES STRAIGHT LINE IS
C     FITTED TO THE DATA TO GIVE AN EXPRESSION IN GALLONS PER HOUR.'
C
      DO 300 K3 = 1, NMBROP
      IF ( X(I) .NE. XIMPL(K3) ) GO TO 300
      IFTYPE = FTYPE(K3)
      IXTYPE = XFTYPE(K3)
      IF ( TPOWRD(K3) .EQ. 0.0 ) Q(K3) = SPHP(I)
      QA(K3) = AXHPLV(I)
      IF ( Q(K3) .EQ. 0.0 ) GO TO 300
      CALL FUEL ( IFTYPE, IXTYPE, K3, I )
  300 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ERROR ( I10, I20, ERCNT )
C
C
C                   REPORTS SPECIFIC ERRORS WHICH HAVE BEEN DETECTED
C
C
C                   COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                   FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCRDR, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRDNTT,
     3XLFTR, XLIFET
C
C
C                   ERROR MESSAGES
C
      ERCNT = ERCNT + 1.0
      GO TO ( 98, 12, 212, 312, 412, 512, 612, 812, 912, 281 ), I10
   98 CALL PAGE
      WRITE ( NPRNTR, 100 )
  100 FORMAT(1H ,///66H PURTR .LE. 0, AN ERROR IN DATA DECK OR LAST PROB
     1LEM HAS BEEN RUN       )
      CALL EXIT
   12 WRITE(NPRNTR,1012) I20
 1012 FORMAT(1H ,///59H  ERROR IN DATA DECK, ATTACH LESS THAN 0.0 FOR OP
     1ERATION,3X,I4     )
      RETURN
  212 WRITE(NPRNTR,1212) I20
 1212 FORMAT(1H ,///70H  ERROR IN DATA DECK, COMBID SHOULD NOT BE LESS T
     1HAN 0.0 FOR OPERATION,3X,I4   )
      RETURN
  312 WRITE(NPRNTR,1312) I20
 1312 FORMAT(1H ,///57H  ERROR IN DATA DECK, AUXENG NOT 1.0 OR 0.0 FOR O
     1PERATION,3X,I4 )
      RETURN
  412 WRITE(NPRNTR,1412) I20
 1412 FORMAT(1H ,///57H  ERROR IN DATA DECK, TPOWRD NOT 1.0 OR 0.0 FOR O
     1PERATION,3X,I4 )
      RETURN
  512 WRITE(NPRNTR,1512) I20
 1512 FORMAT(1H ,///57H  ERROR IN DATA DECK, XNDCTR NOT 1.0 OR 0.0 FOR O
     1PERATION,3X,I4 )
      RETURN
  612 CALL PAGE
      WRITE(NPRNTR,1612) I20
 1612 FORMAT(1H ,///57H  ERROR IN EXECUTION, CNTRCT NOT 1.0 OR 0.0 FOR O
     1PERATION,3X,I4 )
      RETURN
  812 WRITE (NPRNTR,1812) I20
 1812 FORMAT ( 34H  ERROR, NO BASUSD FOR OPERATION      , I4 )
      RETURN
  912 WRITE(NPRNTR,1912) I20
 1912 FORMAT(1H ,///67H  ERROR IN DATA DECK, SPLFTR MUST BE GREATER THAN
     1 0.0 FOR OPERATION,3X,I4,2X,31HSINCE IT IS NOT TRACTOR POWERED )
```

```
      RETURN                                                                 ERR00590
  281 CALL PAGE                                                              ERR00600
      WRITE(NPRNTR,2811) I20                                                 ERR00610
 2811 FORMAT(1H ,///62H ERROR - NEGATIVE ACREAGE - COST COMPUTATION - 52ERR00620
     1XX, IMPLEMENT,3X,I4 )                                                  ERR00630
      RETURN                                                                 ERR00640
      END                                                                    ERR00650
```

```
      SUBROUTINE EXPLMV ( HP, FNHP,  FNTRS, *, * )
C
C
C                 MAKE EXPLORATORY MOVES FOR HOOKE AND JEEVES PATTERN
C                 SEARCH TO FIND THE INTERVAL OF UNCERTAINTY FOR
C                 TRACTOR HORSEPOWER
C
C
C                 COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                 FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
C                 COMMON AREA OF SCALAR VARIABLES
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCRDR, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRONTT,
     3XLFTR, XLIFET
C
C
      HPE = HP + DLTAHP
      CALL SELECT ( HPE, FNHPE,FNTRSE, &18, &19 )
   18 RETURN 1
   19 IF ( FNHPE - FNHP    ) 30, 20, 20
   20 HPE = HP - DLTAHP
      IF ( HPE .LT. 1.0 ) HPE = 1.0
      CALL SELECT ( HPE, FNHPE,FNTRSE, &28, &29 )
   28 RETURN 1
   29 IF ( FNHPE - FNHP    ) 30, 40, 40
   30 FNHP = FNHPE
      FNTRS = FNTRSE
      HP = HPE
   40 RETURN 2
      END
```

```
      SUBROUTINE FCNVRT(FCODE)
C
C
C                    CONVERT ALPHABETIC INPUT FUEL CODE, FCODE, TO A
C                    NUMBER
C
C
C                    COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                    FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
      IF( FCODE - AFCODE(1) ) 1005, 1000, 1005
 1000 FCODE = 1.0
      RETURN
 1005 IF ( FCODE - AFCODE(2)) 1015, 1010, 1015
 1010 FCODE = 2.0
      RETURN
 1015 IF ( FCODE - AFCODE(3)) 1025, 1020, 1025
 1020 FCODE = 3.0
      RETURN
 1025 FCODE = 4.0
      RETURN
      END
```

```
      SUBROUTINE FCP(FCPVAL, XLIFE, TRDINA)
C
C
C                     COMPUTES FIXED COST PERCENTAGE FOR TRACTOR,
C                     IMPLEMENT, OR IMPLEMENT ATTACHMENT
C
C
C                     FCPVAL -- FIXED COST PERCENTAGE VALUE
C                      XLIFE -- EXPECTED LIFE OF EQUIPMENT
C                     TRDINA -- EXPECTED TRADE-IN AGE OF EQUIPMENT
C
C
      IF ( XLIFE - TRDINA ) 1,1, 2
    1 FCPVAL = 0.06 + 0.9/ XLIFE
      RETURN
    2 FCPVAL = 0.06 + 1.8 / ( XLIFE + TRDINA )
      RETURN
      END
```

```
      SUBROUTINE FUEL( IFTYPE, IXTYPE, I, J )
C
C
C                 CALCULATES FUEL EFFICIENCY AND OIL CONSUMPTION RATE
C                 FOR ALL ENGINES IN THE FARM MACHINE SYSTEM.
C
C
C                 IFTYPE -- FUEL TYPE OF TRACTOR OR SELF-PROPELLED
C                           IMPLEMENT
C                 IXTYPE -- FUEL TYPE OF AUXILIARY ENGINE
C                      I -- OPERATION NUMBER
C                      J -- IMPLEMENT NUMBER
C
C
C                 COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                 FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
C                 COMMON AREA OF SCALAR VARIABLES
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCRDR, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRDNTT,
     3XLFTR, XLIFET
C
C
C                 COMMON AREA OF ARRAY VARIABLES
C
      COMMON ACIMP(50), ACIMP1(50), ACIMP2(50), ACIMP3(50), ACIMP4(50),
     1ACIMP5(50), ACIMP6(50), ACIMP7(50), ACIMP8(50), ACRESD(50),
     2ACTOTA(50), ATTACH(50), AUXENG(50), AXHPLV(50), AXLFTR(50),
     3AXMXHP(50), BASUSD(50), CNTRCT(50), COMBID(50), COST1(50),
     4COST2(50), COST3(50), COST4(50), COST5(50), COST6(50), COST7(50),
     5COST8(50), COSTID(50), CROPA(50), CUSTOM(50), CU(50), DBPRTW(4,4),
     6DISTR(50), DTOAHP(4), E(50), EFFIC(50), FCPCTA(50), FCPCTC(50),
     7FCPCTI(50), FEFFIC(50), FEFICX(50), FFACTR(50), FFCTRX(50),
     8FFCTRC(50), FPRICE( 4), FTYPE(50), FUELC(50,4), G(50)
      COMMON HD(50), HPHRTC(50), HPHRTI(50), HPHRTX(50), IMPCLS(50),
     1NCCODE(50), NMCH1(50), NMCH2(50), NMCH3(50), NMCHJ1(50),
     2NMCHJ2(50), NMCHJ3(50), NOP1(50), NOP2(50), NOP3(50), NPR1(50),
     3NPR2(50), NPR3(50), NPR4(50), NPR5(50), NSOIL(50), NTR1(50),
     4NTR2(50), NTR3(50), NTR4(50), NTR5(50)
      COMMON OCSMPA(50), OCSMPT(50), OIL(50,4), OPRICE( 4), PP(50),
     1PURA(50), PURI(50), PURID(50), PURIC(50), Q(50), QA(50), RMA(50),
     2RMI(50), RMIC(50), RNATCH(50), RWNLS(4,4), SFTYPE(50), SNRGOI(50),
     3SNRGOC(50), SNRGP(50), SNRGT(50), SPDEFF(50), SPEED(50), SPHP(50),
     4SPLFTR(50), SUMAC(50), SUMACC(50), TIMLI(50), TIMPMX(50),
     5TONSPR(50), TONSTR(50), TPOWRD(50), TRATIO(4), TREDUC(4),
     6TRDNTA(50), TRDNTI(50), VALUE(50), W(50), WC(50), WMAX(50), WS(50)
      COMMON XIMPL(50), XINDEX(50), X(50), XFTYPE(50), XLABOR(50),
     1XLIFEA(50), XLIFEI(50), XNOCTR(50), XNIMPS(50), XNIMPC(50),
     2XNOPS(50), XNTRSN(50), XTIMES(50), YIELD(50), Z(50)
C
C
C                 CALCULATIONS FOR TRACTOR POWERED OR SELF PROPELLED
C                 IMPLEMENTS
```

```
C
     C1 = ( W(J) * SPEED(I) * ((FFACTR(I) + FFCTRC(I)) / ( 360.0 *
    1DTOAHP(NSOIL(I)))+ (HPHRTI(I) + HPHRTC(I)) * YIELD(I) * EFFIC(I) /
    2 8.25 )) / Q(I)
     GO TO ( 45, 47, 49 ), IFTYPE
C
C
C                   ****GASOLINE****
C
  45 FEFFIC(I) = 0.54 * C1 + 0.62 - 0.04 * SQRT( 697.0 * C1 )
     OCSMPT(I) = 0.00011 * Q(I) + 0.00657
     GO TO 51
C
C
C                   ****DIESEL****
C
  47 FEFFIC(I) = 0.52 * C1 + 0.768 - 0.04 * SQRT( 738.5 * C1 + 173.0 )
     OCSMPT(I) = 0.00021 * Q(I) + 0.00573
     GO TO 51
C
C
C                   ****LP GAS****
C
  49 FEFFIC(I) = 0.534 * C1 + 0.618 - 0.04 * SQRT( 645.9 * C1 )
     OCSMPT(I) = 0.00008 * Q(I) + 0.0075
C
C
C                   CALCULATIONS FOR AUXILIARY ENGINES
C
  51 IF ( AUXENG(I) .NE. 1.0 ) RETURN
     C2 = ( W(J) * SPEED(I) * ( FFCTRX(I) / (360.0 * DTOAHP(NSOIL(I)) )
    1+ HPHRTX(I) * YIELD(I) * EFFIC(I) / 8.25 )) / QA(I)
     GO TO ( 46, 48, 50 ), IXTYPE
C
C
C                   ****GASOLINE****
C
  46 FEFICX(I) = 0.54 * C2 + 0.62 - 0.04 * SQRT( 697.0 * C2 )
     OCSMPA(I) = 0.00011 * QA(I) + 0.00657
     RETURN
C
C
C                   ****DIESEL****
C
  48 FEFICX(I) = 0.52 * C2 + 0.768 - 0.04 * SQRT( 738.5 * C2 + 173.0 )
     OCSMPA(I) = 0.00021 * QA(I) + 0.00573
     RETURN
C
C
C                   ****LP GAS****
C
  50 FEFICX(I) = 0.534 * C2 + 0.618 - 0.04 * SQRT( 645.9 * C2 )
     OCSMPA(I) = 0.00008 * QA(I)+0.0075
     RETURN
     END
```

```
      SUBROUTINE HPEST ( BSHPN )
C
C
C                CALCULATES AN ESTIMATE OF THE OPTIMUM TRACTOR
C                HORSEPOWER
C
C
C                BSHPN -- CALCULATED ESTIMATE OF OPTIMUM TRACTOR
C                         HORSEPOWER
C
C
C                COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
C                COMMON AREA OF SCALAR VARIABLES
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCRDR, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRDNTT,
     3XLFTR, XLIFET
C
C
C                COMMON AREA OF ARRAY VARIABLES
C
      COMMON ACIMP(50), ACIMP1(50), ACIMP2(50), ACIMP3(50), ACIMP4(50),
     1ACIMP5(50), ACIMP6(50), ACIMP7(50), ACIMP8(50), ACRESO(50),
     2ACTOTA(50), ATTACH(50), AUXENG(50), AXHPLV(50), AXLFTR(50),
     3AXMXHP(50), BASUSD(50), CNTRCT(50), COMBID(50), COST1(50),
     4COST2(50), COST3(50), COST4(50), COST5(50), COST6(50), COST7(50),
     5COST8(50), COSTIC(50), CROPA(50), CUSTOM(50), CU(50), DBPRTW(4,4),
     6DISTR(50), DTDAHP(4), E(50), EFFIC(50), FCPCTA(50), FCPCTC(50),
     7FCPCTI(50), FEFFIC(50), FEFICX(50), FFACTR(50), FFCTRX(50),
     8FFCTRC(50), FPRICE( 4), FTYPE(50), FUELC(50,4), G(50)
      COMMON HO(50), HPHRTC(50), HPHRTI(50), HPHRTX(50), IMPCLS(50),
     1NCCODE(50), NMCH1(50), NMCH2(50), NMCH3(50), NMCHJ1(50),
     2NMCHJ2(50), NMCHJ3(50), NOP1(50), NOP2(50), NOP3(50), NPR1(50),
     3NPR2(50), NPR3(50), NPR4(50), NPR5(50), NSOIL(50), NTR1(50),
     4NTR2(50), NTR3(50), NTR4(50), NTR5(50)
      COMMON OCSMPA(50), OCSMPT(50), OIL(50,4), OPRICE( 4), PP(50),
     1PURA(50), PURI(50), PURIO(50), PURIC(50), Q(50), QA(50), RMA(50),
     2RMI(50), RMIC(50), RNATCH(50), RWNLS(4,4), SFTYPE(50), SNRGOI(50),
     3SNRGOC(50), SNRGP(50), SNRGT(50), SPDFF(50), SPEED(50), SPHP(50),
     4SPLFTR(50), SUMAC(50), SUMACC(50), TIMLI(50), TIMPMX(50),
     5TONSPR(50), TONSTR(50), TPOWRD(50), TRATIO(4), TREDUC(4),
     6TRDNTA(50), TRDNTI(50), VALUE(50), W(50), WC(50), WMAX(50), WS(50)
      COMMON XIMPL(50), XINDEX(50), X(50), XFTYPE(50), XLABOR(50),
     1XLIFEA(50), XLIFEI(50), XNDCTR(50), XNIMPS(50), XNIMPC(50),
     2XNOPS(50), XNTRSN(50), XTIMES(50), YIELD(50), Z(50)
C
C
C                INITIALIZE
C
      CALL INITL2 (SMCOST )
      DO 90 I = 1, NMBRIM
   90 SPDFF(I) = 0.0
```

```
C
C
C                 DETERMINE THE GREATEST VALUE OF SPEED TIMES FORCE
C                 FACTOR FOR EACH IMPLEMENT
C
      DO 100 I = 1, NMBRIM
      DO 100 J = 1, NMBROP
      IF ( TPOWRD(J) * CNTRCT(J) .EQ. 0.0 ) GO TO 100
      IF ( X(I) .NE. XIMPL(J) ) GO TO 100
      SFF =  SPEED(J)*((FFACTR(J) +FFCTRC(J) ) / (360.0 *
     1DTOAHP(NSOIL(J)))+ (HPHRTI(J) + HPHRTC(J)) * YIELD(J)
     2* EFFIC(J) / 8.25 )
      IF ( SFF .GT. SPDFF(I) ) SPDFF(I) = SFF
  100 CONTINUE
C
C
C                 COMPUTE THE OPTIMUM HORSEPOWER
C
      SUM1 = 0.0
      SUM2 = 0.0
      DO 200 I = 1, NMBRIM
      DO 200 J = 1, NMBROP
      IF ( TPOWRD(J) * CNTRCT(J) .EQ. 0.0 ) GO TO 200
      IF ( X(I) .NE. XIMPL(J) ) GO TO 200
C
C
C                 FACTORS CONCERNING ENGINE OIL FOR TRACTOR
C
      IFTYPE = FTYPE(J)
      GO TO ( 181, 182, 183 ), IFTYPE
C
C
C                 GASOLINE
C
  181 TROIL = 0.00657 * OPRICE(1)
      GO TO 184
C
C
C                 DIESEL
C
  182 TROIL = 0.00573 * OPRICE(2)
      GO TO 184
C
C
C                 LP GAS
C
  183 TROIL = 0.0075 * OPRICE(3)
C
C
C                 FACTORS CONCERNING ENGINE OIL FOR AUXILIARY ENGINES.
C
  184 AUXOIL = 0.0
      IF ( AUXENG(J) .NE. 1.0 ) GO TO 188
      IXTYPE = XFTYPE(J)
      GO TO ( 185, 186, 187 ), IXTYPE
C
C
C                 GASOLINE
```

```
C
  185 AUXOIL = 0.00657 * OPRICE(1)
      GO TO 188
C
C
C                   DIESEL
C
  186 AUXOIL = 0.00573 * OPRICE(2)
      GO TO 188
C
C
C                   LP GAS
C
  187 AUXOIL = 0.0075 * OPRICE(3)
  188 SUM1 = SUM1 + 8.25 * ACRESO(J) * SPDFF(I) * ( XNOPS(J) + AUXOIL) /
     1( SPEED(J) * EFFIC(J) * XLFTR )
      SUM2 = SUM2 + 8.25 * ACRESO(J) * SPDFF(I) * (TROIL + XLABOR(J) +
     1TIMLI(J) *  CROPA(J) * YIELD(J) * VALUE(J))/ (SPEED(J) * EFFIC(J)
     2* XTIMES(J) * XLFTR )
  200 CONTINUE
      SUM3 = 0.0
C
C
C                   FACTORS CONCERNING FIXED COSTS
C
      DO 310 I = 1, NMBRIM
      IF (SPDFF(I) .EQ. 0.0 ) GO TO 310
      SUM3 = SUM3 + FCPCTI(I) * PURI(I) *  XLFTR / SPDFF(I)
      IF ( RNATCH(I) .EQ. 0.0 ) GO TO 310
      NATCH = RNATCH(I)
      DO 305 INA = 1, NATCH
      RINA = INA
      DO 300 K1 = 1, NMBROP
      IF ( CNTRCT(K1) .EQ. 0.0 ) GO TO 300
      IF ( X(I) .NE. BASUSD(K1) ) GO TO 300
      IF ( ATTACH(K1) .NE. RINA) GO TO 300
      SUM3 = SUM3 + PURA(K1) * FCPCTA(K1) * XLFTR / SPDFF(I)
      GO TO 305
  300 CONTINUE
  305 CONTINUE
  310 CONTINUE
      SUM3 = SUM3 + FCPCTT * PURTR * SMNRGO/(SMNRGP + SMNRGT + SMNRGO)
      BSHPN = SQRT((SUM1 + SUM2 ) / SUM3 )
      RETURN
      END
```

```
      SUBROUTINE ICNVRT(NICODE)
C
C
C                  CONVERT ALPHABETIC INPUT IMPLEMENT CODE, NICODE, TO A
C                  NUMBER
C
C
C                  COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                  FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
      IF (NICODE -  ICODE(1)) 105, 100, 105
  100 NICODE = 1
      RETURN
  105 IF (NICODE -  ICODE(2)) 115, 110, 115
  110 NICODE = 2
      RETURN
  115 IF (NICODE -  ICODE(3)) 125, 120, 125
  120 NICODE = 3
      RETURN
  125 NICODE = 4
      RETURN
      END
```

```
      SUBROUTINE IMPAC ( TRIALW, ACOST, I, HPMAX, XNTRS )
C
C
C                COMPUTES ANNUAL COST FOR IMPLEMENT I
C
C
C                TRIALW -- TRIAL IMPLEMENT WIDTH FOR IMPLEMENT I
C                 ACOST -- ANNUAL COST OF IMPLEMENT I
C                     I -- IMPLEMENT NUMBER
C                 HPMAX -- TOTAL TRACTOR HORSEPOWER AVAILABLE
C                 XNTRS -- NUMBER OF TRACTORS IN FARM MACHINE SYSTEM
C
C
C                COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
C                COMMON AREA OF SCALAR VARIABLES
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCROR, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRONTT,
     3XLFTR, XLIFET
C
C
C                COMMON AREA OF ARRAY VARIABLES
C
      COMMON ACIMP(50), ACIMP1(50), ACIMP2(50), ACIMP3(50), ACIMP4(50),
     1ACIMP5(50), ACIMP6(50), ACIMP7(50), ACIMP8(50), ACRESD(50),
     2ACTOTA(50), ATTACH(50), AUXENG(50), AXHPLV(50), AXLFTR(50),
     3AXMXHP(50), BASUSD(50), CNTRCT(50), COMBIO(50), COST1(50),
     4COST2(50), COST3(50), COST4(50), COST5(50), COST6(50), COST7(50),
     5COST8(50), COST10(50), CROPA(50), CUSTOM(50), CU(50), DBPRTW(4,4),
     6DISTR(50), DTOAHP(4), E(50), EFFIC(50), FCPCTA(50), FCPCTC(50),
     7FCPCTI(50), FEFFIC(50), FEFICX(50), FFACTR(50), FFCTRX(50),
     8FFCTRC(50), FPRICE( 4), FTYPE(50), FUELC(50,4), G(50)
      COMMON HO(50), HPHRTC(50), HPHRTI(50), HPHRTX(50), IMPCLS(50),
     1NCCODE(50), NMCH1(50), NMCH2(50), NMCH3(50), NMCHJ1(50),
     2NMCHJ2(50), NMCHJ3(50), NOP1(50), NOP2(50), NOP3(50), NPR1(50),
     3NPR2(50), NPR3(50), NPR4(50), NPR5(50), NSOIL(50), NTR1(50),
     4NTR2(50), NTR3(50), NTR4(50), NTR5(50)
      COMMON OCSMPA(50), OCSMPT(50), OIL(50,4), OPRICE( 4), PP(50),
     1PURA(50), PURI(50), PURIO(50), PURIC(50), Q(50), QA(50), RMA(50),
     2RMI(50), RMIC(50), RNATCH(50), RWNLS(4,4), SFTYPE(50), SNRGOI(50),
     3SNRGOC(50), SNRGP(50), SNRGT(50), SPDFF(50), SPEED(50), SPHP(50),
     4SPLFTR(50), SUMAC(50), SUMACC(50), TIMLI(50), TIMPMX(50),
     5TONSPR(50), TONSTR(50), TPOWRD(50), TRATIO(4), TREDUC(4),
     6TRONTA(50), TRONTI(50), VALUE(50), W(50), WC(50), WMAX(50), WS(50)
      COMMON XIMPL(50), XINDEX(50), X(50), XFTYPE(50), XLABOR(50),
     1XLIFEA(50), XLIFEI(50), XNDCTR(50), XNIMPS(50), XNIMPC(50),
     2XNOPS(50), XNTRSN(50), XTIMES(50), YIELD(50), Z(50)
C
C
C                 INITIALIZE
C
      W(I) = TRIALW
```

```
      ACIMP1(I) = 0.0
      ACIMP2(I) = 0.0
      ACIMP3(I) = 0.0
      ACIMP4(I) = 0.0
      ACIMP5(I) = 0.0
      ACIMP6(I) = 0.0
      ACIMP7(I) = 0.0
      ACIMP8(I) = 0.0
      ACIMP(I) = 0.0
      CALL DETVAL ( I, HPMAX, XNTRS )
      IF ( TRIALW .EQ. 0.0 ) RETURN
C
C
C                 CALCULATE IMPLEMENT ANNUAL COST
C
C
C                 FIXED COST OF IMPLEMENT
C
      IF ( RNATCH(I) .EQ. 0.0 ) GO TO 114
      NATCH = RNATCH(I)
      DO 105 INA = 1, NATCH
      RINA = INA
      DO 100 K1 = 1, NMBROP
      IF ( CNTRCT(K1) .EQ. 0.0 ) GO TO 100
      IF ( X(I) .NE. BASUSD(K1)) GO TO 100
      IF ( ATTACH(K1) .NE. RINA ) GO TO 100
      ACIMP1(I) = ACIMP1(I) + PURA(K1) * FCPCTA(K1) * TRIALW
      GO TO 105
  100 CONTINUE
  105 CONTINUE
  114 ACIMP1(I) = ACIMP1(I) + PURI(I) * FCPCTI(I) * TRIALW
      DO 200 K3 = 1, NMBROP
      H = 8.25 * ACRESO(K3) / ( SPEED(K3) * TRIALW * EFFIC(K3) )
      IF ( CNTRCT(K3) .EQ. 0.0 ) GO TO 200
      IF ( X(I) .NE. XIMPL(K3) ) GO TO 170
      IFTYPE = FTYPE(K3)
      IXTYPE = FTYPE(K3)
C
C
C                 FIXED COST OF TRACTOR
C
      ACIMP2(I) = ACIMP2(I) + SNRGOI(K3) * FCPCTT * PURTR * Q(K3) *
     1TPOWRD(K3) / (SMNRGP + SMNRGT + SMNRGO )
C
C
C                 COST OF LABOR
C
      ACIMP3(I) = ACIMP3(I) + H * ( XNOPS(K3) * XNIMPS(I) + XNTRSN(K3)
     1* XLABOR(K3) * TPOWRD(K3) / XTIMES(K3) )
C
C
C                 COST OF TIMELINESS
C
      ACIMP4(I) = ACIMP4(I) + H * TIMLI(K3) * CROPA(K3) * YIELD(K3) *
     1VALUE(K3) / XTIMES(K3)
C
C
C                 COST OF FUEL
```

```
C
      ACIMP5(I) = ACIMP5(I) + FEFFIC(K3) * SNRGOI(K3) * FPRICE(IFTYPE)
      IF ( AUXENG(K3) .NE. 1.0 ) GO TO 150
      ACIMP5(I) = ACIMP5(I) + ( .022 * FECTRX(K3) * ACRESO(K3) /
     1 ( EFFIC(K3) * AXLFTR(K3) * 0.96 * DTOAHP(NSOIL(K3))) + HPHRTX(K3)
     2 * ACRESO(K3) * YIELD(K3) / AXLFTR(K3))* FEFICX(K3)*FPRICE(IXTYPE)
C
C
C                   COST OF OIL
C
  150 ACIMP6(I) = ACIMP6(I) + H * ( OCSMPA(K3) * OPRICE(IXTYPE) +
     1OCSMPT(K3) * OPRICE(IFTYPE)/XTIMES(K3) )
C
C
C                   REPAIR AND MAINTENANCE OF TRACTORS
C
  167 ACIMP8(I) = ACIMP8(I) + H * TPOWRD(K3) * RMTR * PURTR * Q(K3) /
     1XTIMES(K3)
C
C
C                   REPAIR AND MAINTENANCE OF IMPLEMENT
C
      ACIMP7(I) = ACIMP7(I) + H * TRIALW * RMI(K3) * PURI(I)
  170 IF ( X(I) .EQ. BASUSD(K3) ) ACIMP7(I) = ACIMP7(I) + H * TRIALW *
     1PURA(K3) * RMA(K3)
  200 CONTINUE
C
C
C                   CALCULATE TOTAL ANNUAL IMPLEMENT COST
C
      ACIMP(I) = ACIMP1(I) + ACIMP2(I) + ACIMP3(I) + ACIMP4(I) +
     1ACIMP5(I) + ACIMP6(I) + ACIMP7(I) + ACIMP8(I)
      ACOST = ACIMP(I)
      RETURN
      END
```

```
      SUBROUTINE INITL1
C
C
C               INITIALIZES ALL VARIABLES THAT REMAIN CONSTANT
C               THROUGHOUT THE ENTIRE OPTIMIZATION PROCESS FOR A
C               GIVEN FARM MACHINE SYSTEM.
C
C
C               COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C               FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
C               COMMON AREA OF SCALAR VARIABLES
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCRDR, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRDNTT,
     3XLFTR, XLIFET
C
C
C               COMMON AREA OF ARRAY VARIABLES
C
      COMMON ACIMP(50), ACIMP1(50), ACIMP2(50), ACIMP3(50), ACIMP4(50),
     1ACIMP5(50), ACIMP6(50), ACIMP7(50), ACIMP8(50), ACRESD(50),
     2ACTOTA(50), ATTACH(50), AUXENG(50), AXHPLV(50), AXLFTR(50),
     3AXMXHP(50), BASUSD(50), CNTRCT(50), COMBID(50), COST1(50),
     4COST2(50), COST3(50), COST4(50), COST5(50), COST6(50), COST7(50),
     5COST8(50), COSTIP(50), CPOPA(50), CUSTOM(50), CU(50), DBPRTW(4,4),
     6DISTR(50), DTOAHP(4), E(50), EFFIC(50), FCPCTA(50), FCPCTC(50),
     7FCPCTI(50), FEFFIC(50), FEFICX(50), FFACTR(50), FFCTRX(50),
     8FFCTRC(50), FPRICE( 4), FTYPE(50), FUELC(50,4), G(50)
      COMMON HO(50), HPHRTC(50), HPHRTI(50), HPHPTX(50), IMPCLS(50),
     1NCCODE(50), NMCH1(50), NMCH2(50), NMCH3(50), NMCHJ1(50),
     2NMCHJ2(50), NMCHJ3(50), NOP1(50), NOP2(50), NOP3(50), NPR1(50),
     3NPR2(50), NPR3(50), NPR4(50), NPR5(50), NSOIL(50), NTR1(50),
     4NTR2(50), NTR3(50), NTR4(50), NTR5(50)
      COMMON OCSMPA(50), OCSMPT(50), OIL(50,4), OPRICE( 4), PP(50),
     1PURA(50), PURI(50), PURIO(50), PURIC(50), Q(50), QA(50), RMA(50),
     2RMI(50), RMIC(50), RNATCH(50), RWNLS(4,4), SFTYPE(50), SNRGOI(50),
     3SNRGOC(50), SNRGP(50), SNRGT(50), SPDFF(50), SPEED(50), SPHP(50),
     4SPLFTR(50), SUMAC(50), SUMACC(50), TIMLI(50), TIMPMX(50),
     5TONSPR(50), TONSTR(50), TPOWRD(50), TRATIO(4), TREDUC(4),
     6TRDNTA(50), TRDNTI(50), VALUE(50), W(50), WC(50), WMAX(50), WS(50)
      COMMON XIMPL(50), XINDEX(50), X(50), XFTYPE(50), XLABOR(50),
     1XLIFEA(50), XLIFEI(50), XNDCTR(50), XNIMPS(50), XNIMPC(50),
     2XNOPS(50), XNTRSN(50), XTIMES(50), YIELD(50), Z(50)
C
C
C               DETERMINE FIXED COST PERCENTAGES
C
C           'IMPORTANT CONSIDERATIONS IN DETERMINING MACHINE FIXED COSTS
C     ARE LENGTH OF SERVICE LIFE AND TIME OF PLANNED REPLACEMENT IF THIS
C     SHOULD BE LESS THAN THE SERVICE LIFE.  STRAIGHT-LINE REDUCTION IS
C     CONSIDERED AN ADEQUATE DESCRIPTION OF DEPRECIATION COSTS.  THE
C     PERCENTAGE OF THE PURCHASE PRICE FOR THE NEW MACHINE INCLUDES
C     DEPRECIATION AND OTHER FIXED COSTS.  THIS PERCENTAGE IS ADJUSTED
```

```
C     AS IN HUNT(1), TABLE 14.1, WITH VARIATIONS IN SERVICE LIFE.  IF
C     REPLACEMENT IS CONTEMPLATED BEFORE THE END OF SERVICE LIFE, THE
C     PROGRAM ADJUSTS THE FIXED-COST PERCENTAGE UPWARD TO COMPENSATE FOR
C     THE OVERESTIMATION OF THE ACTUAL RESALE VALUE SUGGESTED BY
C     STRAIGHT-LINE DEPRECIATION.'
C
C          'THE FIXED COSTS FOR POWER ARE CHARGED AGAINST FIELD
C     OPERATIONS ACCORDING TO THE AMOUNT OF ENERGY REQUIRED FOR THE
C     OPERATION.  IF TWO IMPLEMENTS ARE PULLED IN TANDEM, THE DRAFTS OF
C     EACH ARE SUMMED.'
C
C
C                    COMPUTE TRACTOR FIXED COST PERCENTAGE
C
      CALL FCP ( FCPCTT, XLIFET, TRDNTT )
C
C
C                    COMPUTE IMPLEMENT BASE FIXED COST PERCENTAGE, FCPCTI
C
   10 DO 20 I = 1,NMBROP
      J = XIMPL(I)
      PURI(J) = PURID(I)
      CALL FCP ( FCPCTI(J), XLIFEI(I), TRDNTI(I) )
C
C
C                    COMPUTE IMPLEMENT ATTACHMENT FC PERCENTAGES, FCPCTA
C
   15 IF (ATTACH(I) .EQ. 1.0 ) GO TO 17
      FCPCTA(I) = 0.0
      GO TO 20
   17 CALL FCP ( FCPCTA(I), XLIFEA(I), TRDNTA(I) )
   20 CONTINUE
C
C
C                    SUM OUT-OF-FIELD ENERGY REQUIREMENTS
C
    3 SMNRGP = 0.0
      DO 4 I = 1, NMBRPR
      SNRGP(I)   = G(I) * TONSPR(I)
      SMNRGP = SMNRGP + SNRGP(I)
    4 CONTINUE
      SMNRGT = 0.0
      DO 5 I = 1, NMBRTR
      SNRGT(I) = 1.1 * DISTR(I) * TONSTR(I)
      SMNRGT = SMNRGT + SNRGT(I)
    5 CONTINUE
C
C
C                  COMPUTE CUSTOM COSTS AND DETERMINE FIELD ENERGY
C                  REQUIREMENTS FOR EACH OPERATION
C
      DO 8 I = 1, NMBROP
      CU(I) = ACRESD(I) * CUSTOM(I)
      PRCNTL = XLFTR
      IF ( TPOWRD(I) .EQ.  0.0 ) PRCNTL = SPLFTR(I)
      SNRGOI(I) = 0.022 * ACRESO(I) * FFACTR(I) / ( EFFIC(I) * PRCNTL *
     1.96 * DTOAHP(NSOIL(I)))+ HPHRTI(I) * ACRESO(I) * YIELD(I) / PRCNTL
    8 CONTINUE
```

```
C
C
C                 CONVERT AND STORE IMPLEMENT NUMBERS IN DECIMAL FORM
C
      DO 9 I1 = 1, NMBRIM
    9 X(I1) = I1
C
C
C                 CALCULATE COMBINATION IMPLEMENT FACTORS
C
      DO 271 I8 = 1, NMBROP
      IF ( COMBID(I8) .GT. 0.0 ) GO TO 25
      FCPCTC(I8) = 0.0
      NCCODE(I8) = 4
      PURIC(I8) = 0.0
      RMIC(I8) = 0.0
      GO TO 271
   25 DO 27 I1 = 1, NMBROP
      IF ( COMBID(I8) - XINDEX(I1) ) 27, 26, 27
   26 IF ( COMBID(I1) - XINDEX(I8) ) 27, 261, 27
  261 RMIC(I8) = RMI(I1)
      NCCODE(I8) = IMPCLS(I1)
      L = XIMPL(I1)
      FCPCTC(I8) = FCPCTI(L)
      PURIC(I8) = PURI(L)
   27 CONTINUE
  271 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INITL2 ( SMCOST )
C
C
C                INITIALIZE VARIABLES THAT MUST BE INITIALIZED AT THE
C                START OF THE IMPLEMENT WIDTH SELECTION PROCESS FOR A
C                GIVEN TRACTOR HORSEPOWER LEVEL
C
C
C                SMCOST -- TOTAL ANNUAL COST OF THE FARM MACHINE
C                          SYSTEM
C
C
C                COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
C                COMMON AREA OF SCALAR VARIABLES
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCRDR, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRDNTT,
     3XLFTR, XLIFET
C
C
C                COMMON AREA OF ARRAY VARIABLES
C
      COMMON ACIMP(50), ACIMP1(50), ACIMP2(50), ACIMP3(50), ACIMP4(50),
     1ACIMP5(50), ACIMP6(50), ACIMP7(50), ACIMP8(50), ACRESO(50),
     2ACTOTA(50), ATTACH(50), AUXENG(50), AXHPLV(50), AXLFTR(50),
     3AXMXHP(50), BASUSD(50), CNTRCT(50), COMBIO(50), COST1(50),
     4COST2(50), COST3(50), COST4(50), COST5(50), COST6(50), COST7(50),
     5COST8(50), COSTIO(50), CROPA(50), CUSTOM(50), CU(50), DBPRTW(4,4),
     6DISTR(50), DTOAHP(4), F(50), EFFIC(50), FCPCTA(50), FCPCTC(50),
     7FCPCTI(50), FEFFIC(50), FEFICX(50), FFACTR(50), FFCTRX(50),
     8FFCTRC(50), FPRICE( 4), FTYPE(50), FUELC(50,4), G(50)
      COMMON HO(50), HPHRTC(50), HPHRTI(50), HPHRTX(50), IMPCLS(50),
     1NCCODE(50), NMCH1(50), NMCH2(50), NMCH3(50), NMCHJ1(50),
     2NMCHJ2(50), NMCHJ3(50), NOP1(50), NOP2(50), NOP3(50), NPR1(50),
     3NPR2(50), NPR3(50), NPR4(50), NPR5(50), NSOIL(50), NTR1(50),
     4NTR2(50), NTR3(50), NTR4(50), NTR5(50)
      COMMON OCSMPA(50), OCSMPT(50), OIL(50,4), OPRICE( 4), PP(50),
     1PURA(50), PURI(50), PURIO(50), PURIC(50), Q(50), QA(50), RMA(50),
     2RMI(50), RMIC(50), RMATCH(50), RWNLS(4,4), SFTYPE(50), SNRGOI(50),
     3SNRGOC(50), SNRGP(50), SNRGT(50), SPDFF(50), SPEED(50), SPHP(50),
     4SPLFTR(50), SUMAC(50), SUMACC(50), TIMLI(50), TIMPMX(50),
     5TONSPR(50), TONSTR(50), TPOWRD(50), TRATIO(4), TREDUC(4),
     6TRDNTA(50), TRDNTI(50), VALUE(50), W(50), WC(50), WMAX(50), WS(50)
      COMMON XIMPL(50), XINDEX(50), X(50), XFTYPE(50), XLABOR(50),
     1XLIFEA(50), XLIFEI(50), XNOCTR(50), XNIMPS(50), XNIMPC(50),
     2XNOPS(50), XNTRSN(50), XTIMES(50), YIELD(50), Z(50)
C
C
C                INITIALIZE
C
      HT = 0.0
      SMCOST = 0.0
```

```
      TPP = 0.0
      TPPI = 0.0
      DO 70 I9 = 1, NMBRIM
      PP( I9 ) = 0.0
      RNATCH(I9) = 0.0
      TIMPMX(I9) = 5000.0
      W( I9 ) = 0.0
      WS( I9 ) = 5000.0
      DO 65 J = 1, NMBROP
      IF ( X(I9) * CNTRCT(J) .NE. XIMPL(J) ) GO TO 60
      IF ( WMAX(J) .LT. WS(I9) ) WS(I9) = WMAX(J)
      IF ( E(J) .LT. TIMPMX(I9) ) TIMPMX(I9) = E(J)
   60 IF ( BASUSD(J) * CNTRCT(J) .NE. X(I9) ) GO TO 65
      IF ( ATTACH(J) .GT. RNATCH(I9) ) RNATCH(I9) = ATTACH(J)
   65 CONTINUE
      IF ( TIMPMX(I9) .EQ. 5000.0 ) TIMPMX(I9) = 0.0
      IF ( WS(I9) .EQ. 5000.0 ) WS(I9) = 0.0
   70 CONTINUE
      DO 31 I3 =1, NMBROP
      XNIMPC(  I3) = 0.0
      WC(  I3) = 0.0
      Z( I3 ) = 0.0
      COST1(I3) = 0.0
      COST2(I3) = 0.0
      COST3(I3) = 0.0
      COST4(I3) = 0.0
      COST5(I3) = 0.0
      COST6(I3) = 0.0
      COST7(I3) = 0.0
      COST8(I3) = 0.0
      COSTIO(  I3) = 0.0
      DO 31 I11 = 1, 4
      FUELC(I3, I11) = 0.0
      OIL(I3, I11) = 0.0
   31 CONTINUE
C
C
C                    SUM FIELD ENERGY REQUIREMENTS
C
      SMNRGD = 0.0
      DO 6 I1 = 1, NMBROP
      SMNRGD = SMNRGD + SNRGDI(I1) * TPOWRD(I1) * CNTRCT(I1)
    6 CONTINUE
C
C
C                    COMPUTE SUM OF IMPLEMENT ANNUAL ACREAGES
C
      DO 23 J = 1, NMBRIM
      SUMAC(J) = 0.0
      DO 23 I2 = 1, NMBROP
      IF ( X(J) .NE. XIMPL(I2) ) GO TO 23
      SUMAC(J) = SUMAC(J) + ACRESO(I2) * CNTRCT(I2)
   23 CONTINUE
C
C
C                    CALCULATE COMBINATION IMPLEMENT FACTORS
C
      DO 271 I8 = 1, NMBROP
```

```
      IF ( COMBID(I8) .GT. 0.0 ) GO TO 25                               IN201170
      FFCTRC(I8) = 0.0                                                  IN201180
      HPHRTC(I8) = 0.0                                                  IN201190
      SNRGOC(I8) = 0.0                                                  IN201200
      SUMACC(I8) = 0.0                                                  IN201210
      GO TO 271                                                         IN201220
   25 DO 27 I1 = 1, NMBROP                                              IN201230
      IF ( COMBID(I8) - XINDEX(I1) ) 27, 26, 27                         IN201240
   26 IF ( COMBID(I1) - XINDEX(I8) ) 27, 261, 27                        IN201250
  261 FFCTRC(I8) = FFACTR(I1) * CNTRCT(I1)                              IN201260
      HPHRTC(I8) = HPHRTI(I1) * CNTRCT(I1)                              IN201270
      SNRGOC(I8) = SNRGOI(I1) * CNTRCT(I1)                              IN201280
      L = XIMPL(I1)                                                     IN201290
      SUMACC(I8) = SUMAC(L)                                             IN201300
   27 CONTINUE                                                          IN201310
  271 CONTINUE                                                          IN201320
      RETURN                                                            IN201330
      END                                                               IN201340
```

```
      SUBROUTINE OUTPUT ( HPMAX, SMCOST, XNTRS )
C
C
C                PRINTS OUT ALL INFORMATION FOR A GIVEN HORSEPOWER
C                LEVEL.
C
C
C                 HPMAX -- TOTAL TRACTOR HORSEPOWER AVAILABLE
C                SMCOST -- ANNUAL COST OF FARM MACHINE SYSTEM
C                 XNTRS -- NUMBER OF TRACTORS IN FARM MACHINE SYSTEM
C
C
C                COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCRDR, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRDNTT,
     3XLFTR, XLIFET
C
C
C                COMMON AREA OF ARRAY VARIABLES
C
      COMMON ACIMP(50), ACIMP1(50), ACIMP2(50), ACIMP3(50), ACIMP4(50),
     1ACIMP5(50), ACIMP6(50), ACIMP7(50), ACIMP8(50), ACRESD(50),
     2ACTOTA(50), ATTACH(50), AUXENG(50), AXHPLV(50), AXLFTR(50),
     3AXMXHP(50), BASUSD(50), CNTRCT(50), COMBID(50), COST1(50),
     4COST2(50), COST3(50), COST4(50), COST5(50), COST6(50), COST7(50),
     5COST8(50), COST10(50), CROPA(50), CUSTOM(50), CU(50), DBPPTW(4,4),
     6DISTR(50), DTDAHP(4), E(50), EFFIC(50), FCPCTA(50), FCPCTC(50),
     7FCPCTI(50), FEFFIC(50), FFFICX(50), FFACTR(50), FFCTRX(50),
     8FFCTRC(50), FPRICE( 4), FTYPE(50), FUELC(50,4), G(50)
      COMMON HO(50), HPHRTC(50), HPHRTI(50), HPHRTX(50), IMPCLS(50),
     1NCCODE(50), NMCH1(50), NMCH2(50), NMCH3(50), NMCHJ1(50),
     2NMCHJ2(50), NMCHJ3(50), NOP1(50), NOP2(50), NOP3(50), NPR1(50),
     3NPR2(50), NPR3(50), NPR4(50), NPR5(50), NSOIL(50), NTR1(50),
     4NTR2(50), NTR3(50), NTR4(50), NTR5(50)
      COMMON OCSMPA(50), OCSMPT(50), OIL(50,4), OPRICE( 4), PP(50),
     1PURA(50), PURI(50), PURIO(50), PURIC(50), Q(50), QA(50), RMA(50),
     2RMI(50), RMIC(50), RNATCH(50), RWNLS(4,4), SFTYPE(50), SNRGOI(50),
     3SNRGOC(50), SNRGP(50), SNRGT(50), SPDFF(50), SPEED(50), SPHP(50),
     4SPLFTR(50), SUMAC(50), SUMACC(50), TIMLI(50), TIMPMX(50),
     5TONSPR(50), TONSTR(50), TPOWRD(50), TRATIO(4), TREDUC(4),
     6TRDNTA(50), TRDNTI(50), VALUE(50), W(50), WC(50), WMAX(50), WS(50)
      COMMON XIMPL(50), XINDEX(50), X(50), XFTYPE(50), XLABOR(50),
     1XLIFEA(50), XLIFEI(50), XNDCTR(50), XNIMPS(50), XNIMPC(50),
     2XNOPS(50), XNTRSN(50), XTIMES(50), YIELD(50), Z(50)
C
C
C                POWER LEVEL ANSWERS
C
      CALL PAGE
      WRITE (NPRNTR,502)
  502 FORMAT (1H ,33X,13HFACTORY RATED/,10X,88HSYSTEM ANNUAL COSTS     T
     1RACTOR PTO HP     NO. OF TRACTORS  SYSTEM HOURS       INVESTMENT  /)
```

```
  503 WRITE(NPRNTR,504)     SMCOST    , HPMAX    , XNTRS    , HT    , TPPI
  504 FORMAT (15X,1H$, F10.2, 9X,F10.2,14X, F3.0, 9X, F6.1,
     1 9X, 1H$, F10.2   /// )
C
C
C                 PRINT OPTIMUM IMPLEMENT SELECTION
C
      WRITE(NPRNTR,602)
  602 FORMAT(1H ,///52X,12HPOWER LEVELS/46X,24(1H*)/15H  IMPLEMENT
     115H  OPTIMUM SIZE ,2X,11H NO. REQ'D ,2X,15H SELF-PROPELLED,4X,
     26HAUXENG,4X,14HPURCHASE PRICE /   )
      WRITE(NPRNTR,603) (NMCHJ1(J), NMCHJ2(J), NMCHJ3(J), W(   J),
     1XNIMPS(J), SPHP(J), AXHPLV(J), PP(J), J = 1, NMBRIM )
  603 FORMAT (1X, 3A4, 7X, F5.1, 10X, F4.0,10X,F6.1,9X,F6.1,9X,F9.2)
      WRITE(NPRNTR,6032) PPTRAC
 6032 FORMAT( / 9H TRACTORS, 70X, F9.2 )
      WRITE(NPRNTR,6031) TPPI
 6031 FORMAT ( 45X, 33HINVESTMENT INCLUDING TRACTORS = $   F10.2  ///)
C
C
C                 PRINT A BREAKDOWN OF IMPLEMENT COSTS
C
C
C                 SUM EACH SPECIFIC IMPLEMENT COST FOR ALL IMPLEMENTS
C
      SUM1 = 0.0
      SUM2 = 0.0
      SUM3 = 0.0
      SUM4 = 0.0
      SUM5 = 0.0
      SUM6 = 0.0
      SUM7 = 0.0
      SUM8 = 0.0
      SUM9 = 0.0
      DO 6060 I = 1, NMBRIM
      SUM1 = SUM1 + ACIMP1(I)
      SUM2 = SUM2 + ACIMP2(I)
      SUM3 = SUM3 + ACIMP3(I)
      SUM4 = SUM4 + ACIMP4(I)
      SUM5 = SUM5 + ACIMP5(I)
      SUM6 = SUM6 + ACIMP6(I)
      SUM7 = SUM7 + ACIMP7(I)
      SUM8 = SUM8 + ACIMP8(I)
      SUM9 = SUM9 + ACIMP(I)
 6060 CONTINUE
      CALL PAGE
      WRITE(NPRNTR,6065)
 6065 FORMAT(1H ,48X,35HBREAKDOWN OF IMPLEMENT ANNUAL COSTS ///)
      WRITE(NPRNTR,6070)
 6070 FORMAT(21X,10HFIXED COST,51X,20HREPAIR & MAINTENANCE/15X,21(1H*),
     146X,21(1H*)/2X,9HIMPLEMENT,4X,10HIMPLEMENT ,4X,7HTRACTOR,6X,
     25HLABOR,2X,10HTIMELINESS,7X,4HFUEL,8X,3HOIL,1X,10HIMPLEMENT ,4X,
     37HTRACTOR,7X,5HTOTAL    /  )
      DO 6074 J = 1, NMBRIM
 6074 WRITE(NPRNTR,6075) NMCHJ1(J), NMCHJ2(J), NMCHJ3(J), ACIMP1(J),
     1ACIMP2(J), ACIMP3(J), ACIMP4(J), ACIMP5(J), ACIMP6(J), ACIMP7(J),
     2ACIMP8(J), ACIMP(J)
 6075 FORMAT(1X,3A4,1X,3(1X,F10.2),1X,5(1X,F10.2),2X,F10.2 )
```

```
      WRITE(NPRNTR,6080) SUM1, SUM2, SUM3, SUM4, SUM5, SUM6, SUM7, SUM8,
     1SUM9
 6080 FORMAT(/1X,13HCOLUMN TOTALS,3(1X,F10.2),1X,5(1X,F10.2),2X,F10.2 )
C
C
C                  PRINT OPERATION COSTS
C
      CALL PAGE
      WRITE(NPRNTR,604)
  604 FORMAT(54X,27HFIELD OPERATION INFORMATION     ///
     118X,8HTRACTORS,66X,6HNO. OF/11H  OPERATION,8X,6HNEEDED
     2,4X,21HCOST OF OPERATION      ,15HCUSTOM COST     ,17H     COMBINATION
     3 W ,8X,10HCOMB.IMPS.,20H  ANNUAL HOURS REQ'D  /  )
      DO 6050 I = 1, NMBROP
      IF ( XNDCTR(I) .EQ. 0.0 ) GO TO 6050
      WRITE(NPRNTR,605)  NOP1(I), NOP2(I), NOP3(I), XNTRSN(I),COSTIO(I),
     1Z(I), WC(I), XNIMPC(I), HO(I)
  605 FORMAT ( 1X, 3A4, 3X, F9.2, 3X, F10.2, 12X, F10.2, 10X, F7.1,
     117X, F3.0,15X, F6.1 )
 6050 CONTINUE
      WRITE(NPRNTR,6051) HT
 6051 FORMAT ( 96X, 16H  SYSTEM HOURS =   F6.1  )
C
C
C                  PRINT A BREAKDOWN OF OPERATION COSTS
C
C
C                  SUM EACH SPECIFIC OPERATION COST FOR ALL OPERATIONS
C
      SUM1 = 0.0
      SUM2 = 0.0
      SUM3 = 0.0
      SUM4 = 0.0
      SUM5 = 0.0
      SUM6 = 0.0
      SUM7 = 0.0
      SUM8 = 0.0
      SUM9 = 0.0
      SUM10 = 0.0
      DO 7051  I = 1, NMBROP
      IF ( XNDCTR(I) .EQ. 0.0 ) GO TO 7051
      SUM1 = SUM1 + COST1(I)
      SUM2 = SUM2 + COST2(I)
      SUM3 = SUM3 + COST3(I)
      SUM4 = SUM4 + COST4(I)
      SUM5 = SUM5 + COST5(I)
      SUM6 = SUM6 + COST6(I)
      SUM7 = SUM7 + COST7(I)
      SUM8 = SUM8 + COST8(I)
      SUM9 = SUM9 + Z(I)
      SUM10 = SUM10 + COSTIO(I)
 7051 CONTINUE
      CALL PAGE
      WRITE(NPRNTR,7010)
 7010 FORMAT(1H ,51X,30HBREAKDOWN OF OPERATION COSTS  ///)
      WRITE(NPRNTR, 7020)
 7020 FORMAT(21X,10HFIXED COST,51X,20HREPAIR & MAINTENANCE/15X,21(1H*),
     146X,21(1H*)/2X,9HOPERATION,4X,10HIMPLEMENTS,4X,7HTRACTOR,6X,
```

```
     25HLABOR,2X,10HTIMELINESS,7X,4HFUEL,8X,3HOIL,1X,10HIMPLEMENTS,4X,
     37HTRACTOR,6X,6HCUSTOM,7X,5HTOTAL    /   )
      DO 7049 I = 1, NMBROP
      IF ( XNOCTR(I) .EQ. 0.0 ) GO TO 7049
      WRITE(NPRNTR,7050)  NOP1(I), NOP2(I), NOP3(I), COST1(I), COST7(I),
     2COST2(I), COST4(I), COST8(I), COST6(I), COST3(I), COST5(I),
     3Z(I), COST10(I)
 7050 FORMAT(1X,3A4,1X,3(1X,F10.2),1X,5(1X,F10.2),2(2X,F10.2))
 7049 CONTINUE
      WRITE(NPRNTR,7055) SUM1, SUM7, SUM2, SUM4, SUM8, SUM6, SUM3,
     1SUM5, SUM9, SUM10
 7055 FORMAT(/1X,13HCOLUMN TOTALS,3(1X,F10.2),1X,5(1X,F10.2),
     12(2X,F10.2))
C
C
C                  PRINT A TABLE OF THE OIL AND FUEL CONSUMPTION
C                  FOR EACH OPERATION
C
C
C                  SUM EACH OIL AND FUEL TYPE FOR ALL OPERATIONS
C
      SUM1 = 0.0
      SUM2 = 0.0
      SUM3 = 0.0
      SUM4 = 0.0
      SUM5 = 0.0
      SUM6 = 0.0
      DO 7091 I = 1, NMBROP
      SUM1 = SUM1 + FUELC(I,1)
      SUM2 = SUM2 + FUELC(I,2)
      SUM3 = SUM3 + FUELC(I,3)
      SUM4 = SUM4 + OIL(I,1)
      SUM5 = SUM5 + OIL(I,2)
      SUM6 = SUM6 + OIL(I,3)
 7091 CONTINUE
      CALL PAGE
      WRITE(NPRNTR,7060)
 7060 FORMAT(1H ,48X,38HFUEL AND OIL CONSUMPTION PER OPERATION ///)
      WRITE(NPRNTR,7061)
 7061 FORMAT(43X,4HFUEL,52X,3HOIL/20X,51(1H_),4X,51(1H_))
      WRITE(NPRNTR,7065)
 7065 FORMAT(26X,9HHP-HR/GAL,17X,12HGALLONS USED,19X,6HGAL/HR,18X,12HGAL
     1LONS USED)
      WRITE(NPRNTR,7070)
 7070 FORMAT(16X,2(4X,21(1H*),4X,26(1H*)))
      WRITE(NPRNTR,7075)
 7075 FORMAT(5X,9HOPERATION,2X,2(4X,11HTRACTOR, SP,3X,7HAUX ENG,4X,
     18HGASOLINE,3X,6HDIESEL,3X,6HLP GAS)/)
      DO 7080 I = 1, NMBROP
      IF ( CNTRCT(I) .EQ. 0.0 ) GO TO 7080
      FEFFT = 0.0
      FEFFAX = 0.0
      IF ( FEFFIC(I) .GT. 0.0 ) FEFFT = 1.0 / FEFFIC(I)
      IF ( FEFICX(I) .GT. 0.0 ) FEFFAX = 1.0 / FEFICX(I)
      WRITE(NPRNTR,7085) NOP1(I), NOP2(I), NOP3(I), FEFFT,
     1FEFFAX, FUELC(I,1), FUELC(I,2), FUELC(I,3), OCSMPT(I),
     2OCSMPA(I), OIL(I,1), OIL(I,2), OIL(I,3)
 7085 FORMAT(4X,3A4,2X,2(4X,F9.2,1X,F9.2,3X,3F9.2))
```

```
7080 CONTINUE
     WRITE(NPRNTR,7095) SUM1, SUM2, SUM3, SUM4, SUM5, SUM6
7095 FORMAT(/4X,13HCOLUMN TOTALS,1X,2(4X,9(1H-),1X,9(1H-),3X,3F9.2))
C
C
C                 PRINT INFORMATION CONCERNING TRACTOR PERFORMANCE
C
     CALL PAGE
     WRITE(NPRNTR,8000)
8000 FORMAT(1H ,56X,22HINFORMATION CONCERNING//59X,17HFACTORS AFFECTING
    1//54X,27HOPTIMUM TRACTOR PERFORMANCE////)
     PRCNTL = XLFTR * 100.0
     WRITE(NPRNTR,8010) PRCNTL
8010 FORMAT(65X,17HAVAILABLE TRACTOR/45X,13HFACTORY RATED,7X,14HPTO HP,
    1 USING ,F5.1,1H%/45X,14HTRACTOR PTO HP,6X,21HOF THE FACTORY RATING
    2/ )
     APTOHP = HPMAX * XLFTR
     AXLEHP = APTOHP * .96
     WRITE(NPRNTR,8015)HPMAX, APTOHP
8015 FORMAT(47X,F9.2,14X,F9.2///)
     WRITE(NPRNTR,8019)
8019 FORMAT(67X,8HREQUIRED/27X,87(1H*)/
    128X,13HFACTORY RATED,28X,
    27HNO LOAD,4X,5HTOTAL,4X,10HTOTAL REAR,2X,13HTOTAL TRACTOR/
    313X,9HOPERATION,5X,14HTRACTOR PTO HP,6X,6HPTO HP,
    48X,5HDB HP,2X,9HSPEED,MPH,2X,8HPULL,LBS,4X,6HWT,LBS,7X,6HWT,LBS/)
     DO 8025 I = 1, NYBROP
     IF ( TPOWRD(I)*CNTRCT(I)*XNDCTR(I) .NE. 1.0 ) GO TO 8025
     K = XIMPL(I)
     RDBHP = SPEED(I) * (FFACTR(I) + FFCTRC(I)) * W(K) / 375.0
     RAXHP = RDBHP / DTOAHP(NSOIL(I))
     RPTOHP = ( HPHRTI(I) + HPHRTC(I) ) * YIELD(I) * SPEED(I) * W(K)
    1* EFFIC(I) / 8.25
     RFPTOH = ( RAXHP / 0.96 + RPTOHP ) / XLFTR
     RNLTS = SPEED(I) / TRATIO(NSOIL(I))
     RRWT = W(K) * FFACTR(I) / DBPRTW(NSOIL(I),IMPCLS(I)) + W(K)
    1*FFCTRC(I)/DBPRTW(NSOIL(I),NCCODE(I))
     TOTPUL = W(K) * (FFACTR(I) + FFCTRC(I))
     TTRWT = RRWT / .75
     WRITE(NPRNTR,8020) NOP1(I), NOP2(I), NOP3(I), RFPTOH, RPTOHP,
    1RDBHP, RNLTS, TOTPUL, RRWT, TTRWT
8020 FORMAT(12X,3A4,2X,F9.2,9X,F9.2,4X,F9.2,3X,F8.2,2X,F8.1,2X,F8.1,
    16X,F8.1 )
8025 CONTINUE
     RETURN
     END
```

```
      SUBROUTINE PAGE
C
C
C                 NUMBERS OUTPUT PAGES
C
C
C                 COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                 FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
C                 COMMON AREA OF SCALAR VARIABLES
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCRDR, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TETYPE, TPP, TPPI, TRDNTT,
     3XLFTR, XLIFET
C
C
      KPAGE = KPAGE + 1
      WRITE(NPRNTR,100) KPAGE
  100 FORMAT(1H1,5HPAGE ,I5//)
      RETURN
      END
```

```
      SUBROUTINE SCNVRT(ISCODE)
C
C
C                    CONVERT ALPHABETIC INPUT SOIL CODE, ISCODE, TO A
C                    NUMBER
C
C
C                    COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                    FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
      IF ( ISCODE - NSCODE(1)) 105, 100, 105
  100 ISCODE = 1
      RETURN
  105 IF ( ISCODE - NSCODE(2)) 115, 110, 115
  110 ISCODE = 2
      RETURN
  115 IF ( ISCODE - NSCODE(3)) 125, 120, 125
  120 ISCODE = 3
      RETURN
  125 ISCODE = 4
      RETURN
      END
```

```
      SUBROUTINE SELECT ( HPMAX, SMCOST, XNTRS, *, * )
C
C
C                 CALCULATES OPERATION COSTS AND COMPARES WITH CUSTOM
C                 COSTS TO DETERMINE WHICH IS MOST ECONOMICAL
C
C
C                  HPMAX -- TOTAL TRACTOR HORSEPOWER AVAILABLE
C                 SMCOST -- TOTAL ANNUAL COST OF THE FARM MACHINE
C                           SYSTEM
C                  XNTRS -- NUMBER OF TRACTORS IN THE FARM SYSTEM
C
C
C                 COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                 FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
C                 COMMON AREA OF SCALAR VARIABLES
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCFDR, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRDNTT,
     3XLFTR, XLIFET
C
C
C                 COMMON AREA OF ARRAY VARIABLES
C
      COMMON ACIMP(50), ACIMP1(50), ACIMP2(50), ACIMP3(50), ACIMP4(50),
     1ACIMP5(50), ACIMP6(50), ACIMP7(50), ACIMP8(50), ACRESD(50),
     2ACTOTA(50), ATTACH(50), AUXENG(50), AXHPLV(50), AXLFTR(50),
     3AXMXHP(50), BASUSD(50), CNTRCT(50), COMBID(50), COST1(50),
     4COST2(50), COST3(50), COST4(50), COST5(50), COST6(50), COST7(50),
     5COST8(50), COST10(50), CPOPA(50), CUSTOM(50), CU(50), DRPRTW(4,4),
     6DISTR(50), DTOAHP(4), E(50), EFFIC(50), FCPCTA(50), FCPCTC(50),
     7FCPCTI(50), FEFFIC(50), FEFFICX(50), FFACTR(50), FFCTRX(50),
     8FFCTPC(50), FPRICE( 4), FTYPE(50), FUELC(50,4), G(50)
      COMMON HO(50), HPHRTC(50), HPHRTI(50), HPHRTX(50), IMPCLS(50),
     1NCCODE(50), NMCH1(50), NMCH2(50), NMCH3(50), NMCHJ1(50),
     2NMCHJ2(50), NMCHJ3(50), NOP1(50), NOP2(50), NOP3(50), NPR1(50),
     3NPR2(50), NPR3(50), NPR4(50), NPR5(50), NSOIL(50), NTR1(50),
     4NTR2(50), NTR3(50), NTR4(50), NTR5(50)
      COMMON OCSMPA(50), OCSMPT(50), OIL(50,4), OPRICE( 4), PP(50),
     1PURA(50), PURI(50), PURIO(50), PURIC(50), Q(50), QA(50), RMA(50),
     2RMI(50), RMIC(50), RNATCH(50), RWNLS(4,4), SFTYPE(50), SNRGOI(50),
     3SNRGOC(50), SNRGP(50), SNRGT(50), SPDFF(50), SPEED(50), SPHP(50),
     4SPLFTR(50), SUMAC(50), SUMACC(50), TIMLI(50), TIMPMX(50),
     5TONSPR(50), TONSTR(50), TPOWRD(50), TRATIO(4), TREDUC(4),
     6TRDNTA(50), TRDNTI(50), VALUE(50), W(50), WC(50), WMAX(50), WS(50)
      COMMON XIMPL(50), XINDEX(50), X(50), XFTYPE(50), XLABOR(50),
     1XLIFFA(50), XLIFEI(50), XNDCTR(50), XNIMPS(50), XNIMPC(50),
     2XNOPS(50), XNTRSN(50), XTIMES(50), YIELD(50), Z(50)
C
C
C                 INITIALIZE
C
      DO 58 I3 = 1, NMBROP
```

```
   58 CNTRCT(I3) = 1.0
   99 CALL INITL2 (SMCOST)
C
C
C                 DETERMINE THE NUMBER OF TRACTORS IN THE FARM MACHINE
C                 SYSTEM
C
      NTRS = HPMAX / HPPER + 0.99999
      XNTRS = NTRS
C
C
C                 FIND OPTIMUM IMPLEMENT WIDTHS
C
      CALL WIDTH ( HPMAX, XNTRS )
C
C
C                 COMPUTE PURCHASE PRICE FOR EACH IMPLEMENT
C
      DO 400 I4 = 1, NMBRIM
      PP(I4) = W(I4) * PURI(I4)
      IF ( RNATCH(I4) * W(I4) .EQ. 0.0 ) GO TO 400
      NATCH = RNATCH(I4)
      DO 405 INA = 1, NATCH
      RINA = INA
      DO 410 I5 = 1, NMBROP
      IF ( X(I4) .NE. BASUSD(I5) * CNTRCT(I5) ) GO TO 410
      IF ( ATTACH(I5) .NE. RINA ) GO TO 410
      PP(I4) = PP(I4) + PURA(I5) * W(I4)
      GO TO 405
  410 CONTINUE
  405 CONTINUE
  400 CONTINUE
C
C
C                 COMPUTE COSTS FOR EACH IMPLEMENT OPERATION
C
      DO 55 I = 1, NMBROP
      IFTYPE = FTYPE(I)
      IXTYPE = XFTYPE(I)
      J = XIMPL(I)
      IF ( W(J) .GE. 0.0 .AND. CNTRCT(I) .EQ. 0.0 ) GO TO 3699
      IF ( W(J) .GT. 0.0 ) GO TO 3651
      IF ( COMBID(I) .NE. 0.0 ) GO TO 3610
      CNTRCT(I) = 0.0
      GO TO 99
 3610 DO 3650 I1 = 1, NMBROP
      IF ( COMBID(I1) * CNTRCT(I1) .NE. XINDEX(I) ) GO TO 3650
      IF ( COMBID(I) .NE. XINDEX(I1) ) GO TO 3650
      CNTRCT(I) = 0.0
      CNTRCT(I1) = 0.0
      GO TO 99
 3650 CONTINUE
 3651 IF ( COMBID(I) .EQ. 0.0 ) GO TO 3699
      DO 3660 I1 = 1, NMBROP
      IF ( COMBID(I1) * CNTRCT(I1) .NE. XINDEX(I) ) GO TO 3660
      IF ( COMBID(I) .NE. XINDEX(I1) ) GO TO 3660
      J1 = XIMPL(I1)
      WC(I) = W(J1)
```

```
      XNIMPC(I) = XNIMPS(J1)
      GO TO 3699
 3660 CONTINUE
C
C
C                    COMPUTE HOURS OF USE
C
 3699 HO(I) = 0.0
      IF ( W(J) .EQ. 0.0 ) GO TO 3702
 3700 HO(I) = 8.25 * ACRESO(I)/( SPEED(I) * W(J) * EFFIC(I)) * CNTRCT(I)
C
C
C                    SHIFT MACHINE NAME
C
 3702 NMCHJ1(J) = NMCH1(I)
      NMCHJ2(J) = NMCH2(I)
      NMCHJ3(J) = NMCH3(I)
      IF ( CNTRCT(I) - 1.0 ) 55, 441, 612
  612 CALL ERROR ( 7, I, ERCNT )
      RETURN 1
  441 IF ( Q(I) .EQ. 0.0 ) GO TO 55
C
C
C                    COMPUTE OPERATION COSTS FOR COMPARISON WITH CUSTOM
C                    RATES
C
      FXDCST = 0.0
      IF ( SUMAC(J) ) 391, 393, 3921
  391 CALL ERROR ( 10, J, ERCNT )
      RETURN 1
 3921 FXDCST = FXDCST + FCPCTI(J) * PURI(J) / SUMAC(J)
  393 IF ( ACTOTA(I)) 391, 52, 3931
 3931 FXDCST = FXDCST + FCPCTA(I) * PURA(I) / ACTOTA(I)
C
C
C                    FIXED COST FOR THE IMPLEMENTS, IT IS PRORATED
C                    ACCORDING TO THE AREA WORKED FOR THIS OPERATION
C                    OVER THE TOTAL AREA WORKED BY THE IMPLEMENT
C
   52 COST1(I) =  W(J) * ACRESO(I) * FXDCST
C
C
C                    COST OF LABOR
C
      COST2(I) =  HO(I) * (XNTRSN(I) * XLABOR(I) * TPOWRD(I) / XTIMES(I)
     1+ XNOPS(I) * XNIMPS(J) )
C
C
C                    REPAIR AND MAINTENANCE COSTS FOR THE IMPLEMENTS
C
      COST3(I) = HO(I) * W(J) * (RMI(I) * PURIO(I) + RMA(I) * PURA(I) )
C
C
C                    COST OF TIMLINESS
C
      COST4(I) =  HO(I) * TIMLI(I) * CROPA(I) * YIELD(I) * VALUE(I) /
     1 XTIMES(I)
C
```

```
C
C                 COST OF REPAIR AND MAINTENANCE FOR THE TRACTOR
C
      COST5(I) =  HO(I) * TPOWRD(I) * RMTR * PURTR * Q(I) / XTIMES(I)
C
C
C                 COST OF OIL
C
      OIL(I,IFTYPE) = OIL(I,IFTYPE) +  HO(I) * OCSMPT(I) / XTIMES(I)
      OIL(I,IXTYPE) = OIL(I,IXTYPE) + HO(I) * OCSMPA(I)
      COST6(I) = OIL(I,1) * OPRICE(1) + OIL(I,2) * OPRICE(2) + OIL(I,3)
     1* OPRICE(3) + OIL(I,4) * OPRICE(4)
C
C
C                 FIXED COST OF THE TRACTORS, PRORATED ACCORDING
C                 TO THE ENERGY USED FOR THIS OPERATION OVER THE
C                 TOTAL ENERGY USED
C
      COST7(I) = SNRGOI(I) * FCPCTT * PURTR * TPOWRD(I) * Q(I)  /
     1(SMNRGP + SMNRGT + SMNRGO)
C
C
C                 COST OF FUEL
C
      FUELC(I,IFTYPE) = FUELC(I,IFTYPE) +   SNRGOI(I) * FEFFIC(I)
      IF ( AUXENG(I) .NE. 1.0 ) GO TO 521
      FUELC(I,IXTYPE) = FUELC(I,IXTYPE) + (0.022 * FFCTRX(I) * ACRESO(I)
     1/ (EFFIC(I) * AXLFTR(I) * 0.96 * DTOAHP(NSOIL(I)))+ HPHRTX(I) *
     2ACRESO(I) * YIELD(I) / AXLFTR(I) ) * FEFICX(I)
  521 COST8(I) = FUELC(I,1) * FPRICE(1) + FUELC(I,2) * FPRICE(2) +
     1FUELC(I,3) * FPRICE(3) + FUELC(I,4) * FPRICE(4)
C
C
C                 TOTAL COST, COSTIO
C
      COSTIO(I) = COST1(I) + COST2(I) + COST3(I) + COST4(I) + COST5(I)
     1+ COST6(I) + COST7(I) + COST8(I)
   55 CONTINUE
C
C
C     COMPARE OPERATION COST WITH CUSTOM COST
C     AND '...IF THE CUSTOM COST FOR ANY SINGLE OPERATION SHOULD
C     BE LOWER, AN  INDICATOR NUMBER FOR THAT OPERATION IS DEFINED AS
C     ZERO AND THE SOLUTION IS STARTED AGAIN.'  THE VARIABLE NAME FOR
C     THE INDICATOR NUMBER IS CNTRCT.
C
      DO 4000 I1 = 1, NMBROP
      IF ( XNDCTR(I1) .EQ. 0.0 ) GO TO 4000
      IF ( COMBID(I1) .NE. 0.0 ) GO TO 4200
      IF ( CNTRCT(I1) .EQ. 0.0 ) GO TO 4100
      IF ( COSTIO(I1) - COST4(I1) - CU(I1) - C .LE. 0.0 ) GO TO 4054
      CNTRCT(I1) = 0.0
      GO TO 99
 4100 COSTIO(I1) = CU(I1) + TIMLI(I1) * CROPA(I1) * YIELD(I1) *VALUE(I1)
     1/XTIMES(I1) * 8.25 * ACRESO(I1) / ( SPEED(I1) * WMAX(I1) *
     2EFFIC(I1))
      Z(I1) = CU(I1)
      COST4(I1) = COSTIO(I1) - CU(I1)
```

```
      GO TO 4054
 4200 DO 4500 I2 = 1, NMBROP
      IF ( COMBID(I1) .NE. XINDEX(I2) )GO TO 4500
      IF ( COMBID(I2) .NE. XINDEX(I1) ) GO TO 4500
      IF ( CNTRCT(I1) .EQ. 0.0 ) GO TO 4300
      IF ( COSTIO(I1) + COSTIO(I2) - COST4(I1) - COST4(I2) - CU(I1) -
     1C .GT. 0.0 ) GO TO 4550
      COSTIO(I1) = COSTIO(I1) + COSTIO(I2)
      COST1(I1) = COST1(I1) + COST1(I2)
      COST2(I1) = COST2(I1) + COST2(I2)
      COST3(I1) = COST3(I1) + COST3(I2)
      COST4(I1) = COST4(I1) + COST4(I2)
      COST5(I1) = COST5(I1) + COST5(I2)
      COST6(I1) = COST6(I1) + COST6(I2)
      COST7(I1) = COST7(I1) + COST7(I2)
      COST8(I1) = COST8(I1) + COST8(I2)
      GO TO 4054
 4300 COSTIO(I1) = CU(I1) + ( TIMLI(I1) + TIMLI(I2)) * CROPA(I1) *
     1YIELD(I1) * VALUE(I1)/XTIMES(I1) * 8.25 * ACRESO(I1)/(SPEED(I1) *
     2WMAX(I1) * EFFIC(I1))
      Z(I1) = CU(I1)
      COST4(I1) = COSTIO(I1) - CU(I1)
      GO TO 4054
 4550 CNTRCT(I1) = 0.0
      CNTRCT(I2) = 0.0
      GO TO 99
 4500 CONTINUE
      GO TO 4000
C
C
C                    SUM COSTS, HOURS, AND INVESTMENTS
C
C
C     'THE SUM OF THE INDIVIDUAL OPERATION COSTS IS THE COST OF THE
C     MACHINE SYSTEM AT THAT PARTICULAR POWER LEVEL AND IS CALLED SMCOST
C
 4054 SMCOST = SMCOST + COSTIO(I1)
      HT = HT + HO(I1)
 4000 CONTINUE
      DO 550 J = 1, NMBRIM
      TPP     = TPP     + PP(   J)
  550 CONTINUE
      PPTRAC = PURTR * HPMAX
      TPPI      = TPP + PPTRAC
C
C
C                    PRINT OUT POWER LEVEL ANSWERS
C
      CALL OUTPUT ( HPMAX, SMCOST, XNTRS )
      RETURN 2
      END
```

```
      SUBROUTINE WIDTH ( HPMAX, XNTRS )
C
C
C                CONTROLS SEARCH FOR OPTIMUM IMPLEMENT WIDTH.
C
C
C                HPMAX -- TOTAL TRACTOR HORSEPOWER AVAILABLE
C                XNTRS -- NUMBER OF TRACTORS IN FARM MACHINE SYSTEM
C
C
C                COMMON AREA OF INPUT DATA CODES FOR IMPLEMENTS,
C                FUELS, AND SOILS
C
      COMMON AFCODE(4), ICODE(4), NSCODE(4)
C
C
C                COMMON AREA OF SCALAR VARIABLES
C
      COMMON A, C, DLTAHP, ESTHPL, FCPCTT, HPPER, HT, KPAGE, NCROP, NM1,
     1NM2, NM3, NM4, NM5, NMBRIM, NMBROP, NMBRPR, NMBRTR, NPRNTR,PPTRAC,
     2PURTR, RMTR, SMNRGO, SMNRGP, SMNRGT, TFTYPE, TPP, TPPI, TRDNTT,
     3XLFTR, XLIFET
C
C
C                COMMON AREA OF ARRAY VARIABLES
C
      COMMON ACIMP(50), ACIMP1(50), ACIMP2(50), ACIMP3(50), ACIMP4(50),
     1ACIMP5(50), ACIMP6(50), ACIMP7(50), ACIMP8(50), ACRESO(50),
     2ACTOTA(50), ATTACH(50), AUXENG(50), AXHPLV(50), AXLFTR(50),
     3AXMXHP(50), BASUSD(50), CNTRCT(50), COMBID(50), COST1(50),
     4COST2(50), COST3(50), COST4(50), COST5(50), COST6(50), COST7(50),
     5COST8(50), COSTIO(50), CROPA(50), CUSTOM(50), CU(50), DBPPTW(4,4),
     6DISTR(50), DTOAHP(4), E(50), EFFIC(50), FCPCTA(50), FCPCTC(50),
     7FCPCTI(50), FEFFIC(50), FEFICX(50), FFACTR(50), FFCTRX(50),
     8FFCTRC(50), FPRICE( 4), FTYPF(50), FUELC(50,4), G(50)
      COMMON HO(50), HPHRTC(50), HPHRTI(50), HPHRTX(50), IMPCLS(50),
     1NCCODE(50), NMCH1(50), NMCH2(50), NMCH3(50), NMCHJ1(50),
     2NMCHJ2(50), NMCHJ3(50), NOP1(50), NOP2(50), NOP3(50), NPR1(50),
     3NPR2(50), NPR3(50), NPR4(50), NPR5(50), NSOIL(50), NTR1(50),
     4NTR2(50), NTR3(50), NTR4(50), NTR5(50)
      COMMON OCSMPA(50), OCSMPT(50), OIL(50,4), OPRICE( 4), PP(50),
     1PURA(50), PURI(50), PURIO(50), PURIC(50), Q(50), QA(50), RMA(50),
     2RMI(50), RMIC(50), RNATCH(50), RWNLS(4,4), SFTYPE(50), SNRGOI(50),
     3SNRGOC(50), SNRGP(50), SNRGT(50), SPDFF(50), SPEED(50), SPHP(50),
     4SPLFTR(50), SUMAC(50), SUMACC(50), TIMLI(50), TIMPMX(50),
     5TONSPR(50), TONSTR(50), TPOWRD(50), TRATIO(4), TREDUC(4),
     6TRDNTA(50), TRDNTI(50), VALUE(50), W(50), WC(50), WMAX(50), WS(50)
      COMMON XIMPL(50), XINDEX(50), X(50), XFTYPE(50), XLABOR(50),
     1XLIFEA(50), XLIFEI(50), XNDCTR(50), XNIMPS(50), XNIMPC(50),
     2XNOPS(50), XNTRSN(50), XTIMES(50), YIELD(50), Z(50)
C
C
C                FIND INITIAL INTERVAL OF UNCERTAINTY FOR IMPLEMENT
C                WIDTH
C
      DO 850 I = 1, NMBRIM
      IF ( TIMPMX(I) * WS(I) .EQ. 0.0 ) GO TO 96
      IF ( W(I) .EQ. 0.0 ) GO TO 99
```

```
      CALL IMPAC ( W(I), ACOST, I, HPMAX, XNTRS )
      GO TO 850
   96 W(I) = 0.0
      GO TO 850
C
C
C                   DEFINE MINIMUM WIDTH OF IMPLEMENT AS 0.1 FOOT
C
   99 W2 = 0.1
      CALL IMPAC ( W2, FW2, I, HPMAX, XNTRS )
C
C
C                   INITIALIZE TOTAL MAXIMUM WIDTH FOR IMPLEMENT EQUAL TO
C                   5.0 TIMES THE DESIRED MAXIMUM WIDTH OF A SINGLE
C                   IMPLEMENT UNIT
C
      W1 = WS(I) * 5.0
      IF ( TIMPMX(I) .EQ. 100.0 ) GO TO 31
      DO 100 J = 1, NMBROP
      IF ( X(I) .NE. XIMPL(J) * CNTRCT(J) ) GO TO 100
      IF (  TPOWRD(J) .NE. 1.0 ) GO TO 100
C
C
C                   FOR TRACTOR POWERED IMPLEMENTS REDUCE TOTAL MAXIMUM
C                   WIDTH TO SATISFY HORSEPOWER PER TRACTOR CONSTRAINT
C
      WLIMIT = XLFTR*(HPMAX/XNTRS)/(SPEED(J) * (FFACTR(J) + FFCTRC(J)) /
     1(360.0 * DTOAHP(NSOIL(J)))+ ( HPHRTI(J) + HPHRTC(J)) * YIELD(J) *
     2SPEED(J) * EFFIC(J) / 8.25 )
      IF ( WLIMIT .GT. WS(I) * TIMPMX(I)) WLIMIT = WS(I) * TIMPMX(I)
      IF ( WLIMIT * XNTRS .LT. W1 ) W1 = WLIMIT * XNTRS
  100 CONTINUE
C
C
C                   FOR TRACTOR POWERED IMPLEMENTS, REDUCE TOTAL MAXIMUM
C                   WIDTH TO SATISFY NUMBER OF IMPLEMENT UNITS PER
C                   TRACTOR CONSTRAINT
C
   31 NIMPS = W1 / WS(I) + 0.99999
      RNIMPS = NIMPS
      IF ( TIMPMX(I) .EQ. 100.0 ) GO TO 81
      IF ( XNTRS * TIMPMX(I) .GE. RNIMPS ) GO TO 81
      W1 = W1 - 0.5
      IF ( W1 .LT. 1.0 ) GO TO 850
      GO TO 31
C
C
C                   FOR IMPLEMENTS HAVING AUXILIARY ENGINES, REDUCE TOTAL
C                   MAXIMUM WIDTH TO SATISFY AUXILIARY ENGINE HORSEPOWER
C                   CONSTRAINT
C
   81 DO 110 J = 1, NMBROP
      IF ( X(I) .NE. XIMPL(J) * CNTRCT(J) ) GO TO 110
      IF ( AUXENG(J) .NE. 1.0 ) GO TO 110
      WLIMIT = AXMXHP(J) * AXLFTR(J) * RNIMPS / (SPEED(J) * FFCTRX(J) /
     1(360.0 * DTOAHP(NSOIL(J)))+ HPHRTX(J) * YIELD(J) * SPEED(J) *
     2EFFIC(J) / 8.25)
      IF ( WLIMIT .GE. W1 ) GO TO 110
```

```
      W1 = WLIMIT
      GO TO 31
  110 CONTINUE
      IF ( W1 .LT. 1.0 ) GO TO 850
      CALL IMPAC ( W1, FW1, I, HPMAX, XNTRS )
      WLRGE = W1
      WLOW = W2
      WHIGH = W1
      WRNGE = WHIGH - WLOW
      IF ( WRNGE .GT. 0.5 ) GO TO 190
      W(I) = W1
      IF ( FW2 .LE. FW1 ) W(I) = W2
      GO TO 825
C
C
C                USE FIBONACCI SEARCH TO FIND OPTIMUM IMPLEMENT WIDTH
C
C                INTERVAL OF UNCERTAINTY REMAINING AFTER SEARCH IS
C                0.5 FEET
C
  190 N = 1
      F0 = 1.0
      F1 = 1.0
      FN = 1.0
  191 IF ( 1.0 / FN .LE. 0.5 / WRNGE ) GO TO 192
      FN = F0 + F1
      F0 = F1
      F1 = FN
      N = N + 1
      GO TO 191
  192 W1 = F0 * WRNGE / FN + WLOW
      W2 = WLOW + WHIGH - W1
      CALL IMPAC( W1, FW1, I, HPMAX, XNTRS )
      CALL IMPAC ( W2, FW2, I, HPMAX, XNTRS )
      IF ( N .LE. 2 ) GO TO 197
      DO 195 M = 3, N
      IF ( FW1 .GE. FW2 ) GO TO 196
      WLOW = W2
      W2 = W1
      FW2 = FW1
      W1 = WLOW + WHIGH - W2
      CALL IMPAC ( W1, FW1, I, HPMAX, XNTRS )
      GO TO 195
  196 WHIGH = W1
      W1 = W2
      FW1 = FW2
      W2 = WLOW + WHIGH - W1
      CALL IMPAC ( W2, FW2, I, HPMAX, XNTRS )
  195 CONTINUE
  197 W(I) = W2
      IF ( FW2 .GE. FW1 ) W(I) = W1
  825 IF ( W(I) .LT. 1.0 ) GO TO 850
      DO 55 I1 = 1, NMBROP
      IF ( COMBID(I1) * CNTRCT(I1) .EQ. 0.0 ) GO TO 55
      IF ( XIMPL(I1) .NE. X(I) ) GO TO 55
      DO 50 I2 = 1, NMBROP
      IF ( COMBID(I1) .NE. XINDEX(I2) * CNTRCT(I2) ) GO TO 50
      IF ( COMBID(I2) .NE. XINDEX(I1) ) GO TO 50
```

```
      I3 = XIMPL(I2)
      IF ( XIMPL(I2) .GT. XIMPL(I1) ) W(I3) = W(I)
   50 CONTINUE
   55 CONTINUE
  850 CONTINUE
C
C
C                   IF OPTIMUM WIDTH IS LESS THAN 1.0 FOOT, SET IMPLEMENT
C                   WIDTH TO 0.0
C
      DO 900 I = 1, NMBRIM
      IF ( W(I) .LT. 1.0 ) W(I) = 0.0
      CALL IMPAC ( W(I), ACOST, I, HPMAX, XNTRS )
  900 CONTINUE
      RETURN
      END
```

OPTIMIZATION OF FARM EQUIPMENT SELECTION

by

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AN ABSTRACT OF A MASTER'S THESIS

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A computer program which performs an economic analysis of farm machine systems was obtained from Donnell Hunt. The program selects tractor horsepower level and implement widths which minimize the total annual cost of operation of the machine system.

Hunt's program has been improved so that computer time is used more efficiently and its applicability has been increased. Input parameters required describe the type of implements and field operations in the farm machine system. The program has been revised so that it is now possible to select a fuel type for every engine, use energy requirements for PTO driven equipment, and use tractor drawbar performance information in determining drawbar horsepower requirements. The program has been re-designed as a set of subroutines which use several optimization techniques used in management science.

Information received from the program has also been increased. Information concerning tractors includes optimum horsepower level, initial investment cost, annual cost of tractor operation, fuel and oil consumption rates for each field operation, and an estimate of tractor weight needed for optimum tractor drawbar performance. For each implement type, recorded information includes optimum width, initial investment cost, and annual operating expense.

The program was validated by analyzing solutions suggested by the program for existing farm machine systems.