AN EXPERT SYSTEM TO MANAGE SELECTION OF TRACTOR IMPLEMENT SYSTEMS

By

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IMPLEMENT SYSTEMS

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NOMENCLATURE

%FWD	ratio of dynamic weight on front axle to total tractor weight
%FWS	ratio of static weight on front axle to total tractor weight
2WD	two-wheel-drive tractor
4WD	four-wheel-drive tractor
Ballast1	the first part of the Ballasting Program that receives all tractor and tire information
Ballast2	the second part of the Ballasting Program that recommends the right decision
BNF	mobility number for front tire
BNR	mobility number for rear tire
BPRESSURE	DBase III Plus file which contains bias tire sizes and loads at various inflation pressures
cacl2	calcium chloride
DBHP	tractor drawbar horsepower (HP)
DBHT	drawbar height above ground (in)
DRAFT	implement draft (lb)
EDRAFT	estimated soil draft (lb/ft)
EFWS	estimated static front axle weight(lb)
ERWS	estimated static rear axle weight (lb)
Fcacl2	the weight of cacl2 inside front tire (lb)
FOD	overall diameter of front tire (in)
Fsecw	front tire section width (in)
FSW	maximum weight that front tire can carry (lb)

FTIRE	DBase III Plus file which contains required front tire information
FWA	front wheel assist tractor
Fwater	the weight of water inside front tire (lb)
FWD	dynamic front axle weight (lb)
FWS	static front axle weight (lb)
HP	horsepower
lb	pound
LP	linear programing
Main Expert	an expert program for controlling the Expert System
Matching	an expert program for matching implement with tractor
MWF	front motion resistance ratio
MWR	rear motion resistance ratio
OS	operating speed (miles per hour)
P	drawbar pull (lb)
psi	pounds per square inch
PTOHP	tractor PTO horsepower (HP)
QRWF	front torque ratio
QRWR	rear torque ratio
Rcacl2	the weight of cacl2 inside rear tire (lb)
ROD	overall diameter of rear tire (in)
RPRESSURE	DBase III Plus file which contains radial tire sizes and loads at various inflation pressures
Rsecw	rear tire section width (in)
RSW	maximum weight that rear tire can carry (lb)
RTIRE	DBase III Plus file which contains required rear tire information
Rwater	the weight of water inside rear tire (lb)

RWD	dynamic rear axle weight (lb)
RWS	static rear axle weight (lb)
SLIP	wheel slip (% of travel speed)
SOIL-DRAFT	DBase III Plus file which contains estimated draft per unit width for some typical soil conditions and implements
SYSTEM	tractor type (2WD, 4WD, FWA)
TE	tractive efficiency (% [DBHP/PTOHP])
Tire1	the first part of Tire Selection Program that finds the optimum tire type
Tire2	the second part of Tire Selection Program that finds the optimum tire configuration and tire size
TRACTOR	DBase III Plus file which contains required tractor information
TRACTOR_PULL	tractor drawbar pull (lb)
TWD	static tractor weight (lb)
TWS	dynamic tractor weight (lb)
WB	tractor wheelbase (in)
WIDTH	implement width (ft)

CHAPTER I

INTRODUCTION

The tractor is perhaps the most important tool in agriculture. Though tractors are both expensive and difficult to manage, farmers in the U.S. are often not trained to use tractors efficiently. The problem is even more acute in other countries, especially third world countries.

To help farmers overcome their difficulties in using tractors, many technical papers and much software dealing with tractor management have been produced. Usually, each of these systems is designed to help farmers with one or two tractor management problems such as ballasting, selecting tires, implement matching, selecting tractor size, operation and maintenance, and estimating purchase and operating costs.

Currently, technical specialists are developing "expert systems" which will be more comprehensive in dealing with problems in agriculture. An expert system is a computer program that solves problems in the same way that an expert would do in his field of expertise. Expert systems allow users to become more knowledgeable about a problem as they interact with the program. Expert system development employs backward and forward chaining, while only forward chaining is used in conventional computer programs. In backward chaining, the expert system starts with goals, and works backward via rules to determine what initial data are required for the goals to be satisfied. Initial data must be provided before rules can be tested in forward chaining. Expert systems can deal with uncertainty. Expert knowledge is coded into a "knowledge base" which provides the "intelligence" on which decisions are made. Though expert systems can deal with problems that have particular solutions, typically they deal with problems that have many possible solutions. Conventional computer programs usually deal only with problems that have definite solutions. The expert system interacts with the user, gathering information necessary to determine which element of the knowledge base applies.

Statement of Problem

Though there are many technical papers and computer programs (software packages) available to farmers for managing tractors, it is often difficult to make a comprehensive management decision based on any single source of information. Conventional computer programs tend to be generic in providing information. Also, if several problems are included, computer programs become more complex in structure. Tractor management software is difficult for farmers to use, because it often requires information they may not know. While the software requires technical information from the user, it may not provide enough details for him to understand the problem. Finally, there is no specific tire selection program to help select the right tire type for a particular application.

Objectives

To solve the above problems, an Expert System and knowledge base was developed to provide all the information that a farmer would need in making a typical management decision for tractor-implement systems.

The main objective of the project was to consolidate several tractor management functions into one package.

Specific management areas included in the Expert System were:

A) Ballasting the tractor

B) Matching the tractor with the implement

C) Selecting drive tires

D) Finding the correct tire pressure.

A related objective for the Expert System was education. Besides helping the farmer make the right decision, the system can educate the user through explanatory features. The Expert System uses simple sentences to explain complex knowledge base details in a manner the farmer can understand.

Scope and Limitation

This project is comprehensive enough to help farmers make prudent choices on tire selection, ballasting, and implement matching. The project was specifically confined to John Deere tractors of 100 HP and above, because of the time limitations.

Software Packages

VP-Expert and DBase III Plus were used to develop the Expert System. VP-Expert is a software package developed to build an expert knowledge base on IBM personal or compatible computers. It has many features that allow development of an expert system. DBase III Plus was used to build data files for the Expert System.

CHAPTER II

LITERATURE REVIEW

Introduction

There is much information available on making recommendations for tire selection, ballasting, implement matching, and tire pressure. However, researchers continue efforts to increase tractor efficiency and performance.

Ballasting

Zoz (1972) developed a graphical method to predict travel speed, drawbar pull, drawbar horsepower, slippage, and tractive efficiency for various soil conditions. The graph is useful to estimate ballast requirements, but applies only to two-wheel-drive (2WD) tractors.

Wismer and Luth (1974) developed a set of prediction equations for single tires under different soil conditions and tire characteristics. Macnab, et al. (1977) used Wismer and Luth's equations to develop a FORTRAN computer program to model tractive performance of both two and four wheel-drive tractors.

Brixius (1987) improved prediction of tractor performance and extended the range of application to bias ply tires. He revised Wismer and Luth's equations. Zoz

(1987) used Brixius' equations to develop Lotus 1-2-3 templates that can predict tractor performance for both two and four wheel-drive tractors (including front wheel assist tractors). These templates have two modes: "performance" mode, to calculate drawbar performance and slippage given static axle weights and tire parameters, and "weight" mode, to calculate the required tractor axle weights for a given slippage and desired front axle dynamic weight.

Evans, et al. (1989), using Brixius' equations (1987), developed a traction prediction and ballast model using TK Solver (software package to solve equations). The slippage parameter in Brixius' equations was changed from -7.5 to -3.78 to more accurately predict the pull on a grass surface.

Bashford (1975) estimated total tractor weight requirements for typical Nebraska firm and tilled soils. He showed that 67 to 79 kg/kw (110 to 130 lbs/hp) were needed for light draft operations, 79 to 94 kg/kw (130 to 155 lbs/hp) for average draft, and 94 to 122 kg/kw (155 to 200 lbs/hp) for heavy draft operations. Shell and Batey (1987) reported that the axle weight ratio should be varied depending on the size of tractors. They found the optimum axle weight ratio for heavy tractors (100 kg/rated PTO-kw (165 lb/PTO hp)) to be 55% on the rear axle, for medium tractors (94 kg/rated PTO-kw (155 lb/PTO hp)) to be 60% on the rear axle, and for light tractors (88 kg/rated PTO-kw (145 lb/PTO hp)) to be 65% on the rear axle.

Pacey and Shrock (1981) showed that the front axle weight ratio of a four-wheel-drive (4WD) tractor should be between 55% and 60%. Kraving (1986) reported that 65% of the tractor weight should be on the front axle.

Bashford, et al. (1985) found the best tractive efficiencies for a front-wheel-assist (FWA) tractor occurred when 60% to 55% of the total weight was on the rear axle. They also found that tractive efficiency was most sensitive to axle weight distribution for operation on loose soil rather than firm soil or concrete.

Bashford (1975) and Pacey and Shrock (1981) found that optimum axle weight ratio for 2WD tractors was 25% of total weight on the front axle for towed implements. The optimum ballast was a function of soil type, speed, and tractor power.

Tires

Much research has been done on the radial tractor tire since it was introduced. Kraving (1986) reported some of advantages for radial tires over bias ply tires:

1) Increased tire footprint
2) Higher tractive efficiency
3) Reduced wheel slippage
4) Smoother ride in the field
5) Reduced fuel consumption
6) Increased productivity

The main disadvantage identified for radial tires was cost. However, reduced fuel consumption and increased field productivity frequently offset higher initial cost. Pacey (1984) presented an example cost analysis to calculate hours required for simple payback on the cost difference. Coates (1984) found no significant advantage in using radial tires on a soft soil.

Bashford, et al. (1987) tested the performance of a FWA tractor in plowed wheat stubble, disked wheat stubble, and disked sandy soil conditions. They found no significant difference in the performance of a FWA tractor with dual tires and a FWA tractor with single tires. Jurek and Newendrop (1983) found only a 2% to 3% improvement in fuel economy when using dual tires over single tires on a 2WD tractor in tilled soil, and 4% to 8% improvement in untilled soil. They concluded that dual tires provide more benefit when they are used with 2WD tractors than with FWA tractors. Kucera, et al. (1985) tested 2WD and FWA tractors both with dual and single tires under varying soil and load conditions. They concluded that a FWA tractor with dual tires used 3% to 11% more fuel than a FWA tractor with single tires. According to Bashford, et al. (1987) the major advantages of dual tires are handling tractor load and floatation to reduce compaction.

Tire Pressure

Researchers have recognized the effects of inflation pressure and dynamic load for many years. Mckibben and Davidson (1940) reported that inflation pressure is one of the most important factors affecting motion resistance of unpowered pneumatic tires. Kliehefoth (1966) and Zombori (1967) studied the effects of inflation pressure on the performance of bias-ply tractor tires. They showed that a decrease in inflation pressure resulted in an increase in drawbar pull at constant slip. Burt and Bailey (1982) experimentally optimized the tractive efficiency for a radial-ply tractor tire. Results show that tractive efficiency can be significantly improved by selecting appropriate levels of inflation pressure and dynamic load for a particular soil condition.

Pacey and Shrock (1981) stated that the maximum load of the tire must decrease when inflation pressures decrease. Tire manufacturers set guidelines for tire inflation pressures and loads. The user should not exceed load recommendations.

Esch and Bashford (1987) tested the tractive performance of a tractor operating on different soil conditions with changing tire pressures. They did not find a significant difference in tractive performance. The air pressure in the inside dual was held at 110 KPa (16 psi) and in the outside dual was varied from 83 KPa (12 psi) to 138 KPa (20 psi). Kraving (1986) reported that the outer dual mostly provides stability and flotation and the inner dual is the primary drive tire. He suggested that the outer dual should be inflated 13 KPa (2 psi) lower than the inside dual as long as the maximum load for that pressure is not exceeded.

Expert Systems

Kline, et al. (1986) used Texas Instruments PCplus to develop FINDS (Farm-Level Intelligent Decision Support System), a program for machinery selection that expanded LP methods (McCarl, 1982). FINDS helps users select the right machine and size to increase farm profit. The authors structured FINDS into three environments: Lisp, which contains two frames (Model running and Model interpreter), DBase III Plus, and REPFRAM (1982) (five main FORTRAN modules) environments. PCplus provides good communication between the LISP functions and the DBase III Plus environments.

Clarke, et al. (1989) developed an expert system, "IRRIGATOR" for scheduling supplemental irrigation in Ontario (a sub-humid region). The authors used PCplus to develop "IRRIGATOR".

Gauthier and Guay (1989) developed an expert system to diagnose disorders of greenhouse tomatoes. The expert system can handle both biotic and abiotic disorders, determine the cause of disorders, and recommend solutions. The project was limited to six diseases. The authors used

Common LISP with 20 rules and 160 instances, in an object-oriented environment. The expert system can be expanded and easily maintained.

Gaultney, et al. (1989) developed an expanded expert system for trouble shooting tractor hydraulic systems. The authors provided the knowledge base from the hydraulic diagnosis manual for the John Deere 50 Series tractor, and limited the knowledge base to the hydraulic diagnosis manual with a quad-range transmission. The researchers followed the 56 steps in the manual to develop the expert system. Rules were grouped into 19 frames using PCplus.

CHAPTER III

KNOWLEDGE BASED SYSTEM

Introduction

A block diagram of the knowledge base system (KBS) is shown in figure 3.1. The knowledge base is composed of five rule groups: Main Expert, Ballasting, Implement Matching, Rear Tire Selection, and Tire Pressure.

Main Expert

This section of the Expert System provides control of the other Expert System files by guiding the user in selecting the specific program (file) desired.

Ballasting Program

The ballasting rule group estimates the static front and rear axle weights, then calculates the dynamic front and rear axle weights at an indicated speed. To minimize processing time , the ballasting rule group has been divided into two parts (programs): Ballast1 and Ballast2.

Ballasting uses Zoz's (1970) and Brixius' (1987) equations. All the required tractor and tire information was stored in DBase III Plus files called TRACTOR and TIRE, respectively.

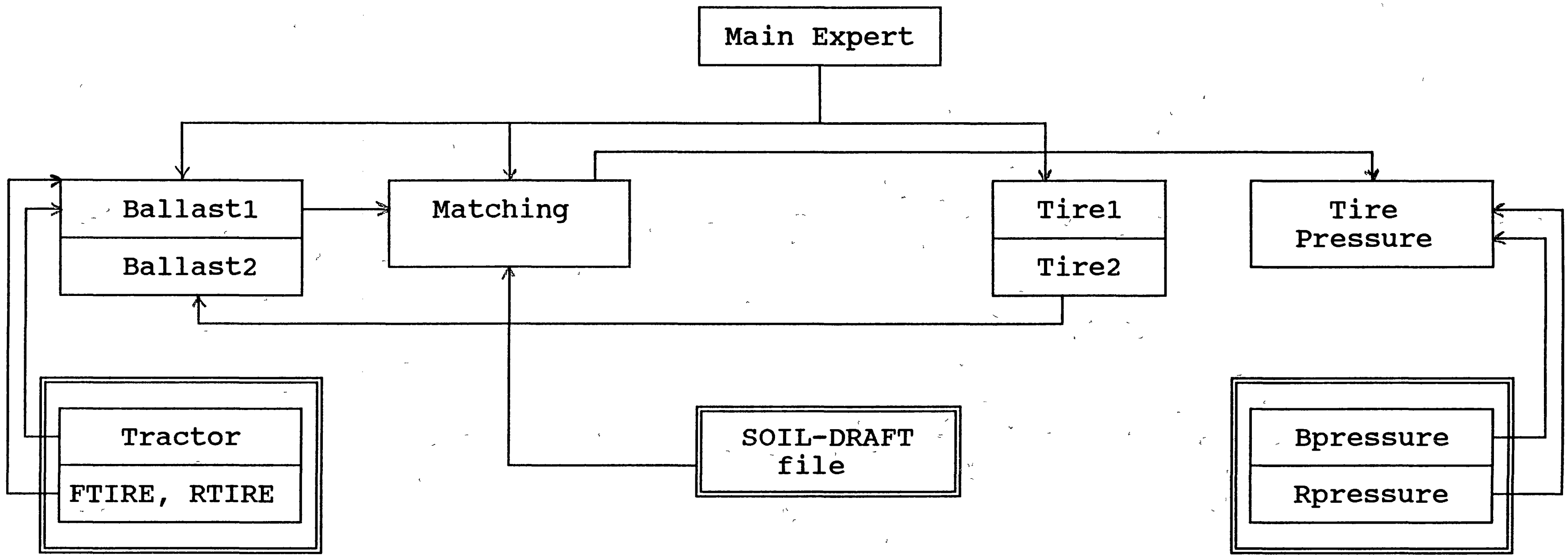

Figure 3.1 Main System Knowled Base

TRACTOR File

TRACTOR file contains the following required tractor information: wheel base, estimated front and rear axle weight, drawbar height, tractor PTO-horsepower, and tractor type. All the above information was taken from Nebraska Tractor Tests (N.T.T 1982). However, this file was limited to John Deere tractors with 100 PTO-horsepower or higher because of time limitations (Table I).

TIRE File

TIRE file contains required tire information: tire section width, overall diameter, maximum load, and the weights of water and cacl2 that the tire can carry. All the information was taken from the tire selection table for Agricultural Machines of Future Design (ASAE S220.4). TIRE file has been divided into two files: FTIRE (Front Tire) and RTIRE (Rear Tire) files because VP-Expert can not read the same data from one file two times (Table II and III).

TABLE I

TRACTOR DATA

MAKE	MODEL	WB[1]	PTOHP[2]	RWS[3]	FWS[4]	DBHT[5]	SYSTEM[6]
JOHN-	4050	106.7	105	9170	3550	22.5	2WD
DEERE	4250	106.7	120	10065	3790	24.5	2WD
	4450	106.7	140	11165	3790	22.0	2WD
	4650	118.5	165	13650	4935	24.5	2WD
	8450	125.0	186	14230	14920	17.5	4WD
	8650	125.0	238	14310	15960	17.5	4WD
	8850	133.0	304	15340	22360	17.0	4WD

1. tractor wheelbase (in)
2. tractor PTO horsepower (hp)
3. static rear axle weight (lb)
4. static front axle weight (lb)
5. drawbar height above ground (in)
6. tractor type (2WD, 4WD, FWA)

TABLE II

FRONT TIRE DATA

SIZE	FSW[1]	FSECW[2]	FOD[3]	FWATER[4]	FCACL2[5]
6.0-16	1260	6.26	29.02	0.0	0.0
7.5-15	1590	8.19	29.49	0.0	0.0
7.5-16	1650	8.15	31.5	0.0	0.0
7.5-18	1790	7.91	33.82	0.0	0.0
7.5-20	1930	7.91	35.83	0.0	0.0
9.5L-15	1700	9.80	30.12	0.0	0.0
9.5-20	2770	9.61	38.58	0.0	0.0
10.0-16	2130	10.59	34.80	0.0	0.0
11.0L-15	1910	11.5	31.89	0.0	0.0
11.0-16	3780	12.40	38.11	0.0	0.0
11.2-24	2310	11.2	43.39	200	237
12.4-24	3120	12.4	45.79	250	308
12.4-42	3440	11.54	63.82	400	486
13.6-28	4210	13.86	51.42	359	439
13.6-38	3660	13.82	61.10	475	581
14.9-24	3880	14.41	49.80	392	474
14.9-26	4530	14.80	51.89	400	486
14.9-28	4680	14.69	54.02	442	545
14.9-30	4830	14.88	55.51	475	568
15.5-38	5110	15.51	61.61	550	663
16.9-24	4920	17.20	52.09	509	616
16.9-26	5080	17.20	54.09	542	663

TABLE II (Continued)

SIZE	FSW[1]	FSECW[2]	FOD[3]	FWATER[4]	FCACL2[5]
16.9-28	5250	16.81	55.59	575	699
16.9-30	5410	16.42	58.50	609	746
16.9-34	5250	17.60	62.52	684	829
16.9-38	5560	17.20	66.81	751	912
18.4-26	5830	18.31	56.89	659	805
18.4-28	4530	17.91	59.41	701	852
18.4-30	5330	18.40	61.42	742	912
18.4-34	5650	18.74	65.20	834	1007
18.4-38	7880	18.9	69.09	917	1113
18.4-42	7360	18.39	73.39	959	1160
20.8-34	6440	21.30	68.58	1068	1291
20.8-38	7670	20.98	72.60	1168	1421
20.8-42	8090	20.79	76.42	1234	1503
23.1-26	6280	23.03	63.31	1068	1291
23.1-30	6690	23.66	66.81	1193	1457
23.1-34	7110	23.58	71.18	1326	1610
24.5-32	8700	24.88	71.30	1418	1729
30.5L-32	9120	30.51	71.60	1809	2202

1. maximum weight that front tire can carry (lb)
2. front tire section width (in)
3. overall diameter of front tire (in)
4. the weight of water inside front tire (lb)
5. the weight of calcium chloride inside front tire (lb)

TABLE III

REAR TIRE DATA

SIZE	RSW[1]	RSECW[2]	ROD[3]	RWATER[4]	RCACL2[5]
12.4-24	3120	12.4	45.79	250	308
12.4-42	3440	11.54	63.82	400	486
13.6-28	4210	13.86	51.42	359	439
13.6-38	3660	13.82	61.10	475	581
14.9-24	3880	14.41	49.80	392	474
14.9-26	4530	14.80	51.89	400	486
14.9-28	4680	14.69	54.02	442	545
14.9-30	4830	14.88	55.51	475	568
15.5-38	5110	15.51	61.61	550	663
16.9-24	4920	17.20	52.09	509	616
16.9-26	5080	17.20	54.09	542	663
16.9-28	5250	16.81	55.59	575	699
16.9-30	5410	16.42	58.50	609	746
16.9-34	5250	17.60	62.52	684	829
16.9-38	5560	17.20	66.81	751	912
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18.4-30	5330	18.40	61.42	742	912
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TABLE III (Continued)

SIZE	RSW[1]	RSECW[2]	ROD[3]	RWATER[4]	RCACL2[5]
20.8-34	6440	21.30	68.58	1068	1291
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23.1-26	6280	23.03	63.31	1068	1291
23.1-30	6690	23.66	66.81	1193	1457
23.1-34	7110	23.58	71.18	1326	1610
24.5-32	8700	24.88	71.30	1418	1729
30.5L-32	9120	30.51	71.60	1809	2202

1. maximum weight that rear tire can carry (lb)
2. rear tire section width (in)
3. overall diameter of rear tire (in)
4. the weight of water inside rear tire (lb)
5. the weight of calcium chloride inside rear tire (lb)

Ballast1 Program

A block diagram of Ballast1 knowledge base, which calculates static front and rear axles weight, is shown in Figure 3.2. Ballast1 begins by calling TRACTOR, FTIRE, and RTIRE files, and receiving all tractor and tire information. Information from the TRACTOR file is obtained after the make and model of the tractor are input by the user. FTIRE and RTIRE files are accessed by the size of front and rear tires, respectively. Ballast1 then continues to check for situation information such as:

1. Is there additional iron weight on front and rear axles?
2. Does the tractor have dual or single tires?
3. Is there water or cacl2 inside the tire?

Ballast1 can estimate the static front and rear axle weights, if the user does not know them, and the ratio of static weight on the front axle (%FWS) based on the above information. However, the user can change the ratio of static weight on the front axle (%FWS), thus changing the estimation of static front and rear axle weights. Ballast1 saves the results, and then calls Ballast2 program.

Ballast2 Program

A block diagram of Ballast2 knowledge base, which estimates the tractor drawbar pull and the tractor weight at a given operating (indicated) speed and slippage, is shown in Figure 3.3.

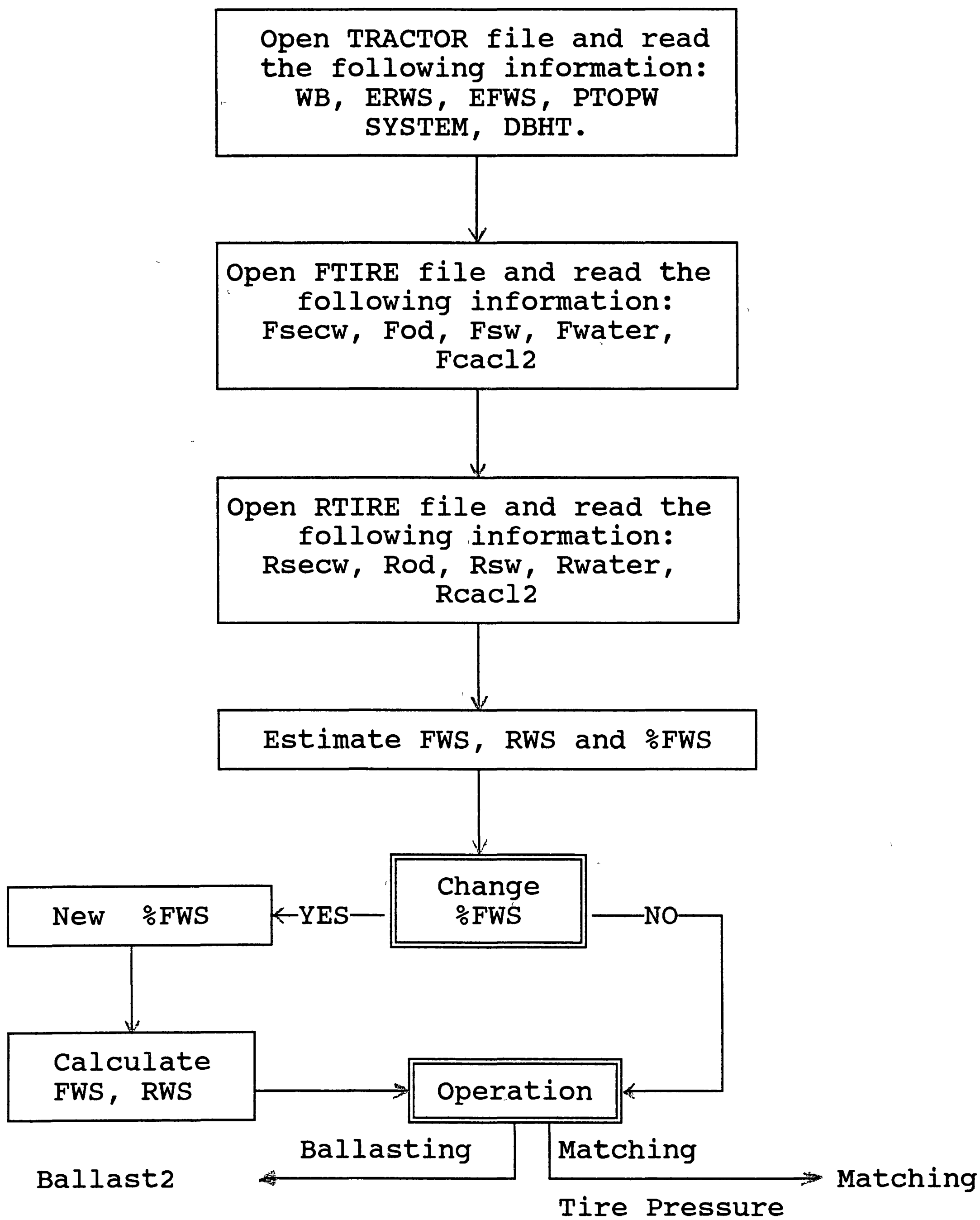


Figure 3.2. Ballast1 Knowledge Base

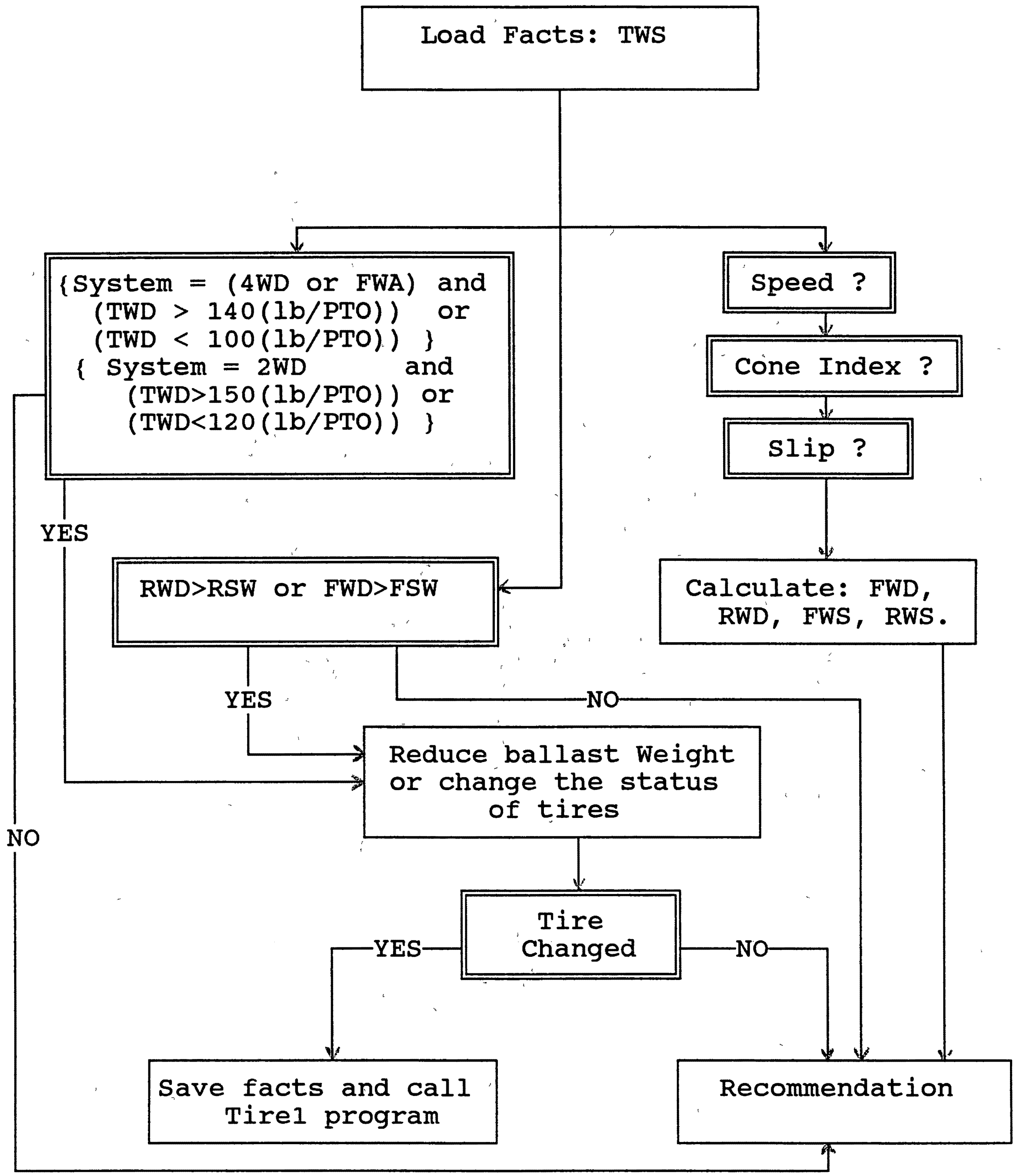


Figure 3.3. Ballast2 Knowledge Base

Ballast2 program starts by loading TWS data from Ballast1. The user is asked about operating speed, slip, and soil cone index for the field. Information is shown to assist in estimating the cone index and slip if they are not known (Table IV and V).

TABLE IV

CONE INDEX ESTIMATION

Cone Index	Soil condition
250	Hard, packed
200	Hard, packed with stubble
150	Firm
80	Tilled
60	Soft, wet

Ballast2 can make several recommendations depending on the following points:

1. Reduce rear or front axle weight if it is over the maximum tire load, or change size.
2. Reduce ballasting weight if the tractor is 2WD and total tractor weight is over 150 lb/PTOHP.
3. Reduce ballasting weight if the tractor is 4WD or FWA and the total tractor weight is over 140 lb /PTOHP.

TABLE V

ESTIMATION OF SLIPPAGE

Soil	Tractor Type		
	2WD	FWA	4WD
Firm	10-12	8-10	8-10
Tilled	12-14	10-11.5	10-11.5
Sandy	14-16	11.5-13	11.5-13

Finally, Ballast2 saves facts, then quits or accesses Tire Selection, Tire Pressure, or Matching program.

Matching Program

A block diagram of Implement Matching program knowledge base is shown in Figure 3.4. This section of the Expert System estimates tractor speed and slip at a given drawbar pull, tractor speed and drawbar pull at a given slip, and drawbar pull and slip at a given indicated speed. Matching program estimates the above twice. The first estimate is based on the current tractor weight, and the second is based on the optimum tractor weight. The optimum tractor weight is defined as 125 lb/PTOHP for 4WD tractors and 140 lb/PTOHP for 2WD tractors.

Matching program starts by obtaining implement draft from the user or SOIL-DRAFT file (Table VI, p28).

$$DRAFT = EDRAFT * WIDTH \qquad 1$$

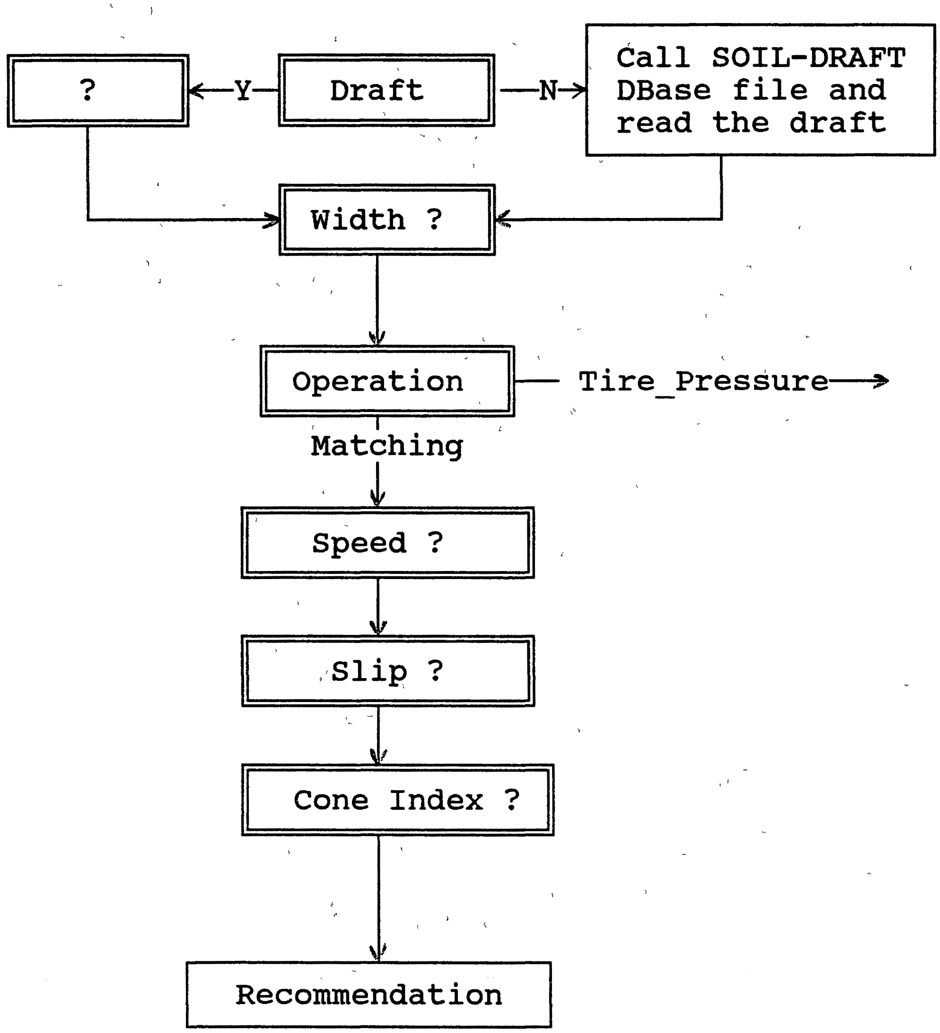


Figure 3.4 Matching Knowledge Base

where

DRAFT Implement draft (lb)

EDRAFT Estimated draft per unit (lb/ft)

WIDTH Implement width (ft).

However, if the user does not know the implement draft and is not sure about the data in SOIL-DRAFT file, an estimated implement draft will be used (Table VII, p29).

Matching program uses the implement draft to calculate RWD (dynamic rear axle weight) and FWD (dynamic front axle weight) and estimates the tire slippage based on the P (tractor drawbar pull). The tractor has been assumed to be loaded at 75% of full load.

$$P = DRAFT / 0.75 \tag{2}$$

$$FWD = FWS - (P*DBHT/WB) \tag{3}$$

$$RWD = RWS + (P*DBHT/WB) \tag{4}$$

$$BNR = (CI*RSECW*ROD**(A)/(RWD/2))* ((1+5*.18)/(1+3*RSECW/ROD)) \tag{5}$$

$$SLIP = (LN[1-(375*PTOHP*POEFF/(OS*RWD) - 0.04)/0.88/ (1 - EXP(-0.1*BNR))]/-7.5)*100 \tag{6}$$

Matching program uses Zoz's (1972) equations (3,4) to calculate FWD and RWD, where the draft angle was estimated to be zero for towed implements connected to the drawbar. Zoz's equations then take the form of equations 3 and 4. To calculate BNR and SLIP, Matching uses Brixius' (1987) equations 5 and 6.

At this point, Matching program may access the Tire Pressure program after saving the DRAFT data, or check the implement matching based on the user's choice in Main Expert. The tractor drawbar pull will be matched with the required implement draft based on the following Brixius' (1987) equations:

```
QRWR = 0.88*(1-EXP(-0.1*BNR))*
       (1-EXP(-7.5*(SLIP/100)))+0.04                          7
MWR = ((1/BNR)+0.04+0.5*(SLIP/100)/SQRT(BNR)                  8
QRWF = 0.88*(1-EXP(-0.1*BNF))*
       (1-EXP(-7.5*(SLIP/100)))+0.04                          9
MWF = ((1/BNF)+0.04+0.5*(SLIP/100)/SQRT(BNF)                  10
TRACTOR_PULL = (((QRWR-MWR)*RWD)-(((1/BNF)+0.04)*FWD))        11
            for 2WD tractors, OR
TRACTOR_PULL = ((QRWR-MWR)*RWD)+((QRWF-MWF)*FWD)              12
            for 4WD and FWA tractors.
```

SOIL-DRAFT File

SOIL-DRAFT file is a DBase III Plus file containing estimated draft per unit width for some typical soil conditions and implements for areas of Western Oklahoma (Table VI) (Downs). SOIL-DRAFT data can be easily expanded or changed.

TABLE VI

OKLAHOMA IMPLEMENT DRAFT

Soil Condition	Implement	Draft(lb/ft) of implement width
Tuttle silt loam	Moldboard plow	618
	Chisel	345
	Chisel with sweeps	253
	Tandem disk	289
Pulaski fine sandy loam	Chisel	262
	Offset disk	262
	V-blade	203
Meno loamy fine sand	Chisel	227
	Offset disk	246
	Tandem disk	251
	V-blade	367
Port silt loam	Moldboard plow	475
	Chisel	236
	V-blade	358
	Offset disk	246
	Tandem disk	291

TABLE VII

IMPLEMENT DRAFT

Implement	Draft(lb/ft) of implement width
Moldbard plow	547
Chisel	268
Chisel with sweeps	253
Tandem disk	277
Offset disk	251
V-blade	309

Tire Pressure Program

A block diagram of the Tire Pressure knowledge base is shown in Figure 3.5. This section of the Expert System was developed to recommend a tire pressure for specific operating conditions.

Tire Pressure starts by determining dynamic load, tractor type, and tire conditions (dual or single, and bias or radial) from Ballasting and Matching. The tire pressure then will be read from TIRE PRESSURE files.

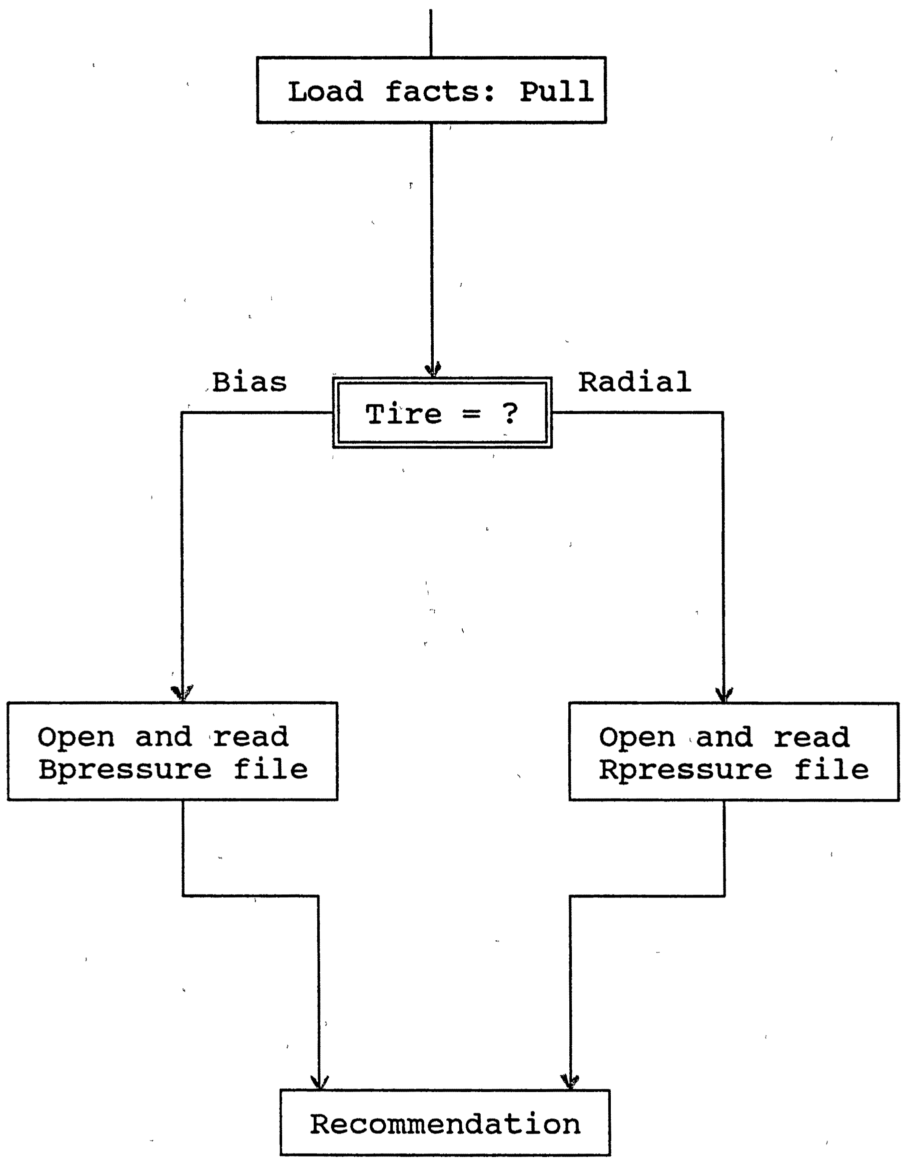


Figure 3.5. Tire Pressure knowledge base

TIRE PRESSURE File

TIRE PRESSURE files are two DBase III Plus files that contain tire loads at various inflation pressures, one for bias tires and the other for radial tires (Tables VIII and IX) (ASAE S430).

TABLE VIII

AGRICULTURAL TRACTOR BIAS TIRE LOADINGS AND INFLATION PRESSURE

Tire size Designation	psi 12	psi 14	psi 16	psi 18	psi 20	psi 22	psi 24	psi 26	psi 28
8.3-16	720	790	850	910	970	1030	1080	1130	
8.3-24	970	1060	1150	1230	1310	1380			
9.5-16	910	1000	1080	1160	1230	1300	1370	1430	
9.5-24	1210	1330	1430	1540	1630	1730	1820	1910	
11.2-24	1470	1610	1740	1860	1980	2090	2200	2310	
11.2-28	1570	1850	1990						
11.2-36	1770	1930	2090	2240					
11.2-38	1820	1990	2150	2300					
12.4-16	1350	1480	1590	1710	1820	1920	2020	2120	
12.4-24	1760	1920	2080	2230	2370	2510	2640	2760	
12.4-28	1880	2050	2220						
13.4-36	2110	2310	2500						
12.4-38	2170	2380	2570	2760	2930	3100	3260		
13.6-24		2270	2450	2630	2790	2960	3110	3260	3400
13.6-28	2210	2420	2620	2800	2980	3150	3320	3480	3630
13.6-38		2810	3030	3250	3460	3660			
13.9-36		2740	2960	3170	3370				
14.9-24	2470	2700	2920	3130	3330	3520	3710	3880	
14.9-26		2790	3020	3240	3440	3640	3830	4010	
14.9-28		2890	3120	3340	3560	3760	3960	4140	
14.9-30		2980	3220	3450	3670				
14.9-38		3350	3620	3880	4120				
15.5-38		3160	3410	3660	3890				
16.9-24	3000	3280	3550	3880	4040	4270	4500	4710	4920
16.9-26	3100	3390	3660	3920	4170	4410	4640	4870	5080
16.9-28			3780	4050	4310	4560	4800	5030	5250
16.9-30			3900	4180					
16.9-34			4150	4440					
16.9-38			4390	4700	5000	5290	5560		
18.4-16	2370	2600	2810	3010	3200				
18.4-24			4240	4550	4840	5110	5380	5640	
18.4-26	3710	4060	4380	4700	5000	5280	5560	5830	
18.4-28			4530	4850	5160	5460	5740	6020	
18.4-30			4670	5010	5330				
18.4-34			4960	5320	5650				
18.4-38			5250	5630	5980	6330	6660	6980	
18.4-42			5540	5930	6310	6670	7020	7360	
20.8-34			6010	6440					
20.8-38			6360	6820	7250	7670			
20.8-42			6710	7190	7650	8090			
23.1-26	5310	5810	6280	6730	7160	7570	7960		
23.1-30			6690	7170	7630				
23.1-34			7110	7610	8100				
24.5-32	6450	7060	7640	8180	8700	9200	9680		

TABLE IX

AGRICULTURAL TRACTOR RADIAL TIRE LOADINGS AND INFLATION PRESSURES

Tire size designation	psi 14	psi 16	psi 18	psi 20	psi 22	psi 24	psi 26	psi 28	psi 30
13.6R28	2590	2800	3030	3190	3380	3660	3720	3890	4000
14.9R26	2990	3230	3420	3680	3890	4130	4300	4490	4710
14.9R28	3090	3340	3530	3810	4020	4240	4430	4620	4860
14.9R30	3190	3450	3660	3920	4150	4370	4580	4770	5010
16.9R24		3790	4000	4320	4580	5010	5050	5260	5440
16.9R26		3920	4240	4470	4730	5140	5200	5440	5740
16.9R28		4040	4370	4620	4880	5290	5370	5610	5910
16.9R38		4690	5010	5350	5650	6080	6230	6530	6850
18.4R26		4690	5010	5350	5650	5910	6230	6530	6850
18.4R34		5310	5740	6060	6400	6580	7060	7380	7650
18.4R38		5630	6080	6400	6790	7060	7490	7810	8130
18.4R42		5930	6420	6740	7120	7440	7860	8240	8610
20.8R34		6420	6850	7330	7760	8130	8560	8930	9420
20.8R38		6790	7280	7760	8190	8610	9040	9470	9740
20.8R42		7170	7650	8190	8670	9150	9520	9950	10330
23.1R34		7600	8130	8670	9150	9740	10110	10540	10910
24.5R32			8830	9310	9840	10330	10810	11340	11770
30.5LR32			10330	11130	11770	12520	12950	13590	14120

Tire Selection Program

Tire Selection knowledge base was developed to recommend a tire type for the user under specific field conditions. To minimize the processing time, Tire Selection program has been divided into two sections: Tire1 and Tire2.

Tire1 Program

A block diagram of Tire1 knowledge base is shown in Figure 3.6. Tire1 program was developed to find the optimum tire type (general, high-cleat, industrial) depending on soil conditions.

Tire1 program begins by registering information about current tires and problems from the user. Tire1 then recommends reweighing the tractor by calling the Ballasting program, or tests existing tire conditions by calling Tire2 program. Finally, Tire1 program saves the results and quits.

Tire2 Program

A block diagram of the Tire2 knowledge base is shown in Figure 3.7. Tire2 assists the user in finding the optimum tire configuration (single or dual, radial or bias) and tire size.

Tire2 loads data from Tire1, then evaluates the status of tires to make recommendations to the user.

Tire recommendations depend on the following points:

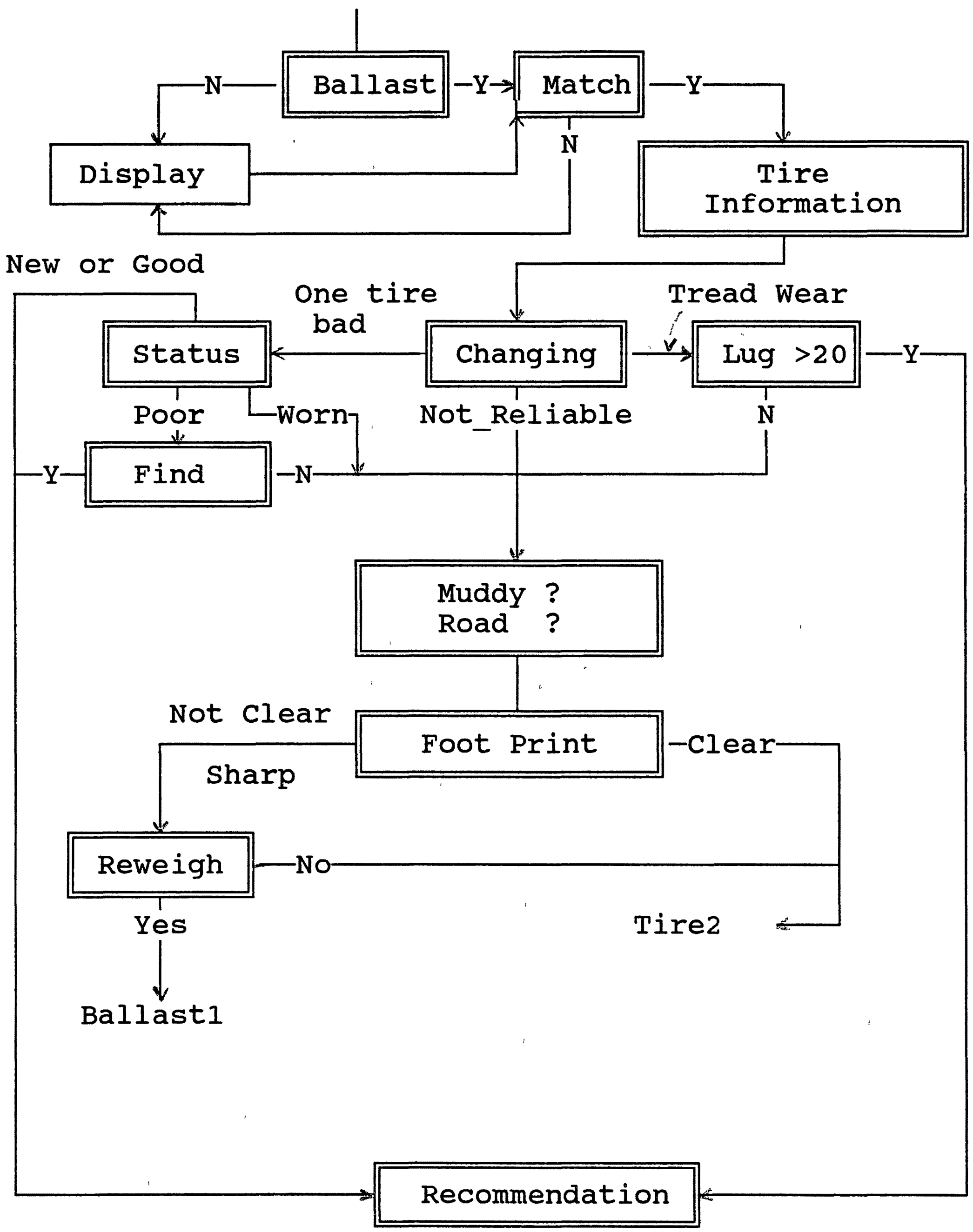
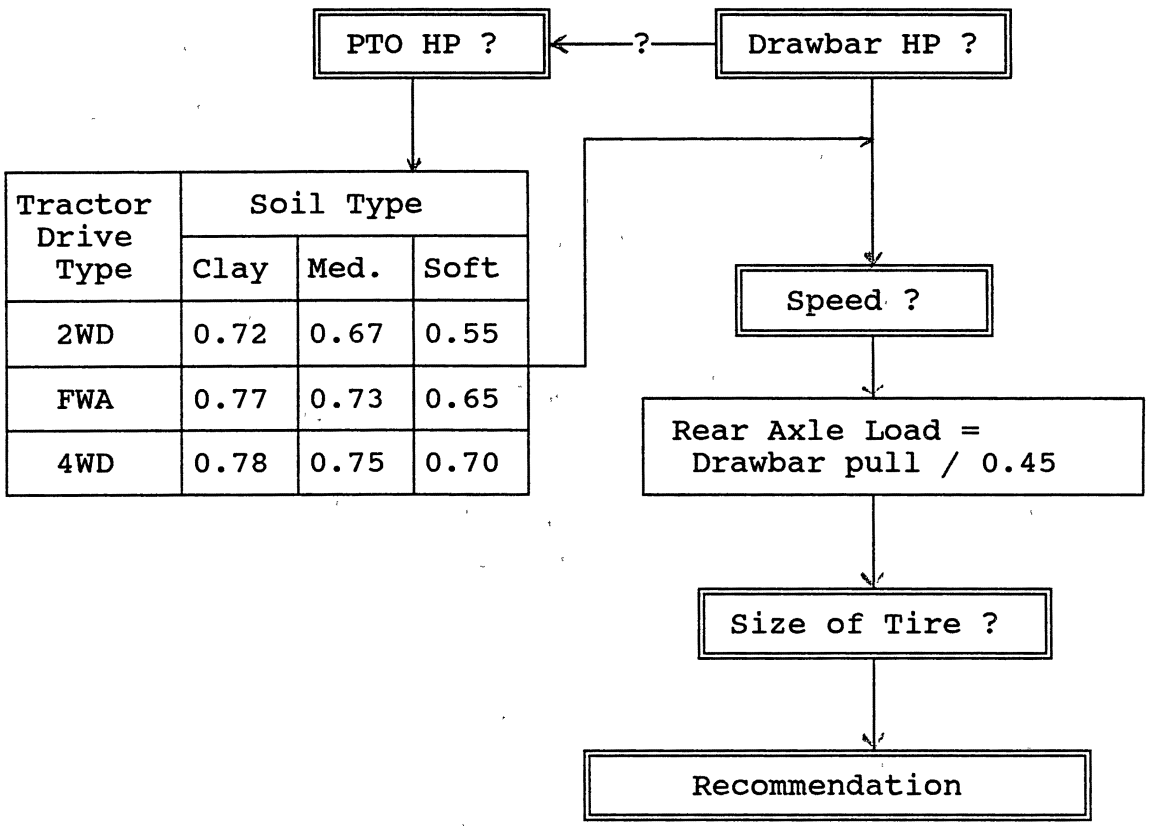


Figure 3.6 Tire1 Knowledge Base



Tractor Drive Type	Soil Type		
	Clay	Med.	Soft
2WD	0.72	0.67	0.55
FWA	0.77	0.73	0.65
4WD	0.78	0.75	0.70

Figure 3.7 Tire2 Knowledge Base

1. Radial tires are not recommended in sandy and wet soils (Coates 1984).
2. Dual tires are recommended for 2WD tractors of 140 PTOHP and above (Jurek and Newendrop 1983, Downs 1990).
3. Radial tires perform better than bias tires on tilled and firm soil (Kraving 1986, Coates 1984).
4. Dual tires are recommended for FWA and 4WD tractors primarily to carry tractor weight and reduce compaction (Bashford, et al. 1987).
5. High-cleat tires are recommended if the tractor is used 40% or more of the time in muddy (tight or sticky soils) areas and 20% or less in hard (roads or any other hard soils) areas, because using high-cleat tires in hard areas causes undesirable distortion that shortens tire life (Downs 1990).
6. Industrial tires are recommended if the tractor is used 60% or more of the time in hard areas and 20% or less in muddy areas, because industrial tires causes high slip in muddy areas (Downs 1990).
7. General tires are recommended if the above do not apply (Downs 1990).
8. Dual radial tires are not recommended for most conditions because of cost and limited performance improvement in most cases (Downs 1990).
9. Compaction problems will be reduced by reducing the ballasting weight or using dual tires (Bashford, et al. 1987).

10. Changing tire configurations is based on the rear axle load.
11. The drawbar load is assumed in maximum to be 45% of the rear axle load (Downs 1990).
12. The drawbar horsepower will be estimated based on tractor PTO horsepower and soil.

The Expert Knowledge

Expert knowledge in the knowledge base of an expert system is used to elicit a conclusion. The knowledge base of an expert system consists of numerous facts, rules, and heuristics (rules of thumb). Determining expert knowledge is one of the most challenging tasks for the expert systems developers, because relevant knowledge is not always immediately apparent. "Expert knowledge consists of concepts, relations, features, chunks, plans, heuristics, theories, mental models, etc." (Cooke, 1986). Mismatch is the discrepancy between the representation of knowledge in the program and what the expert actually means. In order to avoid such a mismatch, the knowledge should be represented in the expert system in the same way as the actual expert knowledge.

ASAE standards, Zoz's (1972) equations, Brixius' (1987) equations, and rules of thumb are the main sources of expert knowledge of the Expert System.

Ballasting

Expert knowledge contained in this section provides for:

1. Selecting the right tractor and tire information from TRACTOR and TIRE files. Information from the TRACTOR file is obtained after the make and model of the tractor are input by the user. The TIRE file is used to access tire size.
2. Estimating tractor weight. There are two ways to estimate tractor weight. First, it may be obtained directly from the user. If unknown, it is estimated by adding estimated tractor shipping weight to user supplied estimates of additional iron weight and water or cacl2 inside the tire. Tractor shipping weight is stored in the TRACTOR file. Water or cacl2 weight is stored in the TIRE file.
3. Warning the user if the tractor weight is over or under the recommended tractor weight by displaying a warning massage.
4. Guiding the user in choosing the ratio of static weight on the front axle (%FWS), soil cone index, and desired slip by displaying expert recommendations (Tables IV and V).
5. Changing tire configuration or reducing ballasting weight if the tractor weight is over the maximum tire load. Maximum tire load is stored in the TIRE file.
6. Calculating front and rear axles weight based on

Brixius' (1987) equations (Appendix C).

Matching

Expert knowledge in this section is used for the following:

1. Estimating tractor speed and slip at a given implement width. Estimations of tractor speed and slip are based on Brixius' (1987) equations. Brixius' equations are organized to change tractor speed in 0.05 mile per hour increments. Changing tractor speed changes tractor slip until the implement width equals the given width (Appendix D).
2. Estimating tractor slip and implement width at a given speed. The estimations are based on simultaneous solution of Brixius' equations (Appendix D).
3. Estimating tractor speed and implement width at a given slip. The estimations are based on simultaneous solution of Brixius' equations (Appendix D).
4. Estimating the above based on current tractor weight and optimum tractor weight. Optimum tractor weight is defined to be 125 lb/PTOHP for 4WD tractors, 130 lb/PTOHP for FWA tractors, and 140 lb/PTOHP for 2WD tractors (Downs 1990).
5. Obtaining implement draft from the user, SOIL-DRAFT file or by eliciting the average of SOIL-DRAFT file data.

Tire Pressure

Expert knowledge in this section is used to:

1. Select tire pressure from BPRESSURE or RPRESSURE files given the size of tire.
2. Estimate unknown tire pressure. For example, for a 20.8-38 tire:

   The acceptable load under 18 psi is 6820 lbs (Table VIII).

   The acceptable load under 16 psi is 6360 lbs (Table VIII).

   The load under 14 psi is UNKNOWN (Table VIII),

Therefore:

The estimated load under 14 psi =

2*6360 - 6820 = 5900 lbs.

Tire Selection

The expert knowledge in this section helps to:

1. Select tire type (general, high-cleat, industrial). This selection is based on soil conditions.
2. Select tire configuration (single or dual, radial or bias) based on rear axle load and soil conditions.
3. Select tire size based on rear axle load.
4. Predict tractor weight (overballast or underballast) based on the footprint of tires. For example, tractor weight is underballasted if the tire print is sheared away.

CHAPTER IV

DISCUSSION

Introduction

Appendix H is an example of the Expert System and its capabilities with DBase files. Below is an arbitrary application example.

TRACTOR: JOHN DEERE 4650 (2WD)

TIRE:

Front

size - 14.9-24

ply - 6

psi - 44

system - single

Rear

size - 20.8-38

ply - 10

psi - 14

system - dual

Type - Bias

IMPLEMENT - Chisel

SOIL - Tuttle silt loam

Ballasting

"System Program" is the first loaded program that shows the file selections (question 1). Since the selection is BALLASTING, Expert System loads "Ballast1 Program". Then, Ballast1 starts to collect information about the tractor (question 2-15). Ballast1 program has interfaced with TRACTOR and TIRE files and reserves all the information. However, a warning message may appear if the tractor weight is not recommended.

Ballast2 loads the static load vectors and starts to calculate the required tractor weight based on the indicated speed, soil cone index, and slippage from the user (questions 16-18). The recommended tractor weight is then displayed. A warning message may appear if the front or rear dynamic weight (FWD or RWD) is over the maximum tire load and if the tractor weight is over the recommended weight.

The Expert System allows the user to look at other situations by using Matching, Tire pressure, or Tire selection programs (question 19).

Matching

Matching Program is selected (question 20) from a System file. Then, Ballast1 is loaded. The answer from question 21 is YES, because Ballast1 has been used and the tractor information has been stored. The matching file is then loaded, because the answer to question 22 is NO.

Matching program estimates the current implement draft and matches it with tractor pull at the estimated speed and slippage. Questions (23-29) are necessary to make the matching recommendations. Matching recommendation shows the implement matching situations, but does not emphasize one in particular. Finally, the Expert System allows the user to use another file (question 30).

Tire pressure

Since dynamic rear axle weight is necessary to find the tire pressure, the Tire Pressure program must use Ballast1 and Matching programs to calculate the dynamic rear axle weight (question 31-35).

The Tire Pressure program starts by loading dynamic rear axle weight. Due to the difference in load pressures for bias and radial tires, the user is asked to identify the tire type. The Expert System then shows the correct recommendation.

In this example the dynamic rear axle weight is 16937 lbs, resulting in 4812 lbs on each single 20.8-38 bias tire, because each single tire of dual tires uses 88% of the loads (ASAE S430). The tire pressure from diagonal (bias) ply agricultural drive wheel tractor tires (Table VI) is 16 psi under 6360 lbs, and the load under 14 psi is not included. Therefore, the Expert System estimates the load under 14 psi by knowing the load under 16 psi and 18 psi.

LOAD(14 psi) = 2*LOAD(16 psi) - LOAD(18 psi)

LOAD(14 psi) = 5900

as the load under 14 psi

LOAD(12 psi) = 5440

Then, the recommended tire pressure will be 12 psi, because it is the lowest recommended tire pressure for dual tires (ASAE S430).

Tire Selection

The tire selection file starts by loading "Tire1 Program" determining the current tire conditions. Questions 42 and 43 test the ballasting and implement matching situation, respectively. Question 46 checks for replacement causes. Another branch will be used if the selection was "ONE TIRE BAD" which discuses the condition of other tires (NEW, GOOD, POOR, WORN). If the height of the current tire's lug is more than 20% of original tire, the user will be advised to not replace them, if the tires generally are in good condition (Downs, 1990). Question 50 and 51 suggest a tread design based on the following:

HIGH-CLEAT: MUDDY AREA <= 20 AND HARD AREA => 60

INDUSTRIAL: MUDDY AREA => 40 AND HARD AREA <= 20

GENERAL : NONE OF THE ABOVE.

Question 52 was developed to test the ballasting and implement matching conditions. "SHARP" and "NOT CLEAR" conditions probably mean the tractor is improperly ballasted or matched.

Since the user did not want to test the tractor weight (question 53), "Tire2 Program" was loaded. The final recommendation is based on tractor drawbar horsepower (question 54). Since the user does not know the drawbar horsepower, questions 55-58 were asked to estimate the tractor drawbar horsepower. The user should select the tire size, because the Expert System selects the section width. The diameter of the rim, however, does not change.

CHAPTER V

VALIDATION

Introduction

Validation is one of the most important steps in completing an expert system. The accuracy of the system must be established by a thorough validation. There is a difference between validation and verification. Verification means building the system in the right way; the expert knowledge is correctly organized to achieve the appropriate conclusion given the facts stored in its knowledge base. However, errors in the relationships stored in the knowledge base could result in an incorrect conclusion. In contrast, validation can be defined as building the system so that it elicits the correct conclusion for the actual conditions (Newton, et al. 1987). The validity of an expert system is most important when the expert system is used by non-experts or is used as part of a control system.

Validation of an expert system can be accomplished by carefully comparing its recommendations with those actually provided by experts in the knowledge area. Previously verified examples can also be processed through the expert system to verify that it produces an equivalent result.

Furthermore, expert system can be validated against known results.

Ballasting

Validation of the Ballasting program is performed by comparing it with Zoz's templates (1987). Tables X and XI (pp 50 and 51) show that the tractive efficiency indicated by the Expert System is almost equal to Zoz's templates. The ratio of static weight on the front axle is constant in the Expert System, while it is changeable in Zoz's templates. The Expert System controls the ratio of static weight on the front axle, but Zoz's templates control the ratio of dynamic weight on the front axle. The tractor weight per PTO horsepower is lighter using the Expert System for 2WD tractors and almost equal in 4WD tractors. The difference in tractor weights between the Expert System and Zoz's templates is caused by truncation errors, round-off errors, and mostly by the difference in the ratio of static weight on the front axle.

Matching

Table XII (p52) shows the comparison of one option of Matching program of the Expert System with Zoz's templates. The results are almost equal.

Tire Pressure

Validation of Tire Pressure program is performed by comparing it with the recommended tire pressure that is solved manually under the same conditions. After testing many conditions, the tire pressure from the Expert System was found to be accurate (Chapter 5).

Tire Selection

The recommendations on tire selection are accurate based on the knowledge bases in Chapter 3. Some experts might disagree with the assumptions based in the Tire Selection program, and would change recommendations to obtain their own opinions.

Overall, Dr. Downs[1] , Mr. Taylor[2] and Mr. Barnes[3] have gone through the Expert System and are satisfied with the Expert System recommendations for use in their areas. Finally, there has been no mismatch in the expert knowledge known after running the Expert System more than 100 times and testing every single situation.

1. Professor and Extension Agricultural Engineering, Oklahoma State University
2. Extension Agricultural Engineering, Kansas State University
3. Extension Agricultural Engineering, Oklahoma State University

TABLE X

BALLASTING TESTS FOR 2WD TRACTORS

Expert System			Zoz's templates		
W/PTO[1]	RATIO[2]	TE[3]	W/PTO[1]	RATIO[2]	TE[3]
184.7	27.9	.723	188.3	25.1	.715
162	27.9	.728	165.4	26.4	.722
146.6	27.9	.725	149.9	27.4	.720
186.6	27.9	.711	190.9	24.8	.701
163.1	27.9	.720	166.9	26.2	.712
147.2	27.9	.718	150.8	27.3	.712
196.4	27.3	.669	203.8	23.8	.649
169	27.3	.691	175.0	25.4	.677
151.1	27.3	.697	156.2	26.6	.685
153	27.3	.733	155.7	25.2	.726
134.6	27.3	.736	137.2	26.5	.731
121.9	27.3	.732	124.5	27.5	.727
153.8	27.3	.724	156.8	25.1	.716
135	27.3	.729	137.8	26.4	.723
122.1	27.3	.726	124.8	27.4	.721
158.3	27.3	.695	162.9	23.6	.681
137.5	27.3	.708	141.4	25.9	.698
123.7	27.3	.710	127.1	27.0	.701

1. Tractor weight (lb) per PTO horsepower
2. Ratio of static weight on front axle to total tractor weight
3. Tractive efficiency

TABLE XI

BALLASTING TESTS FOR 4WD TRACTORS

Expert System			Zoz's templates		
W/PTO[1]	RATIO[2]	TE[3]	W/PTO[1]	RATIO[2]	TE[3]
155.3	59.3	.736	156.3	54.5	.723
136.2	59.3	.740	136.6	55.1	.737
123.2	59.3	.735	123.5	55.8	.733
157.9	59.3	.723	159.6	54.1	.718
137.7	59.3	.731	138.5	54.9	.726
124.2	59.3	.728	124.7	55.7	.725
170.7	59.3	.674	175.4	53.2	.660
145.6	59.3	.697	148.0	54.3	.688
129.6	59.3	.703	131.2	55.1	.696
128.1	59.3	.747	128.6	54.4	.745
112.7	59.3	.748	112.9	55.2	.746
102.2	59.3	.742	102.4	55.9	.740
129.2	59.3	.738	130.0	54.3	.734
113.3	59.3	.741	113.7	55.0	.738
102.6	59.3	.736	102.9	55.8	.734
135.3	59.3	.705	137.7	53.8	.696
117.0	59.3	.718	118.1	54.7	.711
105.0	59.3	.718	105.8	55.5	.714

1. Tractor weight (lb) per PTO horsepower
2. Ratio of static weight on front axle to total tractor weight
3. Tractive efficiency

TABLE XII

MATCHING PROGRAM TESTS

Expert System			Zoz's templates		
SPEED[1]	SLIP[2]	TE[3]	SPEED[1]	SLIP[2]	TE[3]
4.6	15.9	.742	4.61	16.2	.710
4.0	19.1	.715	4.03	19.4	.688
3.4	24.3	.669	3.39	24.7	.648
3.3	24.5	.664	3.38	25.0	.641
4.0	19.2	.711	4.02	19.6	.682
4.6	16.0	.738	4.60	16.3	.704
4.5	16.4	.726	4.57	16.9	.685
4.0	19.8	.697	3.98	20.5	.661
3.3	25.6	.646	3.3	26.6	.615
4.9	10.9	.745	4.90	11.0	.741
4.3	12.8	.736	4.35	12.9	.732
3.7	15.7	.719	3.79	15.8	.715
3.7	15.9	.711	3.77	16.2	.706
4.3	13.0	.728	4.34	13.2	.723
4.8	11.0	.736	4.89	11.2	.732
4.8	11.7	.711	4.8	12.0	.703
4.3	13.9	.703	4.28	14.3	.694
3.7	17.2	.684	3.7	17.8	.674

1. Tractor speed (mile per hour)
2. Wheel slip
3. Tractive efficiency

CHAPTER VI

SUMMARY & CONCLUSIONS AND RECOMMENDATIONS

Summary and conclusions

An Expert System has been developed using VP-Expert to present all the information that a farmer would need in making a typical management decision for tractor-implement systems. The Expert System assists in selecting drive tires and pressure, matching the implement to the tractor and application, and in ballasting the tractor. The Expert System is interfaced with DBase files that contain tractor and tire information. If the user is unable to supply an input, another line is used to determine the appropriate values. Tractor information is limited to current John Deere tractors of 100 HP and above.

The Expert System recommendations have been validated. Recommendations of Ballasting and Matching programs were compared with Zoz's templates, and they are accurate. Tire Selection and Tire Pressure programs were tested manually. Overall, several experts have reviewed the Expert System and are satisfied with the recommendations.

The Ballasting and Matching programs of the Expert System are limited to bias tires and variables in the range of Brixius' equations (1987). Tire Selection and Tire

Pressure programs are limited to specific tire sizes.

Several problems may occur if the users do not have accurate information about the tractor, tires, and soils. The Expert System is sensitive to soil cone index, wheel slip, operating speed, and the ratio of static weight on the front axle.

Recommendations

1. Expand the tractor DBase file to include most current tractors.
2. Modify the Matching program to estimate the highest tractive efficiency by changing the optimum tractor weight and tractor slip.
3. Develop an expert connection between Matching program and Ballasting program. This connection would determine optimum tractor weight for any soil and implement combination.
4. Add explanation statements to educate the users by using the BECAUSE statement. This feature allows the user to follow each step in the decision making process. For example, the BECAUSE statement for question 38 (Appendix H) may be written as, " The acceptable load of BIAS tires is different from that for RADIAL tires of the same size."
5. Combine the Expert System with other expert systems that deal with tractor management such as FINDS (Farm-Level Intelligent Decision Support System)

(Kline, et al., 1986) and Farm machinery selection and management expert system (Kotzabassis, et al., 1990).

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APPENDIXES

APPENDIX A

SYSTEM KNOWLEDGE BASE

```
EXECUTE;
RUNTIME;
ENDOFF;
ACTIONS
      FIND PROGRAM;


RULE 1
IF    OPERATION = BALLASTING
THEN  PROGRAM = OK
      SAVEFACTS B:OPERATION
      CHAIN B:BALLAST1;

RULE 2
IF    OPERATION = TIRE_SELECTION
THEN  PROGRAM = OK
      SAVEFACTS B:OPERATION
      CHAIN B:TIRE1;

RULE 3
IF    OPERATION = MATCHING
THEN  PROGRAM = OK
      SAVEFACTS B:OPERATION
      CHAIN B:BALLAST1;

RULE 4
IF    OPERATION = TIRE_PRESSURE
THEN  PROGRAM = OK
      SAVEFACTS B:OPERATION
      CHAIN B:BALLAST1;


ASK OPERATION: "What kind of operation would you like to
use?";
CHOICES OPERATION: BALLASTING , TIRE_SELECTION,
MATCHING,TIRE_PRESSURE ;
```

APPENDIX B

BALLAST1 KNOWLEDGE BASE

```
EXECUTE;
RUNTIME;
ENDOFF;
ACTIONS
       LOADFACTS B:OPERATION
       FIND DATA_CHANGING;
RULE 1
IF     OPERATION           = MATCHING      OR
       OPERATION           = TIRE_PRESSURE AND
       USE                 = YES           AND
       DATA_CHANGE         = NO
THEN   DATA_CHANGING       = OK
       CHAIN B:MATCHING;
RULE 2
IF     OPERATION           = BALLASTING  AND
       USE                 = YES         AND
       DATA_CHANGE         = NO
THEN   DATA_CHANGING       = OK
       CHAIN B:BALLAST2;
RULE 3
IF      USE                = YES         AND
        DATA_CHANGE        = YES
THEN    DATA_CHANGING      = OK
        LOADFACTS B:OPERATION
        MENU the_make, ALL,B:TRACTOR, make
        FIND the_make
        MENU the_model, the_make=make,B:TRACTOR, model
        FIND the_model
        WHILEKNOWN make
            GET the_make=make AND the_model = model,
B:TRACTOR,ALL
        RESET the_make
        CLOSE B:TRACTOR
        MENU Ftire_size, ALL,B:FTIRE, SIZE
        FIND FTIRE_SIZE
        WHILEKNOWN SIZE
             GET Ftire_size=size,B:FTIRE, ALL
        RESET Ftire_size
        CLOSE B:FTIRE
        MENU Rtire_size, ALL, B:RTIRE, SIZE
        FIND RTIRE_SIZE
        WHILEKNOWN SIZE
             GET Rtire_size=size,B:RTIRE, ALL
```

```
        RESET Rtire_size
        CLOSE B:RTIRE
        FIND WEIGHT
        END;
RULE 4
IF      USE                      = NO
THEN    DATA_CHANGING            = OK
        LOADFACTS B:OPERATION
        MENU the_marke, ALL,B:TRACTOR, marke
        FIND the_marke
        MENU the_model, the_marke=marke,B:TRACTOR, model
        FIND the_model
        WHILEKNOWN marke
            GET the_marke=marke AND the_model = model,
B:TRACTOR,ALL
        MENU Ftire_size, ALL,B:FTIRE, SIZE
        FIND FTIRE_SIZE
        WHILEKNOWN SIZE
             GET Ftire_size=size,B:FTIRE, ALL
        MENU Rtire_size, ALL, B:RTIRE, SIZE
        FIND RTIRE_SIZE
        WHILEKNOWN SIZE
             GET Rtire_size=size,B:RTIRE, ALL
        FIND WEIGHT
        END;
RULE 5
IF      KNOWING_WEIGHT           = YES           AND
        FRONT_AXLE_WEIGHT        > 0.0           AND
        FSYSTEM                  <> NOT_DUAL     AND
        REAR_AXLE_WEIGHT         > 0.0           AND
        RSYSTEM                  <> NOT_DUAL
THEN    WEIGHT                   = OK
        FWS1                     = (FRONT_AXLE_WEIGHT)
        RWS1                     = (REAR_AXLE_WEIGHT)
        %FWS                     = (100*FWS1/(FWS1+RWS1))
        TWSPTO                   = ((FWS1+RWS1)/PTOPW)
        FIND LOAD3
        FIND TOTAL
        FIND FWEIGHT
        FIND RWEIGHT
        FIND FWEIGHT_SHOW
        FIND RWEIGHT_SHOW
        FIND TWS;
RULE 6
IF      KNOWING_WEIGHT           = NO
THEN    WEIGHT                   = OK
        FIND FWS1
        FIND RWS1
        FIND %FWS
        FORMAT %FWS, 5.1
        FIND LOAD3
        FIND TOTAL
        FIND FWEIGHT
        FIND RWEIGHT
```

```
       FIND FWEIGHT_SHOW
       FIND RWEIGHT_SHOW
       FIND TWS;
RULE 7
IF     FEXTRA                 = NO        AND
       FADD                   = AIR      AND
       FSYSTEM                = SINGLE    OR
       FSYSTEM                = DUAL
THEN   FWS1                   = (EFWS);
RULE 8
IF     FEXTRA                 = YES       AND
       FEXTRA_WEIGHT          >= 0.0       AND
       FADD                   = AIR      AND
       FSYSTEM                = SINGLE    OR
       FSYSTEM                = DUAL
THEN   FWS1                   = (EFWS + FEXTRA_WEIGHT);
RULE 9
IF     FEXTRA                 = NO        AND
       FADD                   = WATER     AND
       FSYSTEM                = SINGLE
THEN   FWS1                   = (EFWS + (2*FWATER));
RULE 10
IF     FEXTRA                 = NO        AND
       FADD                   = CACL2     AND
       FSYSTEM                = SINGLE
THEN   FWS1                   = (EFWS + (2*FCACL2));
RULE 11
IF     FEXTRA                 = YES       AND
       FEXTRA_WEIGHT          >= 0.0       AND
       FADD                   = WATER     AND
       FSYSTEM                = SINGLE
THEN   FWS1                   = (EFWS + (2*FWATER) +
FEXTRA_WEIGHT);
RULE 12
IF     FEXTRA          = YES       AND
       FEXTRA_WEIGHT >= 0.0       AND
       FADD            = CACL2     AND
       FSYSTEM         = SINGLE
THEN   FWS1            = (EFWS + (2*FCACL2) + FEXTRA_WEIGHT);
RULE 13
IF     FEXTRA          = NO        AND
       FADD            = WATER     AND
       FSYSTEM         = DUAL
THEN   FWS1            = (EFWS + (2*FWATER));
RULE 14
IF     FEXTRA          = NO        AND
       FADD            = CACL2     AND
       FSYSTEM         = DUAL
THEN   FWS1            = (EFWS + (2*FCACL2));
RULE 15
IF     FEXTRA          = YES       AND
       FEXTRA_WEIGHT >= 0.0       AND
       FADD            = WATER     AND
       FSYSTEM         = DUAL
```

```
THEN  FWS1           = (EFWS + (2*FWATER) + FEXTRA_WEIGHT);
RULE 16
IF    FEXTRA         = YES      AND
      FEXTRA_WEIGHT >= 0.0      AND
      FADD           = CACL2    AND
      FSYSTEM        = DUAL
THEN  FWS1           = (EFWS + (2*FCACL2) + FEXTRA_WEIGHT);

RULE 17
IF    REXTRA         = NO       AND
      RADD           = AIR     AND
      RSYSTEM        = SINGLE   OR
      RSYSTEM        = DUAL
THEN  RWS1           = (ERWS)
      TWSPTO         = ((FWS1 + RWS1)/PTOPW)
      %FWS           = (100*FWS1/(FWS1+RWS1));
RULE 18
IF    REXTRA         = YES      AND
      REXTRA_WEIGHT >= 0.0      AND
      RADD           = AIR     AND
      RSYSTEM        = SINGLE   OR
      RSYSTEM        = DUAL
THEN  RWS1           = (ERWS + REXTRA_WEIGHT)
      TWSPTO         = ((FWS1 + RWS1)/PTOPW)
      %FWS           = (100*FWS1/(FWS1+RWS1));
RULE 19
IF    REXTRA         = NO       AND
      RADD           = WATER    AND
      RSYSTEM        = SINGLE
THEN  RWS1           = (ERWS + (2*RWATER))
      TWSPTO         = ((FWS1 + RWS1)/PTOPW)
      %FWS           = (100*FWS1/(FWS1+RWS1));
RULE 20
IF    REXTRA         = NO       AND
      RADD           = CACL2    AND
      RSYSTEM        = SINGLE
THEN  RWS1           = (ERWS + (2*RCACL2))
      TWSPTO         = ((FWS1 + RWS1)/PTOPW)
      %FWS           = (100*FWS1/(FWS1+RWS1));
RULE 21
IF    EEXTRA         = YES      AND
      REXTRA_WEIGHT >= 0.0      AND
      RADD           = WATER    AND
      RSYSTEM        = SINGLE
THEN  RWS1           = (ERWS + (2*RWATER) + REXTRA_WEIGHT)
      TWSPTO         = ((FWS1 + RWS1)/PTOPW)
      %FWS           = (100*FWS1/(FWS1+RWS1));
RULE 22
IF    REXTRA         = YES      AND
      REXTRA_WEIGHT >= 0.0      AND
      RADD           = CACL2    AND
      RSYSTEM        = SINGLE
THEN  RWS1           = (ERWS + (2*RCACL2) + REXTRA_WEIGHT)
      TWSPTO         = ((FWS1 + RWS1)/PTOPW)
```

```
      %FWS             = (100*FWS1/(FWS1+RWS1));
RULE 23
IF    REXTRA           = NO        AND
      RADD             = WATER     AND
      RSYSTEM          = DUAL
THEN  RWS1             = (ERWS + (2*RWATER))
      TWSPTO           = ((FWS1 + RWS1)/PTOPW)
      %FWS             = (100*FWS1/(FWS1+RWS1));
RULE 24
IF    REXTRA           = NO        AND
      RADD             = CACL2     AND
      RSYSTEM          = DUAL
THEN  RWS1             = (ERWS + (2*RCACL2))
      TWSPTO           = ((FWS1 + RWS1)/PTOPW)
      %FWS             = (100*FWS1/(FWS1+RWS1));
RULE 25
IF    REXTRA           = YES       AND
      REXTRA_WEIGHT   >= 0.0       AND
      RADD             = WATER     AND
      RSYSTEM          = DUAL
THEN  RWS1             = (ERWS + (2*RWATER) + REXTRA_WEIGHT)
      TWSPTO           = ((FWS1 + RWS1)/PTOPW)
      %FWS             = (100*FWS1/(FWS1+RWS1));
RULE 26
IF    REXTRA           = YES       AND
      REXTRA_WEIGHT   >= 0.0       AND
      RADD             = CACL2     AND
      RSYSTEM          = DUAL
THEN  RWS1             = (ERWS + (2*RCACL2) + REXTRA_WEIGHT)
      TWSPTO           = ((FWS1 + RWS1)/PTOPW)
      %FWS             = (100*FWS1/(FWS1+RWS1));
RULE 27
IF   SYSTEM      = 2WD             AND
     TWSPTO      > 150             OR
     TWSPTO      < 120
THEN LOAD3       = OK
CLS
DISPLAY" The total 2WD tractor weight should not be over 150
lb./PTO horsepower and not less than 120 lb./PTO horsepower.
The total weight of your tractor is {TWSPTO}.
              <Press any key to continue>.~"
CLS;
RULE 28
IF    SYSTEM     = 4WD    OR
      SYSTEM     = FWA    AND
      TWSPTO     > 140    OR
      TWSPTO     < 100
THEN  LOAD3      = OK
CLS
DISPLAY" The total 4WD or FWA tractor weight should not be
over 140 lb./PTO horsepower and not less than 100 lb./PTO
horsepower. The total weight of your tractor is {TWSPTO}.
             <Press any key to continue>.~";
```

```
RULE 29
IF    CHANGE_%FWS      = NO    AND
      NEW_%FWS        <> 0.0
THEN  TOTAL            = (RWS1 + FWS1)
      FWS              = (NEW_%FWS * TOTAL/100)
      RWS              = (TOTAL - RWS)
      FWS_FORMATED     = (FWS)
      RWS_FORMATED     = (RWS)
      FORMAT FWS_FORMATED, 7.0
      FORMAT RWS_FORMATED, 7.0
CLS
DISPLAY"The front axle weight should be {FWS_FORMATED} lbs
and {RWS_FORMATED} lbs on the rear axle.
                     <Press any key>~"
CLS;
RULE 30
IF    CHANGE_%FWS      = YES
THEN  TOTAL            = (FWS1 + RWS1)
      FWS              = (FWS1)
      RWS              = (RWS1);
RULE 31
IF    FSYSTEM        = SINGLE
THEN  FWEIGHT         = (FWS/2);
RULE 32
IF    FSYSTEM        = DUAL
THEN  FWEIGHT         = (FWS/(4*.88));
RULE 33
IF    RSYSTEM        = SINGLE
THEN  RWEIGHT         = (RWS/2);
RULE 34
IF    RSYSTEM        = DUAL
THEN  RWEIGHT         = (RWS/(4*.88));
RULE 35
IF    FWEIGHT         > (FSW)
THEN  FWEIGHT_SHOW     = OK
CLS
DISPLAY"The front axle weight is over the maximum load that
tires can carry.  You should reduce the front axle weight or
change the tires situation by using TIRE SELECTION program.
                <Press any key to continue> ~"
CLS;
RULE 36
IF    RWEIGHT         > (RSW)
THEN  RWEIGHT_SHOW     = OK
CLS
DISPLAY"The rear axle weight is over the maximum load that
tires can carry.  You should reduce the rear axle weight or
change the tires situation by using TIRE SELECTION program.
                <Press any key to continue> ~";
RULE 37
IF    OPERATION        = BALLASTING   AND
      FWS              > 0.0          AND
      RWS              > 0.0
THEN  TWS              =(FWS + RWS)
```

```
      SAVEFACTS B:TWS
      CHAIN B:BALLAST2;
RULE 38
IF    OPERATION       = MATCHING      OR
      OPERATION       = TIRE_PRESSURE AND
      RTIRE_SIZE      <> UNKNOWN      AND
      FWS             > 0.0        AND
      RWS             > 0.0
THEN  TWS             =(FWS + RWS)
      SAVEFACTS B:TWS
      CHAIN B:MATCHING;
ASK USE:"Have you used this program before?";
CHOICES USE:YES,NO;
ASK DATA_CHANGE:"Would you like to change the tractor
information that you
have used?";
CHOICES DATA_CHANGE:YES,NO;
ASK the_make: "What is the tractor make?";
ASK FTIRE_SIZE: "What size are the current front tires?";
ASK the_model: "What is the tractor model?";
ASK RTIRE_SIZE: "What size are the current rear tires?";
ASK RSYSTEM: "Does the tractor have SINGLE or DUAL tires on
the rear axle?";
CHOICES RSYSTEM: SINGLE, DUAL;
ASK FSYSTEM: "Does the tractor have SINGLE or DUAL tires on
the front axle?";
CHOICES FSYSTEM: SINGLE, DUAL;
ASK CHANGE_%FWS: "The front to total tractor weight ratio is
{%FWS}%
Is this acceptable?
Refer to the following table for guidance.
----------------------------------------------------------
Tractor Type         2WD             FWA             4WD
Front Ratio          25%             35%              60%
----------------------------------------------------------";
CHOICES CHANGE_%FWS: NO , YES;
ASK NEW_%FWS:"What is the ratio that you want?";
ASK FEXTRA: "Is there extra iron weight on the FRONT axle?";
CHOICES FEXTRA: YES, NO;
ASK REXTRA: "Is there extra iron weight on the REAR axle?";
CHOICES REXTRA: YES,NO;
ASK FEXTRA_WEIGHT: "How much is it?";
ASK REXTRA_WEIGHT : "How much is it?";
ASK FADD : "What is inside front tires?";
CHOICES FADD: AIR,WATER, CACL2;
ASK RADD : "What is inside rear tires?";
CHOICES RADD: AIR,WATER, CACL2;
ASK KNOWING_WEIGHT:"Do you know the weight of the tractor
both the front and rear axles?";
CHOICES KNOWING_WEIGHT:YES,NO;
ASK FRONT_AXLE_WEIGHT:"How much is the front axle weight
(Ib)?";
ASK REAR_AXLE_WEIGHT :"How much is the rear axle weight
(Ib)?";
```

APPENDIX C

BALLAST2 KNOWLEDGE BASE

```
EXECUTE;
RUNTIME;
ENDOFF;
ACTIONS
      LOADFACTS B:TWS
      FIND FSTSTIC_LOAD
      FIND RSTSTIC_LOAD
      FIND LOAD1
      FIND LOAD2
      FIND LOAD3
      FIND LOAD4
      FIND AF
      FIND AR
      FIND BALLASTING_TEST
      FIND CHANGE_FILE;
RULE 1
IF   FSYSTEM   = SINGLE
THEN FSTSTIC_LOAD = (2*FSW);
RULE 2
IF   FSYSTEM   = DUAL
THEN FSTSTIC_LOAD = (4*0.88*FSW);
RULE 3
IF   RSYSTEM   = SINGLE
THEN RSTSTIC_LOAD = (2*RSW);
RULE 4
IF   RSYSTEM   = DUAL
THEN RSTSTIC_LOAD = (4*0.88*RSW);
RULE 5
IF   FSTSTIC_LOAD <= FWD
THEN LOAD1       = OK
DISPLAY" The weight of the front axle is over the maximum
limit of the tire load. You should reduce the ballasting
weight of the tractor or change the tire situation.
                  <Press any key to continue>~" ;
RULE 6
IF   LOAD1          = OK                  AND
     TIRE_CHANGE    = YES                 AND
     OPERATION      = BALLASTING
THEN LOAD2          = OK
     OPERATION      = TIRE_SELECTION
     CHAIN B:TIRE1;
RULE 7
IF   LOAD1            = OK                  AND
```

```
     TIRE_CHANGE     = NO
THEN LOAD2           = OK
DISPLAY"                          << WARNING >>
                            Overload will cause problems
                            <Press any key to continue>~";
RULE 8
IF   RSTSTIC_LOAD < RWD
THEN LOAD3         = DONE
DISPLAY " The weight of the rear axle is over the maximum
limit of the tire load.  You should reduce the ballasting
weight of the tractor or change the tire situation.
                  <Press any key to continue>~";
RULE 9
IF   LOAD3         = DONE                 AND
     TIRE_CHANGE   = YES                  AND
     OPERATION     = BALLASTING
THEN LOAD4         = OK
     OPERATION     = TIRE_SELECTION
     CHAIN B:TIRE1;
RULE 10
IF   LOAD3           = DONE                    AND
     TIRE_CHANGE     = NO
THEN LOAD4            = OK
DISPLAY"                            << WARNING >>
                           Overload will cause problems
                           <Press any key to continue>~";
RULE 11
IF   FSYSTEM = SINGLE
THEN AF      = (1)
ELSE AF      = (2);
RULE 12
IF   RSYSTEM = SINGLE
THEN AR      = (1)
ELSE AR      = (2);

RULE 13
IF   SYSTEM    = 4WD     AND
     SO        > 0.0     AND
     CI        > 0.0     AND
     NSLIP     > 0.0     AND
     AR        <> 0.0
THEN BALLASTING_TEST     = WORKING
     %FWS = (100*(FWS/(RWS+FWS)))
     RWD       = (RWS)
FOR I =1 TO 15
BNR = ((CI*RSECW*ROD*(AR)/(RWD/2)) *
((1+5*.18)/(1+3*RSECW*(AR)/ROD)))
BNF = ((CI*FSECW*FOD*(AF)/(FWD/2)) *
((1+5*.18)/(1+3*FSECW*(AF)/FOD)))
QRWR = (0.88*(1-@EXP(-0.1*BNR)) *
(1-@EXP(-7.5*(NSLIP/100)))+0.04)
MWR = ((1/BNR)+0.04+0.5*(NSLIP/100)/@SQRT(BNR))
QRWF = (0.88*(1-@EXP(-0.1*BNF)) *
(1-@EXP(-7.5*(NSLIP/100)))+0.04)
```

```
MWF = ((1/BNF)+0.04+0.5*(NSLIP/100)/@SQRT(BNF))
PULL = (((QRWR - MWR)*RWD) + ((QRWF - MWF)*FWD))
AHP = ((PTOPW*0.96)/(1 + 1/(RWD*QRWR/FWD/QRWF)))
RWD  = (AHP*375/SO/QRWR)
RWS =  (RWD - (PULL*DBHT/WB))
FWS = (%FWS*RWS/(100 - %FWS))
FWD = (FWS - (PULL*DBHT/WB))
ACS = (SO*(1 - NSLIP/100))
TE  = ((PULL*ACS/375)/PTOPW)
TWSPTO = ((RWS + FWS)/PTOPW)
END
     FIND TEST1;
RULE 14
IF   SYSTEM    = 2WD     AND
     SO        > 0.0     AND
     CI        > 0.0     AND
     NSLIP     > 0.0     AND
     AR        <> 0.0
THEN BALLASTING_TEST     = WORKING
     %FWS = (100*FWS/(FWS+RWS))
     RWD       = (RWS)
FOR I =1 TO 15
BNR = ((CI*RSECW*ROD*(AR)/(RWD/2)) *
((1+5*.18)/(1+3*RSECW*(AR)/ROD)))
BNF = ((CI*FSECW*FOD*(AF)/(FWD/2)) *
((1+5*.18)/(1+3*FSECW*(AF)/FOD)))
QRWR = (0.88*(1-@EXP(-0.1*BNR)) *
(1-@EXP(-7.5*(NSLIP/100)))+0.04)
MWR   = ((1/BNR)+0.04+0.5*(NSLIP/100)/@SQRT(BNR))
QRWF = (0.88*(1-@EXP(-0.1*BNF)) *
(1-@EXP(-7.5*(NSLIP/100)))+0.04)
MWF   = ((1/BNF)+0.04+0.5*(NSLIP/100)/@SQRT(BNF))
PULL = (((QRWR - MWR)*RWD) - ((0.04 + 1/BNF)*FWD))
AHP  = (PTOPW*0.96)
RWD  = (AHP*375/SO/QRWR)
RWS =  (RWD - (PULL*DBHT/WB))
FWS = (%FWS*RWS/(100 - %FWS))
FWD = (FWS - (PULL*DBHT/WB))
ACS = (SO*(1 - NSLIP/100))
TE  = ((PULL*ACS/375)/PTOPW)
TWSPTO = ((RWS + FWS)/PTOPW)
END
     FIND TEST1;
RULE 15
IF   TWSPTO <> 0.0
THEN TEST1 = OVER
     ETWSPTO = (TWSPTO)
     FORMAT ETWSPTO, 5.1
     FORMAT PULL,7.0
     FORMAT FWS, 7.0
     FORMAT RWS, 7.0
     FORMAT ACS,4.2
     FORMAT TE,5.3
CLS
```

```
DISPLAY"To operate the tractor at {ACS} MPH with {NSLIP}%
slippage, the front axle weight should be {FWS} lbs. and the
rear axle weight is {RWS} lbs. The drawbar pull is {PULL}
lbs. with {TE} tractive efficiency.
The tractor weight per one PTO horsepower is {ETWSPTO}."
DISPLAY"                    <Press any key>~"
FIND TEST;
RULE 16
IF    SYSTEM          = 4WD                OR
      SYSTEM          = FWD                AND
      TWSPTO          > 140                OR
      TWSPTO          < 100
THEN  TEST            = DONE
CLS
DISPLAY"The tractor weight should not be over 140 lbs/PTO
and not less than 100 lbs/PTO.
                <Press any key>~";
 RULE 17
IF    SYSTEM          = 2WD                AND
      TWSPTO          > 150                OR
      TWSPTO          < 120
THEN  TEST            = DONE
CLS
DISPLAY"The tractor weight should not be over 150 lbs/PTO
and not less than 120 lbs/PTO.
                <Press any key>~";
 RULE 18
IF    OPERATION        = BALLASTING          AND
      CHICK            = YES
THEN  CHANGE_FILE      = OK
      CHAIN B:SYSTEM;

RULE 19
IF    OPERATION        = BALLASTING            AND
      CHICK            = NO
THEN  CHANGE_FILE      = OK
DISPLAY"Thank you for using this program.
             <Press any key>~";
ASK CHICK:"Would you like to use another file?";
CHOICES CHICK:YES,NO;
ASK NSLIP:"What is the percentage of tire slip at which you
would like the tractor to operate?
Refer to the following table for guidance.
______________________________________________________
                  Tractor Type
Soil     _____________________________________________
             2WD        FWD         4WD
______________________________________________________
Firm       10-12       8-10        8-10
Tilled     12-14      10-11.5     10-11.5
Sandy      14-16      11.5-13     11.5-13
_______________________________________________________";
ASK TIRE_CHANGE: "Would you like to change tire
situations?";
```

```
CHOICES TIRE_CHANGE:YES,NO;
ASK CI:"What is the estimated Cone Index (psi)?

Refer to the following table for guidance.
________________________________________________________
           CI               SOIL CONDITION
________________________________________________________
          250           HARD, PACKED
          200           HARD, PACKED WITH STUBBLE
          150           FIRM
          80            TILLED
          60            SOFT, WET
________________________________________________________";
ASK SO:"What is the indicated field speed you would like to
achieve with your tractor? (mph)";
```

APPENDIX D

MATCHING KNOWLEDGE BASE

```
EXECUTE;
RUNTIME;
ENDOFF;
ACTIONS
       LOADFACTS B:TWS
       LOADFACTS B:OPERATION
       FIND IMPLEMENT_DRAFT;
RULE 1
IF     DRAFT_OF_IMPLEMENT =YES        AND
       DRAFT_PER_UNIT     < 999999999
THEN   IMPLEMENT_DRAFT    = YES
       IMPLDRAFT          = (DRAFT_PER_UNIT)
       SYSTEM1             = 1
       FIND SYSTEM2;
RULE 2
IF      DRAFT_OF_IMPLEMENT = NO
THEN    IMPLEMENT_DRAFT    = NO
        SYSTEM1            = 1
        MENU THE_SOIL,ALL,B:IMPL-DRA,SOIL
        FIND THE_SOIL
        MENU THE_IMPLEMENT,THE_SOIL=SOIL,B:IMPL-DRA,IMPLEMENT
        FIND THE_IMPLEMENT
        WHILEKNOWN SOIL
              GET THE_SOIL=SOIL AND THE_IMPLEMENT=IMPLEMENT ,
B:IMPL-DRA , ALL
        RESET THE_SOIL
        CLOSE B:IMPL-DRA
        FIND SYSTEM2;
RULE 3
IF      SYSTEM1 = 1
THEN    SYSTEM2 = OK
        FIND DRAFT
        FIND FS
        FIND RS
        FIND FINAL
       FIND CHANGE_FILE;
RULE 4
IF      WIDTH <> 0.0
THEN    DRAFT  = (WIDTH *IMPLDRAFT)
        PULL   = (DRAFT * 1.33)
        RWD    = (RWS + (PULL * DBHT/WB))
        FWD    = (FWS - (PULL * DBHT/WB));
```

```
RULE 5
IF     THE_SOIL      = UNKNOWN            AND
       IMPLEMENT1    = MOLDBOARD_PLOW     AND
       WIDTH         <> 0.0
THEN   DRAFT         = (WIDTH*547)
       PULL          = (DRAFT*1.33)
       RWD           = (RWS + (PULL * DBHT/WB))
       FWD           = (FWS - (PULL * DBHT/WB));
RULE 6
IF     THE_SOIL      = UNKNOWN            AND
       IMPLEMENT1    = CHISEL             AND
       WIDTH         <> 0.0
THEN   DRAFT         = (WIDTH*268)
       PULL          = (DRAFT*1.33)
       RWD           = (RWS + (PULL * DBHT/WB))
       FWD           = (FWS - (PULL * DBHT/WB));
RULE 7
IF     THE_SOIL      = UNKNOWN            AND
       IMPLEMENT1    = OFFSET_DISK        AND
       WIDTH         <> 0.0
THEN   DRAFT         = (WIDTH*251)
       PULL          = (DRAFT*1.33)
       RWD           = (RWS + (PULL * DBHT/WB))
       FWD           = (FWS - (PULL * DBHT/WB));
RULE 8
IF     THE_SOIL      = UNKNOWN            AND
       IMPLEMENT1    = V_BLADE            AND
       WIDTH         <> 0.0
THEN   DRAFT         = (WIDTH*309)
       PULL          = (DRAFT*1.33)
       RWD           = (RWS + (PULL * DBHT/WB))
       FWD           = (FWS - (PULL * DBHT/WB));
RULE 9
IF     THE_SOIL      = UNKNOWN            AND
       IMPLEMENT1    = TANDEM_DISK        AND
       WIDTH         <> 0.0
THEN   DRAFT         = (WIDTH*277)
       PULL          = (DRAFT*1.33)
       RWD           = (RWS + (PULL * DBHT/WB))
       FWD           = (FWS - (PULL * DBHT/WB));
RULE 10
IF     THE_SOIL      = UNKNOWN               AND
       IMPLEMENT1    = CHISEL_WITH_SWEEPS    AND
       WIDTH         <> 0.0
THEN   DRAFT         = (WIDTH*253)
       PULL          = (DRAFT*1.33)
       RWD           = (RWS + (PULL * DBHT/WB))
       FWD           = (FWS - (PULL * DBHT/WB));
RULE 11
IF     THE_SOIL        = UNKNOWN
THEN   THE_IMPLEMENT = UNKNOWN;
RULE 12
IF     SPEED    = UNKNOWN
THEN   SO       = 5.0
```

```
ELSE  SO      = (SPEED);
RULE 13
IF    FSYSTEM        = SINGLE
THEN  FS             = (1);
RULE 14
IF    FSYSTEM        = DUAL
THEN  FS             = (2);
RULE 15
IF    RSYSTEM        = SINGLE
THEN  RS             = (1)
      FIND BNR;
RULE 16
IF    RSYSTEM        = DUAL
THEN  RS             = (2)
      FIND BNR;
RULE 17
IF    OPERATION       = MATCHING             AND
      PULL            > 0.0                  AND
      RWD             > 0.0                  AND
      SO              > 0.0                  AND
      SLIPPAGE        > 0.0                  AND
      CI              > 0.0                  AND
      SYSTEM          = 4WD
THEN  BNR = ((CI*RSECW*ROD*(RS)/(RWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
CLS
DISPLAY" ... PLEASE WAIT..."
BNF = ((CI*FSECW*FOD*(FS)/(FWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
QRWR  = (0.88*(1-@EXP(-0.1*BNR))*
(1-@EXP(-7.5*(SLIPPAGE/100)))+0.04)
QRWF  = (0.88*(1-@EXP(-0.1*BNF))*
(1-@EXP(-7.5*(SLIPPAGE/100)))+0.04)
APR   = ((PTOPW*.96)/(1+1/(RWD*QRWR/FWD/QRWF)))
S1 = ((@LOG(1-(APR*375/(SO*RWD)-.04)/
(.88*(1-@EXP(-.1*BNR)))))*(-100/7.5))
FOR I = 1 TO 5
BNR = ((CI*RSECW*ROD*(RS)/(RWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
BNF = ((CI*FSECW*FOD*(FS)/(FWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
QRWR  = (0.88*(1-@EXP(-0.1*BNR))*
(1-@EXP(-7.5*(S1/100)))+0.04)
MWR   = ((1/BNR)+0.04+0.5*(S1/100)/@SQRT(BNR))
QRWF  = (0.88*(1-@EXP(-0.1*BNF))*
(1-@EXP(-7.5*(S1/100)))+0.04)
MWF   = ((1/BNF)+0.04+0.5*(S1/100)/@SQRT(BNF))
APR   = ((PTOPW*.96)/(1+1/(RWD*QRWR/FWD/QRWF)))
S1 = ((@LOG(1-(APR*375/(SO*RWD)-.04)/
(.88*(1-@EXP(-.1*BNR)))))*(-100/7.5))
PULL1  = ((QRWR - MWR)*RWD + (QRWF - MWF)*FWD)
RWD   = (RWS + (PULL1*DBHT/WB))
FWD   = (FWS - (PULL1*DBHT/WB))
ACS1  = (SO*(1 - S1/100))
```

```
TE1    = (PULL1*ACS1/375/PTOPW)
WIDTH1 = (PULL1/1.33/IMPLDRAFT)
APH1   = (ACS1*WIDTH1/8)
END
      S2 = (S1)
      SO1 = (SO)
      SO2 = (SO)
      SO3 = (SO)
      WIDTH2 = (WIDTH1)
WHILETRUE  WIDTH <= (WIDTH2)  THEN
BNR = ((CI*RSECW*ROD*(RS)/(RWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
BNF = ((CI*FSECW*FOD*(FS)/(FWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
QRWR  = (0.88*(1-@EXP(-0.1*BNR))*
(1-@EXP(-7.5*(S2/100)))+0.04)
MWR   = ((1/BNR)+0.04+0.5*(S2/100)/@SQRT(BNR))
QRWF  = (0.88*(1-@EXP(-0.1*BNF))*
(1-@EXP(-7.5*(S2/100)))+0.04)
MWF   = ((1/BNF)+0.04+0.5*(S2/100)/@SQRT(BNF))
APR   = ((PTOPW*.96)/(1+1/(RWD*QRWR/FWD/QRWF)))
S2 = ((@LOG(1-(APR*375/(SO2*RWD)-.04)/
(.88*(1-@EXP(-.1*BNR)))))*(-100/7.5))
TESTPULL  = ((QRWR - MWR)*RWD + (QRWF - MWF)*FWD)
RWD   = (RWS + (TESTPULL*DBHT/WB))
FWD   = (FWS - (TESTPULL*DBHT/WB))
ACS2  = (SO2*(1 - S2/100))
TE2    = (TESTPULL*ACS2/375/PTOPW)
WIDTH2 = (TESTPULL/1.33/IMPLDRAFT)
APH2   = (ACS2*WIDTH2/8)
SO2    = (SO2 +.05)
END
WHILETRUE  WIDTH > (WIDTH2)  THEN
BNR = ((CI*RSECW*ROD*(RS)/(RWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
BNF = ((CI*FSECW*FOD*(FS)/(FWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
QRWR  = (0.88*(1-@EXP(-0.1*BNR))*
(1-@EXP(-7.5*(S2/100)))+0.04)
MWR   = ((1/BNR)+0.04+0.5*(S2/100)/@SQRT(BNR))
QRWF  = (0.88*(1-@EXP(-0.1*BNF))*
(1-@EXP(-7.5*(S2/100)))+0.04)
MWF   = ((1/BNF)+0.04+0.5*(S2/100)/@SQRT(BNF))
APR   = ((PTOPW*.96)/(1+1/(RWD*QRWR/FWD/QRWF)))
S2 = ((@LOG(1-(APR*375/(SO2*RWD)-.04)/
(.88*(1-@EXP(-.1*BNR)))))*(-100/7.5))
TESTPULL  = ((QRWR - MWR)*RWD + (QRWF - MWF)*FWD)
RWD   = (RWS + (TESTPULL*DBHT/WB))
FWD   = (FWS - (TESTPULL*DBHT/WB))
ACS2  = (SO2*(1 - S2/100))
TE2    = (TESTPULL*ACS2/375/PTOPW)
WIDTH2 = (TESTPULL/1.33/IMPLDRAFT)
APH2   = (ACS2*WIDTH2/8)
SO2    = (SO2 - 0.05)
```

```
END
      S3 = (SLIPPAGE)
FOR T = 1 TO 5
BNR = ((CI*RSECW*ROD*(RS)/(RWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
BNF = ((CI*FSECW*FOD*(FS)/(FWD/2))*
(1+5*.18)/(1+3*FSECW*(FS)/FOD)))
QRWR  = (0.88*(1-@EXP(-0.1*BNR))*
(1-@EXP(-7.5*(S3/100)))+0.04)
MWR   = ((1/BNR)+0.04+0.5*(S3/100)/@SQRT(BNR))
QRWF  = (0.88*(1-@EXP(-0.1*BNF))*
(1-@EXP(-7.5*(S3/100)))+0.04)
MWF   = ((1/BNF)+0.04+0.5*(S3/100)/@SQRT(BNF))
APR   = ((PTOPW*.96)/(1+1/(RWD*QRWR/FWD/QRWF)))
SO3 = (375*APR/RWD/(0.88*(1-@EXP(-0.1*BNR))*
(1-@EXP(-7.5*S3/100))+0.04))
PULL3  = ((QRWR - MWR)*RWD + (QRWF - MWF)*FWD)
RWD   = (RWS + (PULL3*DBHT/WB))
FWD   = (FWS - (PULL3*DBHT/WB))
ACS3  = (SO3*(1 - S3/100))
TE3    = (PULL3*ACS3/375/PTOPW)
WIDTH3 = (PULL3/1.33/IMPLDRAFT)
APH3   = (ACS3*WIDTH3/8)
END
FIND ESFWS;
RULE 18
IF    OPERATION      = MATCHING             AND
      PULL           > 0.0                  AND
      RWD            > 0.0                  AND
      SO             > 0.0                  AND
      SLIPPAGE       > 0.0                  AND
      CI             > 0.0                  AND
      SYSTEM         = 4WD
THEN  RATIO          = (60)
      ESFWS          = (125*PTOPW*RATIO/100)
      ESRWS          = (125*PTOPW - ESFWS)
      ESPULL         = (WIDTH*IMPLDRAFT)
      ESRWD          = (ESRWS + (ESPULL * DBHT/WB))
      ESFWD          = (ESFWS - (PULL * DBHT/WB))
      ESBNR = ((CI*RSECW*ROD*(RS)/(ESRWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
CLS
DISPLAY" ... PLEASE WAIT..."
ESBNF = ((CI*FSECW*FOD*(FS)/(ESFWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
ESQRWR  = (0.88*(1-@EXP(-0.1*ESBNR))*
(1-@EXP(-7.5*(SLIPPAGE/100)))+0.04)
ESQRWF  = (0.88*(1-@EXP(-0.1*ESBNF))*
(1-@EXP(-7.5*(SLIPPAGE/100)))+0.04)
APR   = ((PTOPW*.96)/(1+1/(ESRWD*ESQRWR/ESFWD/ESQRWF)))
ESS1 = ((@LOG(1-(APR*375/(SO*ESRWD)-.04)/
(.88*(1-@EXP(-.1*ESBNR)))))*(-100/7.5))
FOR I = 1 TO 5
ESBNR = ((CI*RSECW*ROD*(RS)/(ESRWD/2))*
```

```
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
ESBNF = ((CI*FSECW*FOD*(FS)/(ESFWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
ESQRWR  = (0.88*(1-@EXP(-0.1*ESBNR))*
(1-@EXP(-7.5*(ESS1/100)))+0.04)
ESMWR   = ((1/ESBNR)+0.04+0.5*(ESS1/100)/@SQRT(ESBNR))
ESQRWF  = (0.88*(1-@EXP(-0.1*ESBNF))*
(1-@EXP(-7.5*(ESS1/100)))+0.04)
ESMWF   = ((1/ESBNF)+0.04+0.5*(ESS1/100)/@SQRT(ESBNF))
APR   = ((PTOPW*.96)/(1+1/(ESRWD*ESQRWR/ESFWD/ESQRWF)))
ESS1 = ((@LOG(1-(APR*375/(SO*ESRWD)-.04)/
(.88*(1-@EXP(-.1*ESBNR)))))*(-100/7.5))
ESPULL1  = ((ESQRWR - ESMWR)*ESRWD + (ESQRWF - ESMWF)*ESFWD)
ESRWD    = (ESRWS + (ESPULL1*DBHT/WB))
ESFWD    = (ESFWS - (ESPULL1*DBHT/WB))
ESACS1   = (SO*(1 - ESS1/100))
ESTE1     = (ESPULL1*ESACS1/375/PTOPW)
ESWIDTH1 = (ESPULL1/1.33/IMPLDRAFT)
ESAPH1    = (ESACS1*ESWIDTH1/8)
END
      ESS2 = (S1)
      ESSO1 = (SO)
      ESSO2 = (SO)
      ESSO3 = (SO)
      ESWIDTH2 = (WIDTH1)
WHILETRUE  WIDTH <= (ESWIDTH2)  THEN
ESBNR = ((CI*RSECW*ROD*(RS)/(ESRWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
ESBNF = ((CI*FSECW*FOD*(FS)/(ESFWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
ESQRWR  = (0.88*(1-@EXP(-0.1*ESBNR))*
(1-@EXP(-7.5*(ESS2/100)))+0.04)
ESMWR   = ((1/ESBNR)+0.04+0.5*(ESS2/100)/@SQRT(ESBNR))
ESQRWF  = (0.88*(1-@EXP(-0.1*ESBNF))*
(1-@EXP(-7.5*(ESS2/100)))+0.04)
ESMWF   = ((1/ESBNF)+0.04+0.5*(ESS2/100)/@SQRT(ESBNF))
APR   = ((PTOPW*.96)/(1+1/(ESRWD*ESQRWR/ESFWD/ESQRWF)))
ESS2 = ((@LOG(1-(APR*375/(ESSO2*ESRWD)-.04)/
(.88*(1-@EXP(-.1*ESBNR)))))*(-100/7.5))
TESTPULL  = ((ESQRWR - ESMWR)*ESRWD + (ESQRWF -
ESMWF)*ESFWD)
      ESRWD   = (ESRWS + (TESTPULL*DBHT/WB))
      ESFWD   = (ESFWS - (TESTPULL*DBHT/WB))
      ESACS2  = (ESSO2*(1 - ESS2/100))
      ESTE2    = (TESTPULL*ESACS2/375/PTOPW)
      ESWIDTH2 = (TESTPULL/1.33/IMPLDRAFT)
      ESAPH2   = (ESACS2*ESWIDTH2/8)
      ESSO2    = (ESSO2 +.05)
 END
WHILETRUE  WIDTH >= (ESWIDTH2)  THEN
ESBNR = ((CI*RSECW*ROD*(RS)/(ESRWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
ESBNF = ((CI*FSECW*FOD*(FS)/(ESFWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
```

```
ESQRWR  = (0.88*(1-@EXP(-0.1*ESBNR))*
(1-@EXP(-7.5*(ESS2/100)))+0.04)
ESMWR   = ((1/ESBNR)+0.04+0.5*(ESS2/100)/@SQRT(ESBNR))
ESQRWF  = (0.88*(1-@EXP(-0.1*ESBNF))*
(1-@EXP(-7.5*(ESS2/100)))+0.04)
ESMWF   = ((1/ESBNF)+0.04+0.5*(ESS2/100)/@SQRT(ESBNF))
APR    = ((PTOPW*.96)/(1+1/(ESRWD*ESQRWR/ESFWD/ESQRWF)))
ESS2 = ((@LOG(1-(APR*375/(ESSO2*ESRWD)-.04)/
(.88*(1-@EXP(-.1*ESBNR)))))*(-100/7.5))
TESTPULL  = ((ESQRWR - ESMWR)*ESRWD + (ESQRWF -
ESMWF)*ESFWD)
ESRWD   = (ESRWS + (TESTPULL*DBHT/WB))
ESFWD   = (ESFWS - (TESTPULL*DBHT/WB))
ESACS2  = (ESSO2*(1 - ESS2/100))
ESTE2    = (TESTPULL*ESACS2/375/PTOPW)
ESWIDTH2 = (TESTPULL/1.33/IMPLDRAFT)
ESAPH2   = (ESACS2*ESWIDTH2/8)
ESSO2    = (ESSO2 -.05)
END
      ESS3 = (SLIPPAGE)
FOR T = 1 TO 5
ESBNR = ((CI*RSECW*ROD*(RS)/(ESRWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
ESBNF = ((CI*FSECW*FOD*(FS)/(ESFWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
ESQRWR  = (0.88*(1-@EXP(-0.1*ESBNR))*
(1-@EXP(-7.5*(ESS3/100)))+0.04)
ESMWR   = ((1/ESBNR)+0.04+0.5*(ESS3/100)/@SQRT(ESBNR))
ESQRWF  = (0.88*(1-@EXP(-0.1*ESBNF))*
(1-@EXP(-7.5*(ESS3/100)))+0.04)
ESMWF   = ((1/ESBNF)+0.04+0.5*(ESS3/100)/@SQRT(ESBNF))
APR    = ((PTOPW*.96)/(1+1/(ESRWD*ESQRWR/ESFWD/ESQRWF)))
ESSO3 = (375*APR/ESRWD/(0.88*(1-@EXP(-0.1*ESBNR))*
(1-@EXP(-7.5*ESS3/100))+0.04))
ESPULL3  = ((ESQRWR - ESMWR)*ESRWD + (ESQRWF - ESMWF)*ESFWD)
ESRWD   = (ESRWS + (ESPULL3*DBHT/WB))
ESFWD   = (ESFWS - (ESPULL3*DBHT/WB))
ESACS3  = (ESSO3*(1 - ESS3/100))
ESTE3    = (ESPULL3*ESACS3/375/PTOPW)
ESWIDTH3 = (ESPULL3/1.33/IMPLDRAFT)
ESAPH3   = (ESACS3*ESWIDTH3/8)
END
FIND ACS;
RULE 19
IF    OPERATION      = MATCHING              AND
      PULL           > 0.0                   AND
      RWD            > 0.0                   AND
      SO             > 0.0                   AND
      SLIPPAGE       > 0.0                   AND
      CI             > 0.0                   AND
      SYSTEM         = 2WD
THEN  BNR = ((CI*RSECW*ROD*(RS)/(RWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
CLS
```

```
DISPLAY" ... PLEASE WAIT..."
BNF = ((CI*FSECW*FOD*(FS)/(FWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD))
QRWR  = (0.88*(1-@EXP(-0.1*BNR))*
(1-@EXP(-7.5*(SLIPPAGE/100)))+0.04)
QRWF  = (0.88*(1-@EXP(-0.1*BNF))*
(1-@EXP(-7.5*(SLIPPAGE/100)))+0.04)
APR   = (PTOPW*.96)
S1 = ((@LOG(1-(APR*375/(SO*RWD)-.04)/
(.88*(1-@EXP(-.1*BNR)))))*(-100/7.5))
FOR I = 1 TO 5
BNR = ((CI*RSECW*ROD*(RS)/(RWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD))
BNF = ((CI*FSECW*FOD*(FS)/(FWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD))
QRWR  = (0.88*(1-@EXP(-0.1*BNR))*
(1-@EXP(-7.5*(S1/100)))+0.04)
MWR   = ((1/BNR)+0.04+0.5*(S1/100)/@SQRT(BNR))
QRWF  = (0.88*(1-@EXP(-0.1*BNF))*
(1-@EXP(-7.5*(S1/100)))+0.04)
MWF   = ((1/BNF)+0.04+0.5*(S1/100)/@SQRT(BNF))
APR   = (PTOPW*.96)
S1 = ((@LOG(1-(APR*375/(SO*RWD)-.04)/
(.88*(1-@EXP(-.1*BNR)))))*(-100/7.5))
PULL1  = ((QRWR - MWR)*RWD + (0.04 + 1/BNF)*FWD)
RWD    = (RWS + (PULL1*DBHT/WB))
FWD    = (FWS - (PULL1*DBHT/WB))
ACS1   = (SO*(1 - S1/100))
TE1     = (PULL1*ACS1/375/PTOPW)
WIDTH1 = (PULL1/1.33/IMPLDRAFT)
APH1    = (ACS1*WIDTH1/8)
END
      S2 = (S1)
      SO1 = (SO)
      SO2 = (SO)
      SO3 = (SO)
      WIDTH2 = (WIDTH1)
WHILETRUE  WIDTH <= (WIDTH2)  THEN
      BNR = ((CI*RSECW*ROD*(RS)/(RWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD))
      BNF = ((CI*FSECW*FOD*(FS)/(FWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD))
      QRWR  = (0.88*(1-@EXP(-0.1*BNR))*
(1-@EXP(-7.5*(S2/100)))+0.04)
      MWR   = ((1/BNR)+0.04+0.5*(S2/100)/@SQRT(BNR))
      QRWF  = (0.88*(1-@EXP(-0.1*BNF))*
(1-@EXP(-7.5*(S2/100)))+0.04)
      MWF   = ((1/BNF)+0.04+0.5*(S2/100)/@SQRT(BNF))
      APR   = (PTOPW*.96)
      S2 = ((@LOG(1-(APR*375/(SO2*RWD)-.04)/
(.88*(1-@EXP(-.1*BNR)))))*(-100/7.5))
      TESTPULL  = ((QRWR - MWR)*RWD + (0.04 + 1/BNF)*FWD)
      RWD   = (RWS + (TESTPULL*DBHT/WB))
      FWD   = (FWS - (TESTPULL*DBHT/WB))
```

```
      ACS2   = (SO2*(1 - S2/100))
      TE2     = (TESTPULL*ACS2/375/PTOPW)
      WIDTH2 = (TESTPULL/1.33/IMPLDRAFT)
      APH2    = (ACS2*WIDTH2/8)
      SO2     = (SO2 +.1)
END
WHILETRUE  WIDTH > (WIDTH2)  THEN
      BNR = ((CI*RSECW*ROD*(RS)/(RWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
      BNF = ((CI*FSECW*FOD*(FS)/(FWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
      QRWR   = (0.88*(1-@EXP(-0.1*BNR))*
(1-@EXP(-7.5*(S2/100)))+0.04)
      MWR    = ((1/BNR)+0.04+0.5*(S2/100)/@SQRT(BNR))
      QRWF   = (0.88*(1-@EXP(-0.1*BNF))*
(1-@EXP(-7.5*(S2/100)))+0.04)
      MWF    = ((1/BNF)+0.04+0.5*(S2/100)/@SQRT(BNF))
      APR    = (PTOPW*.96)
      S2 = ((@LOG(1-(APR*375/(SO2*RWD)-.04)/
(.88*(1-@EXP(-.1*BNR)))))*(-100/7.5))
      TESTPULL  = ((QRWR - MWR)*RWD + (0.04 + 1/BNF)*FWD)
      RWD    = (RWS + (TESTPULL*DBHT/WB))
      FWD    = (FWS - (TESTPULL*DBHT/WB))
      ACS2   = (SO2*(1 - S2/100))
      TE2     = (TESTPULL*ACS2/375/PTOPW)
      WIDTH2 = (TESTPULL/1.33/IMPLDRAFT)
      APH2    = (ACS2*WIDTH2/8)
      SO2     = (SO2 - 0.1)
END
      S3 = (SLIPPAGE)
FOR T = 1 TO 5
    BNR = ((CI*RSECW*ROD*(RS)/(RWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
    BNF = ((CI*FSECW*FOD*(FS)/(FWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
    QRWR   = (0.88*(1-@EXP(-0.1*BNR))*
(1-@EXP(-7.5*(S3/100)))+0.04)
    MWR    = ((1/BNR)+0.04+0.5*(S3/100)/@SQRT(BNR))
    QRWF   = (0.88*(1-@EXP(-0.1*BNF))*
(1-@EXP(-7.5*(S3/100)))+0.04)
    MWF    = ((1/BNF)+0.04+0.5*(S3/100)/@SQRT(BNF))
    APR    = (PTOPW*.96)
    SO3 = (375*APR/RWD/(0.88*(1-@EXP(-0.1*BNR))*
(1-@EXP(-7.5*S3/100))+0.04))
    PULL3  = ((QRWR - MWR)*RWD + (0.04 +1/BNF)*FWD)
    RWD    = (RWS + (PULL3*DBHT/WB))
    FWD    = (FWS - (PULL3*DBHT/WB))
    ACS3   = (SO3*(1 - S3/100))
    TE3     = (PULL3*ACS3/375/PTOPW)
    WIDTH3 = (PULL3/1.33/IMPLDRAFT)
    APH3    = (ACS3*WIDTH3/8)
END
FIND ESFWS;
```

```
RULE 20
IF    OPERATION       = MATCHING              AND
      PULL            > 0.0                   AND
      RWD             > 0.0                   AND
      SO              > 0.0                   AND
      SLIPPAGE        > 0.0                   AND
      CI              > 0.0                   AND
      SYSTEM          = 2WD
THEN  RATIO           = (25)
      ESFWS           = (140*PTOPW*RATIO/100)
      ESRWS           = (140*PTOPW - ESFWS)
      ESPULL          = (WIDTH*IMPLDRAFT)
      ESRWD           = (ESRWS + (ESPULL * DBHT/WB))
      ESFWD           = (ESFWS - (PULL * DBHT/WB))
      ESBNR = ((CI*RSECW*ROD*(RS)/(ESRWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
CLS
DISPLAY" ... PLEASE WAIT..."
      ESBNF = ((CI*FSECW*FOD*(FS)/(ESFWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
      ESQRWR  = (0.88*(1-@EXP(-0.1*ESBNR))*
(1-@EXP(-7.5*(SLIPPAGE/100)))+0.04)
      ESQRWF  = (0.88*(1-@EXP(-0.1*ESBNF))*
(1-@EXP(-7.5*(SLIPPAGE/100)))+0.04)
      APR   = (PTOPW*.96)
      ESS1 = ((@LOG(1-(APR*375/(SO*ESRWD)-.04)/
 (.88*(1-@EXP(-.1*ESBNR)))))*(-100/7.5))
FOR I = 1 TO 5
      ESBNR = ((CI*RSECW*ROD*(RS)/(ESRWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
      ESBNF = ((CI*FSECW*FOD*(FS)/(ESFWD/2))*
          ((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
      ESQRWR  = (0.88*(1-@EXP(-0.1*ESBNR))*
(1-@EXP(-7.5*(ESS1/100)))+0.04)
      ESMWR   = ((1/ESBNR)+0.04+0.5*(ESS1/100)/@SQRT(ESBNR))
      ESQRWF  = (0.88*(1-@EXP(-0.1*ESBNF))*
(1-@EXP(-7.5*(ESS1/100)))+0.04)
      ESMWF   = ((1/ESBNF)+0.04+0.5*(ESS1/100)/@SQRT(ESBNF))
      APR   = (PTOPW*.96)
      ESS1 = ((@LOG(1-(APR*375/(SO*ESRWD)-.04)/
      (.88*(1-@EXP(-.1*ESBNR)))))*(-100/7.5))
      ESPULL1=((ESQRWR-ESMWR)*ESRWD+(0.04+1/ESBNF)*ESFWD)
      ESRWD   = (ESRWS + (ESPULL1*DBHT/WB))
      ESFWD   = (ESFWS - (ESPULL1*DBHT/WB))
      ESACS1  = (SO*(1 - ESS1/100))
      ESTE1    = (ESPULL1*ESACS1/375/PTOPW)
      ESWIDTH1 = (ESPULL1/1.33/IMPLDRAFT)
      ESAPH1   = (ESACS1*ESWIDTH1/8)
END
      ESS2 = (S1)
      ESSO1 = (SO)
      ESSO2 = (SO)
      ESSO3 = (SO)
      ESWIDTH2 = (WIDTH1)
```

```
WHILETRUE  WIDTH <= (ESWIDTH2)  THEN
      ESBNR = ((CI*RSECW*ROD*(RS)/(ESRWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
      ESBNF = ((CI*FSECW*FOD*(FS)/(ESFWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
      ESQRWR  = (0.88*(1-@EXP(-0.1*ESBNR))*
(1-@EXP(-7.5*(ESS2/100)))+0.04)
      ESMWR   = ((1/ESBNR)+0.04+0.5*(ESS2/100)/@SQRT(ESBNR))
      ESQRWF  = (0.88*(1-@EXP(-0.1*ESBNF))*
(1-@EXP(-7.5*(ESS2/100)))+0.04)
      ESMWF   = ((1/ESBNF)+0.04+0.5*(ESS2/100)/@SQRT(ESBNF))
      APR   = (PTOPW*.96)
      ESS2 = ((@LOG(1-(APR*375/(ESSO2*ESRWD)-.04)/
   (.88*(1-@EXP(-.1*ESBNR)))))*(-100/7.5))
      TESTPULL=((ESQRWR-ESMWR)*ESRWD+(0.04 + 1/ESBNF)*ESFWD)
      ESRWD   = (ESRWS + (TESTPULL*DBHT/WB))
      ESFWD   = (ESFWS - (TESTPULL*DBHT/WB))
      ESACS2  = (ESSO2*(1 - ESS2/100))
      ESTE2    = (TESTPULL*ESACS2/375/PTOPW)
      ESWIDTH2 = (TESTPULL/1.33/IMPLDRAFT)
      ESAPH2   = (ESACS2*ESWIDTH2/8)
      ESSO2    = (ESSO2 +.1)
END
WHILETRUE  ESWIDTH > (ESWIDTH2)  THEN
      ESBNR = ((CI*RSECW*ROD*(RS)/(ESRWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
      ESBNF = ((CI*FSECW*FOD*(FS)/(ESFWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
      ESQRWR  = (0.88*(1-@EXP(-0.1*ESBNR))*
(1-@EXP(-7.5*(ESS2/100)))+0.04)
      ESMWR   = ((1/ESBNR)+0.04+0.5*(ESS2/100)/@SQRT(ESBNR))
      ESQRWF  = (0.88*(1-@EXP(-0.1*ESBNF))*
(1-@EXP(-7.5*(ESS2/100)))+0.04)
      ESMWF   = ((1/ESBNF)+0.04+0.5*(ESS2/100)/@SQRT(ESBNF))
      APR   = (PTOPW*.96)
      ESS2 = ((@LOG(1-(APR*375/(ESSO2*ESRWD)-.04)/
   (.88*(1-@EXP(-.1*ESBNR)))))*(-100/7.5))
      TESTPULL=((ESQRWR-ESMWR)*ESRWD+(0.04 + 1/ESBNF)*ESFWD)
      ESRWD   = (ESRWS + (TESTPULL*DBHT/WB))
      ESFWD   = (ESFWS - (TESTPULL*DBHT/WB))
      ESACS2  = (ESSO2*(1 - ESS2/100))
      ESTE2    = (TESTPULL*ESACS2/375/PTOPW)
      ESWIDTH2 = (TESTPULL/1.33/IMPLDRAFT)
      ESAPH2   = (ESACS2*ESWIDTH2/8)
      ESSO2    = (ESSO2 -.1)
END
      ESS3 = (SLIPPAGE)
FOR T = 1 TO 5
    ESBNR = ((CI*RSECW*ROD*(RS)/(ESRWD/2))*
((1+5*.18)/(1+3*RSECW*(RS)/ROD)))
    ESBNF = ((CI*FSECW*FOD*(FS)/(ESFWD/2))*
((1+5*.18)/(1+3*FSECW*(FS)/FOD)))
    ESQRWR  = (0.88*(1-@EXP(-0.1*ESBNR))*
(1-@EXP(-7.5*(ESS3/100)))+0.04)
```

```
    ESMWR    = ((1/ESBNR)+0.04+0.5*(ESS3/100)/@SQRT(ESBNR))
    ESQRWF   = (0.88*(1-@EXP(-0.1*ESBNF))*
(1-@EXP(-7.5*(ESS3/100)))+0.04)
    ESMWF    = ((1/ESBNF)+0.04+0.5*(ESS3/100)/@SQRT(ESBNF))
    APR    = (PTOPW*.96)
    ESSO3 = (375*APR/ESRWD/(0.88*(1-@EXP(-0.1*ESBNR))*
       (1-@EXP(-7.5*ESS3/100))+0.04))
    ESPULL3=((ESQRWR-ESMWR)*ESRWD + (0.04 + 1/ESBNF)*ESFWD)
    ESRWD    = (ESRWS + (ESPULL3*DBHT/WB))
    ESFWD    = (ESFWS - (ESPULL3*DBHT/WB))
    ESACS3   = (ESSO3*(1 - ESS3/100))
    ESTE3     = (ESPULL3*ESACS3/375/PTOPW)
    ESWIDTH3 = (ESPULL3/1.33/IMPLDRAFT)
    ESAPH3    = (ESACS3*ESWIDTH3/8)
END
FIND ACS;
RULE 21
IF     OPERATION    = TIRE_PRESSURE     AND
       RWD         > 0.0
THEN   FINAL        = OK
       SAVEFACTS B:RWD
       CHAIN B:PRESSURE;
RULE 22
IF     OPERATION       = MATCHING         AND
       PULL            > 0.0              AND
       SLIPPAGE        > 0.0
THEN
ACS                = (SO*(1-SLIPPAGE/100))
APH                = (WIDTH*ACS/8)
DBHPOWER           = (WIDTH*1.33*IMPLDRAFT*ACS/375)
TE                 = (DBHPOWER/PTOPW)
DBHPOWER1          = (WIDTH*1.33*IMPLDRAFT*ACS2/375)
TRACTOR_WEIGHT     = ((RWS + FWS)/PTOPW)
ESTRACTOR_WEIGHT = ((ESRWS + ESFWS)/PTOPW)
FORMAT TRACTOR_WEIGHT,5.1
FORMAT ESTRACTOR_WEIGHT,5.1
FORMAT DBHPOWER, 6.1
FORMAT DBHPOWER1,6.1
FORMAT WIDTH1,5.2
FORMAT S1,4.1
FORMAT SO1,4.1
FORMAT TE1,5.3
FORMAT APH1,6.3
FORMAT ACS1,4.1
FORMAT WIDTH2,5.2
FORMAT S2,4.1
FORMAT SO2,4.1
FORMAT TE2,5.3
FORMAT APH2,6.3
FORMAT ACS2,4.1
FORMAT WIDTH3,5.2
FORMAT S3,4.1
FORMAT SO3,4.1
FORMAT TE3,5.3
```

```
FORMAT APH3,6.3
FORMAT ACS3,4.1
FORMAT WIDTH,5.2
FORMAT S,4.1
FORMAT SO,4.1
FORMAT TE,5.3
FORMAT APH,6.3
FORMAT ACS,4.1
FORMAT ESWIDTH1,5.2
FORMAT ESS1,4.1
FORMAT ESSO1,4.1
FORMAT ESTE1,5.3
FORMAT ESAPH1,6.3
FORMAT ESACS1,4.1
FORMAT ESWIDTH2,5.2
FORMAT ESS2,4.1
FORMAT ESSO2,4.1
FORMAT ESTE2,5.3
FORMAT ESAPH2,6.3
FORMAT ESACS2,4.1
FORMAT ESWIDTH3,5.2
FORMAT ESS3,4.1
FORMAT ESSO3,4.1
FORMAT ESTE3,5.3
FORMAT ESAPH3,6.3
FORMAT ESACS3,4.1
FORMAT WIDTH,5.2
FORMAT ESS,4.1
FORMAT ESSO,4.1
FORMAT ESTE,5.3
FORMAT ESAPH,6.3
FORMAT ESACS,4.1
CLS
DISPLAY" For the specified conditions of width = {WIDTH}
foot , speed = {ACS} MPH, and slip = {SLIPPAGE}%.  The
drawbar horsepower of tractor is estimated to be {DBHPOWER}
HP  with {TE} tractive efficiency.  This tractor should be
capable of pulling {WIDTH} foot implement at {ACS2} MPH and
{S2}% slip for a drawbar horsepower of {DBHPOWER1} and
tractive efficiency of {TE2}.
                <Press any key to continue> ~"
CLS
DISPLAY"
Options    Width(Ft)   Speed(MPH)    Slip    T.E.   ACRE/HR
------------------------------------------------------------
The tractor weight is {TRACTOR_WEIGHT} lb/PTO.
1.      {WIDTH1}      {ACS1}       {S1}     {TE1}    {APH1}
2.      {WIDTH2}      {ACS2}       {S2}     {TE2}    {APH2}
3.      {WIDTH3}      {ACS3}       {S3}     {TE3}     {APH3}
The tractor weight is {ESTRACTOR_WEIGHT} lb/PTO.
4.    {ESWIDTH1}    {ESACS1}   {ESS1}    {ESTE1}    {ESAPH1}
5.    {ESWIDTH2}    {ESACS2}   {ESS2}    {ESTE2}    {ESAPH2}
6.    {ESWIDTH3}    {ESACS3}   {ESS3}    {ESTE3}    {ESAPH3}
------------------------------------------------------------
```

```
                <Press any key>        ~"
      FINAL = OK;

RULE 23
IF      OPERATION      = MATCHING        AND
        FINAL          = OK              AND
        CHICK          = YES
THEN    CHANGE_FILE    = OK
        CHAIN B:SYSTEM;
RULE 24
IF      OPERATION      = MATCHING        AND
        FINAL          = OK              AND
        CHICK          = NO
THEN    CHANGE_FILE    = OK
DISPLAY" Thank you for using this program.
              <Press any key>~";
ASK CHICK:"Would you like to use another file?";
CHOICES CHICK:YES,NO;
ASK SPEED:"What is the indicated field speed you would like
to achieve with your tractor during most operations?";
ASK THE_SOIL:"How would you describe the SOIL conditions of
the fields where your tractor is most frequently operated?";
ASK THE_IMPLEMENT:"What type of implement will be frequently
used with this tractor?";
ASK IMPLEMENT:"What type of implement will be frequently
used with this tractor?";
CHOICES IMPLEMENT1: MOLDBOARD_PLOW, CHISEL,OFFSET_DISK,
V_BLADE, TANDEM_DISK, CHISEL_WITH_SWEEPS;
ASK WIDTH:"What is the width of the implement (FEET)?";
ASK SLIPPAGE:"What is the percentage of tire slip at which
you would like the tractor to operate?
Refer to the following table for guidance.
______________________________________________________
                    Tractor Type
Soil     _____________________________________________
             2WD         FWD          4WD
______________________________________________________
Firm        10-12        8-10         8-10
Tilled      12-14      10-11.5      10-11.5
Sandy       14-16      11.5-13      11.5-13
______________________________________________________";
ASK CI:"What is the estimated Cone Index (psi)?
Refer to the following table for guidance.
________________________________________________________
           CI               SOIL CONDITION
________________________________________________________
          250          HARD, PACKED
          200          HARD, PACKED WITH STUBBLE
          150          FIRM
          80           TILLED
          60           SOFT, WET
________________________________________________________";
ASK DRAFT_OF_IMPLEMENT:"Do you know the implement draft?";
CHOICES DRAFT_OF_IMPLEMENT:YES,NO;
ASK DRAFT_PER_UNIT:"How much is it (lbs/ft)?";
```

APPENDIX E

PRESSURE KNOWLEDGE BASE

```
EXECUTE;
RUNTIME;
ENDOFF;
ACTIONS
        LOADFACTS B:RWD
        FIND TIRE3
        FIND TIRE_LOAD
        FIND PRESSURE_TEST
        FIND PRESSURE
        FIND PRESSURE_RECOMMENDED
        FIND CHANGE_FILE;
RULE 1
IF      PRESSURE                = 999
THEN    PRESSURE_RECOMMENDED    = OK
DISPLAY "The weight of the tractor is over the load
limitation. Try to reduce the tractor weight."
DISPLAY"            <Press any key>~";
RULE 2
IF      PRESSURE                = 888
THEN    PRESSURE_RECOMMENDED    = OK
DISPLAY"It is recommended to look at the tire manual "
DISPLAY"            <Press any key>~";
RULE 3
IF      PRESSURE                <> 999      OR
        PRESSURE                <> 888      AND
        TIRES                   = SINGLE
THEN    PRESSURE_RECOMMENDED    = OK
DISPLAY"The estimated tire pressure is {PRESSURE} PSI."
DISPLAY"            <Press any key>~";
RULE 4
IF      PRESSURE                <>  999      OR
        PRESSURE                <>  888      AND
        TIRES                   = DUAL
THEN    PRESSURE_RECOMMENDED    = OK
        INSIDE                  = (PRESSURE + 2)
DISPLAY"The recommended tire pressure is {PRESSURE} psi for
outside dual and {INSIDE} psi for inside dual."
DISPLAY"            <Press any key>~";
RULE 5
IF      TIRE       =      BIAS
THEN    TIRE3      = OK
        WHILEKNOWN SIZE
              GET RTIRE_SIZE=SIZE, B:BPRESSUR,ALL
```

```
        RESET RTIRE_SIZE
        CLOSE B:BPRESSUR;
RULE 6
IF      TIRE         = RADIAL
THEN    TIRE3        = OK
        MENU THE_SIZE,ALL,B:RPRESSUR,SIZE
             FIND THE_SIZE
        WHILEKNOWN SIZE
              GET THE_SIZE=SIZE, B:RPRESSUR,ALL
        RESET THE_SIZE
        CLOSE B:RPRESSUR;
RULE 7
IF      TIRES      = SINGLE      AND
        RWD        > 0.0
THEN    TIRE_LOAD = (RWD/2);
RULE 8
IF      TIRES      = DUAL         AND
        RWD        > 0.0
THEN    TIRE_LOAD = (RWD/(4*.88));
RULE 9
IF      TIRE_LOAD    <> 0.0
THEN    PRESSURE_TEST = DONE
        PSI12A       = (PSI12)
        PSI14A       = (PSI14)
        PSI16A       = (PSI16)
        PSI18A       = (PSI18)
        PSI20A       = (PSI20)
        PSI22A       = (PSI22)
        PSI24A       = (PSI24)
        PSI26A       = (PSI26)
        PSI28A       = (PSI28)
        PSI30A       = (PSI30)
FIND PSI16A_TEST;
RULE 10
IF     PSI16A       = (0.0 )       AND
       PSI18A       > 0.0          AND
       TIRE_LOAD   < (PSI18A)
THEN   PSI16A_TEST  = DONE
       PSI16A      = (2*PSI18A - PSI20A)
FIND PSI14A_TEST;
RULE 11
IF     PSI14A       = 0            AND
       PSI16A       > 0            AND
       TIRE_LOAD   < (PSI16A)
THEN   PSI14A_TEST  = DONE2
       PSI14A      = (2*PSI16A - PSI18A)
FIND PSI12A_TEST;
RULE 12
IF      PSI12A       = 0            AND
        PSI14A       > 0            AND
        TIRE_LOAD  < (PSI14A)
THEN    PSI12A_TEST = DONE2
        PSI12A     = (2*(PSI14A) - (PSI16A));
```

```
RULE 13
IF     TIRE_LOAD  <= (PSI12A + 25)
THEN   PRESSURE   = 12;
RULE 14
IF    TIRE_LOAD    > (PSI12A + 25)     AND
      TIRE_LOAD    < (PSI14A - 25)
THEN  PRESSURE     = 13;
RULE 15
IF    TIRE_LOAD  >= (PSI14A - 25)     AND
      TIRE_LOAD  <= (PSI14A + 25)
THEN  PRESSURE   = 14;
RULE 16
IF    TIRE_LOAD    > (PSI14A + 25)      AND
      TIRE_LOAD    < (PSI16A - 25)
THEN  PRESSURE     = 15;
RULE 17
IF    TIRE_LOAD  >= (PSI16A - 25)     AND
      TIRE_LOAD  <= (PSI16A + 25)
THEN  PRESSURE   = 16;
RULE 18
IF   TIRE_LOAD      > (PSI16A + 25)      AND
     TIRE_LOAD      < (PSI18A - 25)
THEN  PRESSURE      = 17;
RULE 19
IF    TIRE_LOAD  >= (PSI18A - 25)     AND
      TIRE_LOAD  <= (PSI18A + 25)
THEN  PRESSURE   = 18;
RULE 20
IF    TIRE_LOAD     > (PSI18A + 25)        AND
      TIRE_LOAD     < (PSI20A - 25)
THEN  PRESSURE      = 19;
RULE 21
IF    TIRE_LOAD  >= (PSI20A - 25)     AND
      TIRE_LOAD  <= (PSI20A + 25)
THEN  PRESSURE   = 20;
RULE 22
IF    TIRE_LOAD    > (PSI20A + 25)        AND
      TIRE_LOAD    < (PSI22A - 25)
THEN  PRESSURE     = 21;
RULE 23
IF    TIRE_LOAD  >= (PSI22A - 25)     AND
      TIRE_LOAD  <= (PSI22A + 25)
THEN  PRESSURE   = 22;
RULE 24
IF    TIRE_LOAD    > (PSI22A + 25)       AND
      TIRE_LOAD    < (PSI24A - 25)
THEN  PRESSURE     = 23;
RULE 25
IF    TIRE_LOAD  >= (PSI24A - 25)     AND
      TIRE_LOAD  <= (PSI24A + 25)
THEN  PRESSURE   = 24;
RULE 26
IF    TIRE_LOAD    > (PSI24A + 25)        AND
      TIRE_LOAD    < (PSI26A - 25)
```

```
THEN  PRESSURE     = 25;
RULE 27
IF    TIRE_LOAD  >= (PSI26A - 25)     AND
      TIRE_LOAD  <= (PSI26A + 25)
THEN  PRESSURE   = 26;

RULE 28
IF    TIRE_LOAD    > (PSI26A + 25)       AND
      TIRE_LOAD    < (PSI28A - 25)
THEN  PRESSURE     = 27;
RULE 29
IF    TIRE_LOAD  >= (PSI28A - 25)     AND
      TIRE_LOAD  <= (PSI28A + 25)
THEN  PRESSURE   = 28;
RULE 30
IF    TIRE_LOAD     > (PSI28A + 25)     AND
      TIRE_LOAD     < (PSI30A - 25)
THEN  PRESSURE      = 29;
RULE 31
IF    TIRE_LOAD  >= (PSI30A - 25)     AND
      TIRE_LOAD  <= (PSI30A + 25)
THEN  PRESSURE   = 30;
RULE 32
IF     PSI20A     = 0                  AND
       TIRE_LOAD  > (PSI18A)
THEN   PRESSURE   = 888;
RULE 33
IF     PSI22A     = 0                   AND
       TIRE_LOAD  > (PSI20A)
THEN   PRESSURE   = 888;
RULE 34
IF     TIRE_LOAD  > (PSI22A)             AND
       PSI24A     = 0
THEN   PRESSURE   = 888;
RULE 35
IF     TIRE_LOAD  > (PSI24A)            AND
       PSI26A     = 0
THEN   PRESSURE   = 888;
RULE 36
IF    TIRE_LOAD    > (PSI30)
THEN  PRESSURE     = 999;
RULE 37
IF     CHICK          = YES
THEN   CHANGE_FILE    = OK
       CHAIN B:SYSTEM;
RULE 38
IF     CHICK           = NO
THEN   CHANGE_FILE     = OK
DISPLAY "Thank you for using this program.
               <Press any key>~";
ASK TIRE:"Have you been using BIAS or RADIAL tires?";
CHOICES TIRE:BIAS,RADIAL;
ASK TIRES:"Have you been using SINGLE or DUAL tires?";
CHOICES TIRES:SINGLE,DUAL;
```

```
ASK THE_SIZE:"What size are the current tires?";
ASK CHICK:"Would you like to use another file?";
CHOICES CHICK:YES,NO;
```

APPENDIX F

TIRE1 KNOWLEDGE BASE

```
EXECUTE;
RUNTIME;
ENDOFF;
ACTIONS
        FIND RECOMMEND3A
        FIND RECOMMEND3B
        FIND BALLASTING
        FIND RECOMMEND1
        FIND RECOMMEND2
        FIND RECOMMEND3
        FIND RECOMMEND4
        FIND RECOMMEND5;
RULE 1
IF      BALLAST         = NO
THEN    RECOMMEND3A     = DISPLAY1
DISPLAY "Recommendation: test the tractor weight by running
the BALLASTING program first.
                        <Press any key>~";
RULE 2
IF      BALLAST         = YES       OR
        BALLAST         = NO        AND
        MATCH           = NO
THEN    RECOMMEND3B      = DISPLAY2
DISPLAY "Recommendation: test the implement matching by
running the MATCHING program first.
                        <Press any key>~";
RULE 3
IF     BALLAST         = YES            OR
       BALLAST         = NO             AND
       MATCH           = YES            OR
       MATCH           = NO
THEN   BALLASTING      = OK;
RULE 4
IF      BALLASTING      = OK            AND
        TIRE            = BIAS           OR
        TIRE            = RADIAL         AND
        TIRES           = DUAL           OR
        TIRES           = SINGLE         AND
        PROBLEMS        = TREAD_WEAR     AND
        LUG             > 20
THEN    RECOMMEND3      = FINAL1
DISPLAY "There is no reason to change the tires at this
time.
```

```
                        <Press any key>~";
RULE 5
IF     BALLASTING      = OK           AND
       TIRE            = RADIAL       OR
       TIRE            = BIAS         AND
       TIRES           = DUAL         OR
       TIRES           = SINGLE       AND
       PROBLEMS        = NOT_RELIABLE OR
       PROBLEMS        = TREAD_WEAR   AND
       LUG             < 20
THEN   RECOMMEND1      = R8;
RULE 6
IF     BALLASTING      = OK            AND
       TIRE            = BIAS          OR
       TIRE            = RADIAL        AND
       TIRES           = SINGLE        OR
       TIRES           = DUAL          AND
       PROBLEMS        = ONE_TIRE_BAD  AND
       STATUS          = NEW           OR
       STATUS          = GOOD
THEN   RECOMMEND3      = FINAL1
DISPLAY "A new {TIRE} tire is recommended.
                <Press any key>~";
RULE 7
IF     BALLASTING      = OK             AND
       TIRE            = RADIAL         OR
       TIRE            = BIAS           AND
       TIRES           = DUAL           OR
       TIRES           = SINGLE         AND
       PROBLEMS        = ONE_TIRE_BAD   AND
       STATUS          = POOR           AND
       FIND            = YES
THEN   RECOMMEND3      = FINAL1
DISPLAY "It is recommended to have a {TIRE} tire in good
condition.
                        <Press any key >~";
RULE 8
IF     BALLASTING      = OK             AND
       TIRE            = RADIAL         OR
       TIRE            = BIAS           AND
       TIRES           = DUAL           OR
       TIRES           = SINGLE         AND
       PROBLEMS        = ONE_TIRE_BAD   AND
       STATUS          = POOR           AND
       FIND            = NO
THEN   RECOMMEND1      = R8;
RULE 9
IF     BALLASTING      = OK             AND
       TIRE            = RADIAL         OR
       TIRE            = BIAS           AND
       TIRES           = DUAL           OR
       TIRES           = SINGLE         AND
       PROBLEMS        = ONE_TIRE_BAD   AND
       STATUS          = WORN
```

```
THEN    RECOMMEND1      = R8;
RULE 10
IF      RECOMMEND1       = R8              AND
        TIRES_TYPE       = GENERAL         OR
        TIRES_TYPE       = INDUSTRIAL      OR
        TIRES_TYPE       = HIGH_CLEAT      AND
        TILLAGE          = YES             OR
        TILLAGE          = NO              AND
        PER_MUDDY_AREA  >= 40              AND
        PER_HARD_AREA   <= 10
THEN    RECOMMEND2       = HIGH_CLEAT;
RULE 11
IF      RECOMMEND1       = R8              AND
        TIRES_TYPE       = GENERAL         OR
        TIRES_TYPE       = HIGH_CLEAT      OR
        TIRES_TYPE       = INDUSTRIAL      AND
        TILLAGE          = YES             OR
        TILLAGE          = NO              AND
        PER_MUDDY_AREA  <= 10              AND
        PER_HARD_AREA   >= 60
THEN    RECOMMEND2       = INDUSTRIAL
ELSE    RECOMMEND2       = GENERAL;
RULE 12
IF      RECOMMEND2       = HIGH_CLEAT      OR
        RECOMMEND2       = GENERAL         OR
        RECOMMEND2       = INDUSTRIAL      AND
        FOOT_PRINT       = NOT_CLEAR
THEN    RECOMMEND4       = FINAL
CLS
DISPLAY"The foot print of tires is NOT CLEAR print, which
means your tractor is UNDERBALLASTED and it is recommended
to reweigh your tractor.
               < Press any key to continue >~";
RULE 13
IF      RECOMMEND2       = HIGH_CLEAT      OR
        RECOMMEND2       = GENERAL         OR
        RECOMMEND2       = INDUSTRIAL      AND
        FOOT_PRINT       = SHARP
THEN    RECOMMEND4       = FINAL
CLS
DISPLAY"The foot print of the tires is SHARP print, which
means your tractor is  OVERBALLASTED and it is recommended
to reweigh your tractor.
             < Press any key to continue >~";
RULE 14
IF      RECOMMEND2       = HIGH_CLEAT      OR
        RECOMMEND2       = GENERAL         OR
        RECOMMEND2       = INDUSTRIAL      AND
        FOOT_PRINT       = CLEAR
THEN    RECOMMEND3       = FINAL;
RULE 15
IF      RECOMMEND3       = FINAL1      AND
        CHICK            = YES
THEN    RECOMMEND5       = FINAL
```

```
        CHAIN B:SYSTEM;
RULE 16
IF      RECOMMEND3       = FINAL1      AND
        CHICK            = NO
THEN    RECOMMEND5       = FINAL
DISPLAY"Thank you for using this program.
                <Press any key>~";
RULE 17
IF      RECOMMEND3       = FINAL
THEN    RECOMMEND5       = FINAL
        SAVEFACTS B:TIRE
        CHAIN B:TIRE2;
RULE 18
IF      RECOMMEND4       = FINAL         AND
        REWIEGHT         = YES
THEN    RECOMMEND5       = FINAL
        SAVEFACTS B:TIRE
        CHAIN B:BALLAST1
ELSE    SAVEFACTS B:TIRE
        CHAIN B:TIRE2;
ASK CHICK:"Would you like to use another file?";
CHOICES CHICK:YES,NO;
ASK BALLAST: "Has weight been added to your tractor to
improve performance?";
CHOICES BALLAST: YES,NO;
ASK MATCH: "Do you think the slippage of the tractor is
OK?";
CHOICES MATCH: YES,NO;
ASK TIRES: "Have you been using SINGLE or DUAL tires?";
CHOICES TIRES: SINGLE,DUAL;
ASK TIRE: "Have you been using BIAS or RADIAL tires?";
CHOICES TIRE: BIAS,RADIAL;
ASK PROBLEMS: "Why do the current tire(s) need
replacement?";
CHOICES PROBLEMS: ONE_TIRE_BAD,NOT_RELIABLE,TREAD_WEAR;
ASK LUG: "Comparing the height of the current tire's lug to
a new tire, how much percentage tread is left?";
ASK TILLAGE: "Will this particular tractor be used for
tillage or other heavy drawbar loads?";
CHOICES TILLAGE: YES,NO;
ASK TIRES_TYPE: "What was the tread design of the tires you
had been using?";
CHOICES TIRES_TYPE: GENERAL,HIGH_CLEAT,INDUSTRIAL;
ASK STATUS: "What are the conditions of the other tires?";
CHOICES STATUS: NEW,GOOD,POOR,WORN;
ASK FIND: "Would it be possible to locate a used tire having
the same conditions and manufacturer as other tires?";
CHOICES FIND:YES,NO;
ASK FOOT_PRINT: "When you look at the tire track just behind
the tire during operation under normal load, what does it
look like?
    SHARP: Sharp distinct tire print.
    CLEAR: Print somewhat broken up, BUT recognizable.
NOT_CLEAR: The tire print is sheared away.  No clear tire
```

```
print is remaining.";
CHOICES FOOT_PRINT: SHARP,CLEAR,NOT_CLEAR;
ASK PER_HARD_AREA: "What percentage of field area on your
farm has roads or any other hard areas?";
ASK PER_MUDDY_AREA: "What percentage of field area on your
farm contains tight or sticky soils which are frequently
difficult to work?";
ASK REWIEGHT:"Would you like to check the tractor weight?";
CHOICES REWIEGHT:YES,NO;
```

APPENDIX G

TIRE2 KNOWLEDGE BASE

```
EXECUTE;
RUNTIME;
ENDOFF;
ACTIONS
        LOADFACTS B:TIRE
        FIND SRAF
        FIND RECOMMEND_SIZE
        FIND RECOMMENDATION4
        FIND CHANGE_FILE;
RULE 1
IF      DRAWBAR        = UNKNOWN         AND
        SPEED          <> 0.0            AND
        PTOHP          <> 0.0            AND
        TRACTOR        = 4WD             AND
        SOIL           = SANDY
THEN    SRAF           = (PTOHP*0.7*375/(SPEED*0.45))
        LOAD           = (SRAF/2);
RULE 2
IF      DRAWBAR        = UNKNOWN         AND
        SPEED          <> 0.0            AND
        PTOHP          <> 0.0            AND
        TRACTOR        = 4WD             AND
        SOIL           = MED
THEN    SRAF           = (PTOHP*0.75*375/(SPEED*0.45))
        LOAD           = (SRAF/2);
RULE 3
IF      DRAWBAR        = UNKNOWN         AND
        SPEED          <> 0.0            AND
        PTOHP          <> 0.0            AND
        TRACTOR        = 4WD             AND
        SOIL           = CLAY
THEN    SRAF           = (PTOHP*0.78*375/(SPEED*0.45))
        LOAD           = (SRAF/2);
RULE 4
IF      DRAWBAR        = UNKNOWN         AND
        SPEED          <> 0.0            AND
        PTOHP          <> 0.0            AND
        TRACTOR        = 2WD             AND
        SOIL           = SANDY
THEN    SRAF           = (PTOHP*0.55*375/(SPEED*0.45))
        LOAD           = (SRAF/2);
RULE 5
IF      DRAWBAR        = UNKNOWN         AND
```

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        SPEED           <> 0.0          AND
        PTOHP           <> 0.0          AND
        TRACTOR         = 2WD           AND
        SOIL            = MED
THEN    SRAF            = (PTOHP*0.67*375/(SPEED*0.45))
        LOAD            = (SRAF/2);
RULE 6
IF      DRAWBAR         = UNKNOWN       AND
        SPEED           <> 0.0          AND
        PTOHP           <> 0.0          AND
        TRACTOR         = 2WD           AND
        SOIL            = CLAY
THEN    SRAF            = (PTOHP*0.72*375/(SPEED*0.45))
        LOAD            = (SRAF/2);
RULE 7
IF      DRAWBAR         = UNKNOWN       AND
        SPEED           <> 0.0          AND
        PTOHP           <> 0.0          AND
        TRACTOR         = FWA           AND
        SOIL            = SANDY
THEN    SRAF            = (PTOHP*0.65*375/(SPEED*0.45))
        LOAD            = (SRAF/2);
RULE 8
IF      DRAWBAR         = UNKNOWN       AND
        SPEED           <> 0.0          AND
        PTOHP           <> 0.0          AND
        TRACTOR         = FWA           AND
        SOIL            = MED
THEN    SRAF            = (PTOHP*0.73*375/(SPEED*0.45))
        LOAD            = (SRAF/2);
RULE 9
IF      DRAWBAR         = UNKNOWN       AND
        SPEED           <> 0.0          AND
        PTOHP           <> 0.0          AND
        TRACTOR         = FWA           AND
        SOIL            = CLAY
THEN    SRAF            = (PTOHP*0.77*375/(SPEED*0.45))
        LOAD            = (SRAF/2);
RULE 10
IF      DRAWBAR         <> 0.0      AND
        SPEED           <> 0.0
THEN    SRAF             = (DRAWBAR*375/(SPEED*0.45))
        LOAD             = (SRAF/2);
RULE 11
IF     TIRE_SIZE        = T16.9-34[6]    OR
       TIRE_SIZE        = T18.4-34[8]    OR
       TIRE_SIZE        = T20.8-34[6]    OR
       TIRE_SIZE        = T23.1-34[8]    AND
       LOAD            <= 4440
THEN   RECOMMEND_SIZE   = T16.9-34[6]
       RECOMMEND_TIRE   = SINGLE;
RULE 12
IF     TIRE_SIZE        = T16.9-34[6]    OR
       TIRE_SIZE        = T18.4-34[8]    OR
```

```
        TIRE_SIZE         = T20.8-34[6]    OR
        TIRE_SIZE         = T23.1-34[8]    AND
        LOAD             >= 4440            AND
        LOAD             <= 5650
THEN    RECOMMEND_SIZE    = T18.4-34[8]
        RECOMMEND_TIRE    = SINGLE;
RULE 13
IF      TIRE_SIZE         = T16.9-34[6]    OR
        TIRE_SIZE         = T18.4-34[8]    OR
        TIRE_SIZE         = T20.8-34[6]    OR
        TIRE_SIZE         = T23.1-34[8]    AND
        LOAD             >= 5650            AND
        LOAD             <= 6360
THEN    RECOMMEND_SIZE    = T20.8-34[6]
        RECOMMEND_TIRE    = SINGLE;
RULE 14
IF      TIRE_SIZE         = T16.9-34[6]    OR
        TIRE_SIZE         = T18.4-34[8]    OR
        TIRE_SIZE         = T20.8-34[6]    OR
        TIRE_SIZE         = T23.1-34[8]    AND
        LOAD             >= 6360            AND
        LOAD             <= 7110
THEN    RECOMMEND_SIZE    = T23.1-34[8]
        RECOMMEND_TIRE    = SINGLE;
RULE 15
IF      TIRE_SIZE         = T16.9-34[6]    OR
        TIRE_SIZE         = T18.4-34[8]    OR
        TIRE_SIZE         = T20.8-34[6]    OR
        TIRE_SIZE         = T23.1-34[8]    AND
        LOAD             >= 7110            AND
        LOAD             <= 7814
THEN    RECOMMEND_SIZE    = T16.9-34[6]
        RECOMMEND_TIRE    = DUAL;
RULE 16
IF      TIRE_SIZE         = T16.9-34[6]    OR
        TIRE_SIZE         = T18.4-34[8]    OR
        TIRE_SIZE         = T20.8-34[6]    OR
        TIRE_SIZE         = T23.1-34[8]    AND
        LOAD             >= 7814            AND
        LOAD             <= 9944
THEN    RECOMMEND_SIZE    = T18.4-34[8]
        RECOMMEND_TIRE    = DUAL;
RULE 17
IF      TIRE_SIZE         = T16.9-34[6]    OR
        TIRE_SIZE         = T18.4-34[8]    OR
        TIRE_SIZE         = T20.8-34[6]    OR
        TIRE_SIZE         = T23.1-34[8]    AND
        LOAD             >= 9944            AND
        LOAD             <= 11194
THEN    RECOMMEND_SIZE    = T20.8-34[6]
        RECOMMEND_TIRE    = DUAL;
RULE 18
IF      TIRE_SIZE         = T16.9-34[6]    OR
        TIRE_SIZE         = T18.4-34[8]    OR
```

```
        TIRE_SIZE          = T20.8-34[6]    OR
        TIRE_SIZE          = T23.1-34[8]    AND
        LOAD              >= 11194           AND
        LOAD              <= 12514
THEN    RECOMMEND_SIZE     = T23.1-34[8]
        RECOMMEND_TIRE     = DUAL;
RULE 19
IF      TIRE_SIZE          = T16.9-38[6]     OR
        TIRE_SIZE          = T18.4-38[6]     OR
        TIRE_SIZE          = T18.4-38[8]     OR
        TIRE_SIZE          = T20.8-38[8]     OR
        TIRE_SIZE          = T20.8-38[10]    AND
        LOAD              <= 5250
THEN    RECOMMEND_SIZE     = T16.9-38[6]
        RECOMMEND_TIRE     = SINGLE;
RULE 20
IF      TIRE_SIZE          = T16.9-38[6]     OR
        TIRE_SIZE          = T18.4-38[6]     OR
        TIRE_SIZE          = T18.4-38[8]     OR
        TIRE_SIZE          = T20.8-38[8]     OR
        TIRE_SIZE          = T20.8-38[10]    AND
        LOAD              >= 5250            AND
        LOAD              <= 5560
THEN    RECOMMEND_SIZE     = T18.4-38[6]
        RECOMMEND_TIRE     = SINGLE;
RULE 21
IF      TIRE_SIZE          = T16.9-38[6]     OR
        TIRE_SIZE          = T18.4-38[6]     OR
        TIRE_SIZE          = T18.4-38[8]     OR
        TIRE_SIZE          = T20.8-38[8]     OR
        TIRE_SIZE          = T20.8-38[10]    AND
        LOAD              >= 5560            AND
        LOAD              <= 6660
THEN    RECOMMEND_SIZE     = T18.4-38[8]
        RECOMMEND_TIRE     = SINGLE;
RULE 22
IF      TIRE_SIZE          = (T16.9-38[6])     OR
        TIRE_SIZE          = T18.4-38[6]     OR
        TIRE_SIZE          = T18.4-38[8]     OR
        TIRE_SIZE          = T20.8-38[8]     OR
        TIRE_SIZE          = T20.8-38[10]    AND
        LOAD              >= 6660            AND
        LOAD              <= 7250
THEN    RECOMMEND_SIZE     = T20.8-38[8]
        RECOMMEND_TIRE     = SINGLE;
RULE 23
IF      TIRE_SIZE          = T16.9-38[6]     OR
        TIRE_SIZE          = T18.4-38[6]     OR
        TIRE_SIZE          = T18.4-38[8]     OR
        TIRE_SIZE          = T20.8-38[8]     OR
        TIRE_SIZE          = T20.8-38[10]    AND
        LOAD              >= 7250            AND
        LOAD              <= 7670
THEN    RECOMMEND_SIZE     = T20.8-38[10]
```

```
        RECOMMEND_TIRE   = SINGLE;
RULE 24
IF      TIRE_SIZE        = T16.9-38[6]      OR
        TIRE_SIZE        = T18.4-38[6]      OR
        TIRE_SIZE        = T18.4-38[8]      OR
        TIRE_SIZE        = T20.8-38[8]      OR
        TIRE_SIZE        = T20.8-38[10]     AND
        LOAD            >= 7670             AND
        LOAD            <= 9240
THEN    RECOMMEND_SIZE   = T16.9-38[6]
        RECOMMEND_TIRE   = DUAL;
RULE 25
IF      TIRE_SIZE        = T16.9-38[6]      OR
        TIRE_SIZE        = T18.4-38[6]      OR
        TIRE_SIZE        = T18.4-38[8]      OR
        TIRE_SIZE        = T20.8-38[8]      OR
        TIRE_SIZE        = T20.8-38[10]     AND
        LOAD            >= 9240             AND
        LOAD            <= 9786
THEN    RECOMMEND_SIZE   = T18.4-38[6]
        RECOMMEND_TIRE   = DUAL;
RULE 26
IF      TIRE_SIZE        = T16.9-38[6]      OR
        TIRE_SIZE        = T18.4-38[6]      OR
        TIRE_SIZE        = T18.4-38[8]      OR
        TIRE_SIZE        = T20.8-38[8]      OR
        TIRE_SIZE        = T20.8-38[10]     AND
        LOAD            >= 9786             AND
        LOAD            <= 11722
THEN    RECOMMEND_SIZE   = T18.4-38[8]
        RECOMMEND_TIRE   = DUAL;

RULE 27
IF      TIRE_SIZE        = T16.9-38[6]      OR
        TIRE_SIZE        = T18.4-38[6]      OR
        TIRE_SIZE        = T18.4-38[8]      OR
        TIRE_SIZE        = T20.8-38[8]      OR
        TIRE_SIZE        = T20.8-38[10]     AND
        LOAD            >= 11722            AND
        LOAD            <= 12760
THEN    RECOMMEND_SIZE   = T20.8-38[8]
        RECOMMEND_TIRE   = DUAL;
RULE 28
IF      TIRE_SIZE        = T16.9-38[6]      OR
        TIRE_SIZE        = T18.4-38[6]      OR
        TIRE_SIZE        = T18.4-38[8]      OR
        TIRE_SIZE        = T20.8-38[8]      OR
        TIRE_SIZE        = T20.8-38[10]     AND
        LOAD            >= 12760            AND
        LOAD            <= 13499
THEN    RECOMMEND_SIZE   = T20.8-38[10]
        RECOMMEND_TIRE   = DUAL;
RULE 29
IF      TIRE_SIZE        = T24.5-32[10]      OR
```

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        TIRE_SIZE        = T24.5-32[12]     OR
        TIRE_SIZE        = T30.5L-32[10]    OR
        TIRE_SIZE        = T30.5L-32[12]    OR
        TIRE_SIZE        = T30.5L-32[16]    AND
        LOAD            <= 8700
THEN    RECOMMEND_SIZE   = T24.5-32[10]
        RECOMMEND_TIRE   = SINGLE;
RULE 30
IF      TIRE_SIZE        = T24.5-32[10]     OR
        TIRE_SIZE        = T24.5-32[12]     OR
        TIRE_SIZE        = T30.5L-32[10]    OR
        TIRE_SIZE        = T30.5L-32[12]    OR
        TIRE_SIZE        = T30.5L-32[16]    AND
        LOAD            >= 8700             AND
        LOAD            <= 9120
THEN    RECOMMEND_SIZE   = T30.5L-32[10]
        RECOMMEND_TIRE   = SINGLE;
RULE 31
IF      TIRE_SIZE        = T24.5-32[10]     OR
        TIRE_SIZE        = T24.5-32[12]     OR
        TIRE_SIZE        = T30.5L-32[10]    OR
        TIRE_SIZE        = T30.5L-32[12]    OR
        TIRE_SIZE        = T30.5L-32[16]    AND
        LOAD            >= 9120             AND
        LOAD            <= 9680
THEN    RECOMMEND_SIZE   = T24.5-32[12]
        RECOMMEND_TIRE   = SINGLE;
RULE 32
IF      TIRE_SIZE        = T24.5-32[10]     OR
        TIRE_SIZE        = T24.5-32[12]     OR
        TIRE_SIZE        = T30.5L-32[10]    OR
        TIRE_SIZE        = T30.5L-32[12]    OR
        TIRE_SIZE        = T30.5L-32[16]    AND
        LOAD            >= 9680             AND
        LOAD            <= 10390
THEN    RECOMMEND_SIZE   = T30.5L-32[12]
        RECOMMEND_TIRE   = SINGLE;
RULE 33
IF      TIRE_SIZE        = T24.5-32[10]     OR
        TIRE_SIZE        = T24.5-32[12]     OR
        TIRE_SIZE        = T30.5L-32[10]    OR
        TIRE_SIZE        = T30.5L-32[12]    OR
        TIRE_SIZE        = T30.5L-32[16]    AND
        LOAD            >= 10390            AND
        LOAD            <= 14760
THEN    RECOMMEND_SIZE   = T30.5L-32[16]
        RECOMMEND_TIRE   = SINGLE;
RULE 34
IF      TIRE_SIZE        = T24.5-32[10]     OR
        TIRE_SIZE        = T24.5-32[12]     OR
        TIRE_SIZE        = T30.5L-32[10]    OR
        TIRE_SIZE        = T30.5L-32[12]    OR
        TIRE_SIZE        = T30.5L-32[16]    AND
        LOAD            >= 14760            AND
```

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        LOAD              <= 15312
THEN    RECOMMEND_SIZE     = T24.5-32[10]
        RECOMMEND_TIRE     = DUAL;
RULE 35
IF      TIRE_SIZE          = T24.5-32[10]     OR
        TIRE_SIZE          = T24.5-32[12]     OR
        TIRE_SIZE          = T30.5L-32[10]    OR
        TIRE_SIZE          = T30.5L-32[12]    OR
        TIRE_SIZE          = T30.5L-32[16]    AND
        LOAD              >= 15312            AND
        LOAD              <= 16051
THEN    RECOMMEND_SIZE     = T30.5L-32[10]
        RECOMMEND_TIRE     = DUAL;
RULE 36
IF      TIRE_SIZE          = T24.5-32[10]     OR
        TIRE_SIZE          = T24.5-32[12]     OR
        TIRE_SIZE          = T30.5L-32[10]    OR
        TIRE_SIZE          = T30.5L-32[12]    OR
        TIRE_SIZE          = T30.5L-32[16]    AND
        LOAD              >= 16051            AND
        LOAD              <= 17036
THEN    RECOMMEND_SIZE     = T24.5-32[12]
        RECOMMEND_TIRE     = DUAL;
RULE 37
IF      TIRE_SIZE          = T24.5-32[10]     OR
        TIRE_SIZE          = T24.5-32[12]     OR
        TIRE_SIZE          = T30.5L-32[10]    OR
        TIRE_SIZE          = T30.5L-32[12]    OR
        TIRE_SIZE          = T30.5L-32[16]    AND
        LOAD              >= 17036            AND
        LOAD              <= 18286
THEN    RECOMMEND_SIZE     = T30.5L-32[12]
        RECOMMEND_TIRE     = DUAL;
RULE 38
IF      TIRE_SIZE          = T24.5-32[10]     OR
        TIRE_SIZE          = T24.5-32[12]     OR
        TIRE_SIZE          = T30.5L-32[10]    OR
        TIRE_SIZE          = T30.5L-32[12]    OR
        TIRE_SIZE          = T30.5L-32[16]    AND
        LOAD              >= 18286            AND
        LOAD              <= 25978
THEN    RECOMMEND_SIZE     = T30.5L-32[16]
        RECOMMEND_TIRE     = DUAL;
RULE 39
IF      RECOMMEND2         = HIGH_CLEAT       OR
        RECOMMEND2         = INDUSTRIAL       AND
        FOOT_PRINT         = CLEAR              OR
        FOOT_PRINT         = SHARP            OR
        FOOT_PRINT         = NOT_CLEAR
THEN    RECOMMENDATION4 = FINAL
DISPLAY"It is recommended to use {RECOMMEND2}
{RECOMMEND_TIRE} tires with a size and ply rating of
{RECOMMEND_SIZE}.    "
DISPLAY"            <Press any key> ~";
```

```
RULE 40
IF    RECOMMEND2         = GENERAL            AND
      FOOT_PRINT         = SHARP              OR
      FOOT_PRINT         = CLEAR              OR
      FOOT_PRINT         = NOT_CLEAR          AND
      SOIL               = SANDY
THEN  RECOMMENDATION4 = FINAL
CLS
DISPLAY"It is recommended to use {RECOMMEND2}
{RECOMMEND_TIRE} BIAS tires with a size and ply rating of
{RECOMMEND_SIZE}.   "
DISPLAY"            <Press any key> ~";
RULE 41
IF    RECOMMEND2         = GENERAL            AND
      FOOT_PRINT         = SHARP              OR
      FOOT_PRINT         = CLEAR              OR
      FOOT_PRINT         = NOT_CLEAR          AND
      SOIL               = CLAY               OR
      SOIL               = MED               AND
      RECOMMEND_TIRE     = SINGLE
THEN  RECOMMENDATION4 = FINAL
CLS
DISPLAY"It is recommended to use {RECOMMEND2}
{RECOMMEND_TIRE} RADIAL tires with a size and ply rating of
{RECOMMEND_SIZE}.   "
DISPLAY"                <Press any key >~";
RULE 42
IF    RECOMMEND2         = GENERAL            AND
      FOOT_PRINT         = SHARP              OR
      FOOT_PRINT         = CLEAR              OR
      FOOT_PRINT         = NOT_CLEAR          AND
      SOIL               = CLAY               OR
      SOIL               = MED               AND
      RECOMMEND_TIRE     = DUAL
THEN  RECOMMENDATION4 = FINAL
CLS
DISPLAY"It is recommended to use {RECOMMEND2}
{RECOMMEND_TIRE} BIAS tires with a size and ply rating of
{RECOMMEND_SIZE}.   "
DISPLAY"                <Press any key>~";
RULE 43
IF     RECOMMENDATION4 = FINAL               AND
       CHICK           = YES
THEN   CHANGE_FILE     = OK
       CHAIN B:\SYSTEM;
RULE 44
IF     RECOMMENDATION4 = FINAL               AND
       CHICK           = NO
THEN   CHANGE_FILE     = OK
DISPLAY"Thank you for using this program.
            <Press any key>~";
ASK SOIL:"How would you describe the soil conditions of
fields where your tractor is frequently operated?";
CHOICES SOIL:SANDY,MED,CLAY;
```

```
ASK TIRE_SIZE:"What is the size of rear tires with ply
rating?";
CHOICES
TIRE_SIZE:T16.9-34[6],T16.9-38[6],T18.4-38[6],T18.4-34[8],T1
8.4-38[8],T20.8-38[8],T23.1-34[8],T20.8-38[10],T24.5-32[10],
T24.5-32[12],T30.5L-32[10], T30.5L-32[12],T30.5L-32[16];
ASK DRAWBAR:"What is the maximum drawbar horsepower that you
use during most operations ?";
ASK PTOHP:"What is the tractor PTO horsepower ?";
ASK SPEED:"What is the minimum field speed you like to
achieve with your tractor during most operations (MPH)?";
CHOICES SPEED:4,5,6;
ASK CHICK:"Would you like to use another file?";
CHOICES CHICK:YES,NO;
ASK TRACTOR:"What is the tractor type?";
CHOICES TRACTOR:2WD,FWA,4WD;
```

APPENDIX H

EXAMPLE

1. What kind of operation would you like to use?

[BALLASTING]	TIRE SELECTION
MATCHING	TIRE PRESSURE

2. Have you used this program before ?

YES	[NO]

3. What is the tractor make ?

[JOHN-DEERE]

4. What is the tractor model ?

4050	4250	4450
[4650]	8450	8650
8850		

5. What size are the current front tires ?

6.0-16	7.5-15	7.5-16
7.5-18	7.5-20	9.5L-15
9.5-20	10.0-16	11.0L-15
11.0-16	11.2-24	12.4-24
12.4-42	13.6-28	13.6-38
14.9-24	14.9-26	14.9-28
[14.9-30]	15.5-38	16.9-24
16.9-26	16.9-28	16.9-30
16.9-34	16.9-38	18.4-26
18.4-28	18.4-30	18.4-34
18.4-38	18.4-42	20.8-34
20.8-38	20.8-42	23.1-26
23.1-30	23.1-34	24.5-32

6. What size are the current rear tires ?

6.0-16	7.5-15	7.5-16
7.5-18	7.5-20	9.5L-15
9.5-20	10.0-16	11.0L-15
11.0-16	11.2-24	12.4-24
12.4-42	13.6-28	13.6-38
14.9-24	14.9-26	14.9-28
14.9-30	15.5-38	16.9-24
16.9-26	16.9-28	16.9-30
16.9-34	16.9-38	18.4-26
18.4-28	18.4-30	18.4-34
18.4-38	18.4-42	20.8-34
[20.8-38]	20.8-42	23.1-26
23.1-30	23.1-34	24.5-32
30.5-32		

7. Do you know the weight of the tractor both the front and rear axle?

YES	[NO]

8. Is there extra iron weight on the FRONT axle ?
[YES] NO
9. How much is it ?
110
10. What is inside front tires ?
[AIR] WATER CACL2
11. Does the tractor have SINGLE or DUAL tires on the front axle ?
[SINGLE] DUAL
12. Is there extra iron weight on the REAR axle ?
YES [NO]
13. What is inside rear tires ?
AIR [WATER] CACL2
14. Does the tractor have SINGLE or DUAL tires on the rear axle ?
SINGLE [DUAL]
15. The front to total tractor weight ratio is 23.9%
Is this acceptable ?
Refer to the following table for guidance.

Tractor Type	2WD	FWA	4WD
Front Ratio	25%	35%	60%

[YES] NO
16. What field speed would you like to achieve with your tractor during most operations (mph)?
5.5
17. What is the estimated Cone Index (PSI)?
Refer to the following table for guidance.

CI	SOIL CONDITION
250	HARD, PACKED
200	HARD, PACKED WITH STUBBLE
150	FIRM
80	TILLED
60	SOFT, WET

175
18. What is the percentage of tire slip at which you would like the tractor to operate?
Refer to the following table for guidance.

Soil	Tractor Type		
	2WD	FWD	4WD
FIRM	10-12	8-10	8-10
TILLED	12-14	10-11.5	10-11.5
SANDY	14-16	11.5-13	11.5-13

10
"To operate the tractor at 4.95 MPH with 10% slippage the front axle weight should be 6342 lbs. The rear axle weight is 20098 lbs. The drawbar pull is 8883 lbs, with 0.71 tractive efficiency.
The weight of the tractor per PTO horsepower is 160.3.
<Press any key>"
"The tractor weight should not be over 150 lbs/PTO and not less than 120 lbs/PTO.
<Press any key> "
19. Would you like to use another file?

[YES] NO

20. What kind of operation would you like to use?

BALLASTING TIRE SELECTION

[MATCHING] TIRE_PRESSURE

21. Have you used this program before?

[YES] NO

22. Would you like to change the tractor information that you have used?

YES [NO]

23. Do you know the implement draft?

YES [NO]

24. How would you describe the SOIL conditions of the fields where your tractor is most frequently operated?

[TUTTLE SILT LOAM] PULASKI FINE SANDY L

MENO LOAMY FINE SAND PORT SILT LOAM

25. What type of implement will be most frequently used with this tractor?

MOLDBOARD PLOW [CHISEL] CHISEL W/ SWEEPS

TANDEM DISK

26. What is the width of the implement (feet)?

13

27. What field speed would you like to achieve with your tractor during most operations (mph)?

5.5

28. What is the estimated Cone Index (psi)?

Refer to the following table for guidance.

CI	SOIL CONDITION
250	HARD,PACKED
200	HARD,PACKED WITH STUBBLE
150	FIRM
80	TILLED
60	SOFT,WET

175

29. What is the percentage of tire slip at which you would like the tractor to operate?

Refer to the following table for guidance.

Soil	Tractor Type		
	2WD	FWD	4WD
FIRM	10-12	8-10	8-10
TILLED	12-14	10-11.5	10-11.5
SANDY	14-16	11.5-13	11.5-13

10

"For the specified conditions of width = 13 foot, speed = 4.9 MPH, and 10% slip.

The drawbar horsepower of tractor is estimated to be 78.7 HP with 0.477 tractive efficiency.

This tractor should be capable of pulling 13 foot implement at 7.8 MPH and 7.2% slip for a drawbar horsepower of 125.4 and tractive efficiency of 0.762.

<Press any key to continue>"

Options	Width(Ft)	Speed	Slip	TE	Acre/Hr
The tractor weight is 127.4 lbs/PTO					
1.	21.0	4.7	13.8	0.738	12.454

2.	13.02	7.8	7.2	0.761	12.832
3.	16.88	6.0	10	0.762	12.846

The tractor weight is 140 lbs/PTO

4.	20.87	4.8	12.2	0.747	12.601
5.	12.85	8.1	6.3	0.777	13.099
6.	18.17	5.6	10	0.760	12.818

30. Would you like to use another file?
[YES] NO
31.What kind of operation would you like to use?
BALLASTING TIRE SELECTION
MATCHING [TIRE_PRESSURE]
32. Have you used this program before?
[YES] NO
33. Would you like to change the tractor information that you have used?
YES [NO]
34. Do you know the implement draft?
YES [NO]
35. How would you describe the SOIL conditions of the fields where your tractor is most frequently operated?
[TUTTLE SILT LOAM] PULASKI FINE SANDY L
MENO LOAMY FINE SAND PORT SILT LOAM
36. What type of implement will be most frequently used with this tractor?
MOLDBOARD PLOW [CHISEL] CHISEL W/ SWEEPS
TANDEM DISK
37. What is the width of the implement (feet)?
13
38. Have you been using BIAS or RADIAL tires?
[BIAS] RADIAL
39. Have you been using SINGLE or DUAL tires?
SINGLE [DUAL]
"The estimated tire pressure is 12 PSI for outside dual and 14 PSI for inside dual.
<Press any key>"
40. Would you like to use another file?
[YES] NO
41. What kind of operation would you like to use?
BALLASTING [TIRE SELECTION]
MATCHING TIRE_PRESSURE
42. Has weight been added to your tractor to improve performance?
[YES] NO
43. Do you think the slippage of the tractor is OK?
[YES] NO
44. Have you been using BIAS or RADIAL tires?
[BIAS] RADIAL
45. Have you been using SINGLE or DUAL tires?
SINGLE [DUAL]
46. Why do the current tire(s) need replacement?
ONE TIRE BAD NOT RELIABLE [TREAD WEAR]
47. Comparing the lug height of the current tire with new tire, how much tread is left?
10

48. What was the tread design of tires you have been using?
[GENERAL] HIGH CLEAT INDUSTRIAL
49. Will this particular tractor be used mainly for tillage or other heavy drawbar loads?
[YES] NO
50. What percentage of field area on your farm contains tight or sticky soils which are frequently difficult to use?
5
51. What percentage of field area on you farm has roads or any other hard areas?
15
52. When you look at the tire track just behind the tire during operation under normal load, what does it look like?
SHARP: Sharp distinct tire print.
CLEAR: Print somewhat broken up, BUT recognizable.
NOT CLEAR: Tire print sheared away, no clear tire print remaining.
[SHARP] CLEAR NOT CLEAR
"The foot print of the tires is SHARP print, which means your tractor is OVERBALLASTED and it is recommended to reweigh your tractor.
<Press any key to continue>"
53. Would you like to check the tractor weight?
YES [NO]
54. What is the size of rear tires with ply rating?

16.9 34[6]	16.9 38[6]	18.4 38[6]
18.4 34[8]	18.4 38[8]	[20.8 38[8]]
23.1 34[8]	20.8 38[10]	24.5 32[10]
24.5 32[12]	30.5L 32[10]	30.5L 32[12]
30.5L 32[16]		

54. What is the maximum drawbar horsepower that you use during most operations?
?
55. What field speed would you like to achieve with your tractor during most operations (MPH)?
4 [5] 6
56. What is the tractor PTO horsepower?
165
57. What is the tractor type?
[2WD] FWA 4WD
58. How would you describe the soil conditions of fields where your tractor is most frequently operated?
SANDY [MED] CLAY
"It is recommended to use GENERAL DUAL BIAS tires with a size and ply rating of 16.9 38[8].
<Press any key>"
59. Would you like to use another file?
YES [NO]
"Thank you for using this program.
<Press any key>"

VITA

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Master of Science

Thesis: AN EXPERT SYSTEM TO MANAGE SELECTION OF TRACTOR IMPLEMENT SYSTEMS

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