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An Expert System for Tractor Selection

Steven A. Freeman, *Colorado State University*
P. D. Ayers, *Colorado State University*

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S. A. Freeman, P. D. Ayers
STUDENT MEMBER ASAE, ASSOC. MEMBER ASAE

ABSTRACT

A user friendly expert system to assist the farmer in tractor selection was developed based on the evaluation procedure developed by Rider et al. (1979). This evaluation procedure utilizes Nebraska Tractor Test data from 1980 to 1986 along with information provided by the farmer to make selection decisions.

The expert system provides the farmer with a list of tractors that are best suited for a specific operation. However, it is only designed to aid the farmer in the tractor selection process, not to provide a definite solution.

INTRODUCTION

The present economic situation in which the American farmer operates demands that, in order to survive, the best possible use must be made of all the resources available. The key to an economically healthy agricultural operation is continued increases in the productivity of farm workers and the quality of farm products with a resulting reduction in the unit cost of farm products. In the past, this increase in production has largely been tied to the increased application of power. Continued increases in productivity and product quality will most likely follow from the intelligent management of power. In particular, expert systems offer an opportunity to more intelligently manage the resources of the agricultural science and education system. By increasing the management potential of system administrators, expert systems can help members of the agricultural science and education system continue to serve agriculture and the consumer, especially in a time of declining resources (Barrett et al., 1985).

One of the most important machinery management decisions made by a farmer is the selection of a tractor. The cost of buying a farm tractor is such a significant expense in most agricultural operations that the farmer must weigh all possibilities very carefully before making a decision which could dictate financial stability and thus economic survival. In order to overcome such a complex problem, a logical procedure needs to be used.

Numerical procedures for determining the desired tractor power require rigorous computations and a vast array of background knowledge (Hunt, 1983). Computer programs have been developed to simplify these procedures. There are now several microcomputer models available to aid the farmer in determining the required power (Freesmeyer and Hunt, 1985). The most recent is one developed by Chen (1987) which includes improvements over earlier models by decreasing the run time and by making the model user-interactive. An expert system to aid in farm management decisions is also available. This system integrates a farm management linear program and a companion simulation model with a knowledge-based expert system (Kline et al., 1987).

The problem, however, is not solved once the desired power has been calculated. The farmer must now decide which specific tractor model is best suited for the operation. This process involves quantitative and qualitative factors which are difficult to define mathematically. A procedure to aid the farmer in this process was developed by Rider et al. (1979). The farmer can benefit from this procedure; however, presently it does not enable the farmer to easily and efficiently review all the tractors available.

A method which allows the farmer to benefit the most from this procedure could be accomplished with an expert system. An expert system can handle the quantitative and qualitative factors involved in this type of comparison more easily than a conventional computer program. An expert system would allow the farmer to take advantage of this procedure without having to know the variety of tractors available or the background data from the Nebraska tractor tests which are required for each specific model.

OBJECTIVE

The objectives of this project are:

1. To develop a user friendly expert system to assist the farmer in tractor selection.
2. To incorporate tractors ranging from 75 kW to 300 kW (100 hp to 400 hp) into the expert system.
3. To evaluate the system performance for ease of operation, validity of selection decisions and comparative worth.

LITERATURE REVIEW

Suitability of Specific Models

The tractor selection process is not complete once the necessary horsepower has been determined. The decision of which specific manufacturer and model is best suited for a particular operation is a difficult one, especially if there are several models available within the acceptable power range. The farmer has many resources to help in this evaluation, including literature from the

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The authors are: S. A. FREEMAN, Student, and P. D. AYERS, Assistant Professor, Agricultural and Chemical Engineering Dept., Colorado State University, Ft. Collins.

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manufacturer, Nebraska Tractor Test Reports, dealers and other farmers. Each source of information is useful, but screening the information without bias and determining which factors are most important is difficult. The relative importance of the determining factors may vary for different farmers; however, the farmer is allowed to define the relative importance of each main factor.

This procedure is based on rating primary selection factors for each tractor in question and then comparing this total to the total of the other tractors being considered. The primary selection factors included in the quantitative evaluation procedure are fuel efficiency, lugging ability, transmission characteristics, sound level, reliability and dealer services. The values of these selection factors are obtained from Nebraska Tractor Test Reports and from information supplied by the farmer. A worksheet (Appendix A) describes the selection process.

Expert System Applications in Agriculture

Expert systems allow someone who is not an expert in a particular field to make decisions based on the knowledge of the experts in that field. Expert systems have many possible applications in agriculture — from diagnosing plant and animal diseases and soil acidity, to aiding in management decisions (Barrett et al., 1985). Wolfgram et al. (1987) listed several expert systems which are already available including: control of disease in winter wheat crops, control of plant life in ponds, crop rotation, management of apple orchards, rice disease diagnosis and a material handling equipment selector. Some additional expert system applications are Farm-Level Machinery Management (Kline et al., 1987), Management of a Crop Research Facility (Jones et al., 1986), Tomato Greenhouse Environment Controller (Jacobson et al., 1987), and Diagnosing Problems in Hydraulic Systems (Gaultney et al., 1987). The application possibilities of expert systems in agriculture are already numerous and will no doubt continue to expand in the future.

EXPERT SYSTEM DEVELOPMENT

The expert system was developed using the EXSYS Expert System Development Package Version 3.1 (EXSYS, 1985). EXSYS runs on any IBM compatible personal computer. It is a rule based expert system using an if-then-else format.

As discussed earlier, the procedure developed by Rider et al. (1979) forms the basis for the expert system. A knowledge base of stored information necessary to solve the problem was required. The knowledge base was obtained from the Nebraska Tractor Tests. The data required for each specific tractor was determined using the worksheet and input to the knowledge base. The 75% pull was used for all comparisons in the calculation of the fuel efficiency index.

The system is based on the assumption that the farmer knows the approximate tractor horsepower desired. Separate files were developed for each 7.5 kW (10 hp) increment from 75 kW (100 hp) to the largest tractor tested from 1980 to 1986 which was approximately 300 kW (400 hp). Each file covers 10% on both sides of the increment power value. For example, a tractor power of 75 kW (100 hp) evaluates tractors from 67.5 to 82.5 kW (90 to 110 hp). The files were written with the help of the EXSYS editor. The arrangement of the system demands an overlap between the files; thus, a specific tractor will appear on numerous files.

A menu program accompanies the expert system. The menu program does three things for the user. First, it gives the user information about the range of the program and the option to obtain additional information. Secondly, it gives the user a short explanation of how to respond to questions asked by the computer. Most importantly, it provides the farmer with easy access to the expert system.

The selection decisions utilized by the expert system are a direct implementation of the procedure developed by Rider et al. (1979). It was not the direct purpose of this project to evaluate their comparison method. Thus they are considered the "experts." The focus of this study was on the development of the tractor data files and the implementation of the overall expert system rather than on the quantitative analysis procedure. Data for 113 tractors from the 1980 to 1986 Nebraska Tractor Tests were incorporated into the expert systems. Thirty-one (31) data files were developed with the number of tractors in each file shown in Table 1. The system should be maintained to retain its usefulness. The data files can be updated each year when new data becomes available.

EXPERT SYSTEM OPERATION

The overall system is controlled by the menu program (Fig. 1). The user has a choice to review the introduction, review the instructions or run the tractor selection routine. When running the selection routine, the computer interacts with the user to obtain the desired horsepower for tractor comparison. It then uses this information to call the EXSYS runtime program and the appropriate tractor data file. On computers with two floppy disk drives, a request is issued to insert the appropriate disk (containing the knowledge base) into the second floppy disk drive. The user is asked a series of questions requesting information required to complete the worksheet shown in Appendix A. This information

TABLE 1. Number of Tractors Evaluated for Each Power Group Selected

Tractor power, kW (hp)	Number of tractors evaluated	Tractor power, kW (hp)	Number of tractors evaluated
300.0 (400)	2	187.5 (250)	14
292.5 (390)	2	180.0 (240)	14
285.0 (380)	3	172.5 (230)	14
277.5 (370)	4	165.0 (220)	14
270.0 (360)	6	157.5 (210)	14
262.5 (350)	7	150.0 (200)	19
255.0 (340)	7	142.5 (190)	16
247.5 (330)	10	135.0 (180)	27
240.0 (320)	10	127.5 (170)	22
232.5 (310)	9	120.0 (160)	18
225.0 (300)	11	112.5 (150)	19
217.5 (290)	8	105.0 (140)	13
210.0 (280)	11	97.5 (130)	19
202.5 (270)	9	90.0 (120)	20
195.0 (260)	12	82.5 (110)	20
(continues)		75.0 (100)	21

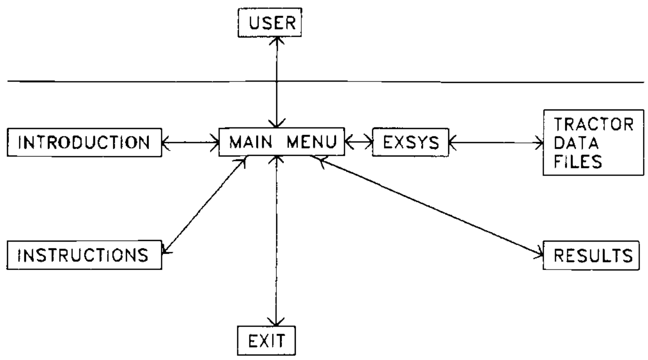

Fig. 1—Schematic diagram of the tractor selection program.

includes: (a) farmer weighting factors, (b) ability to sustain workload, (c) dealer location, (d) dealer parts inventory, and (e) dealer repair services. At this point the user becomes an "expert" at the local level and the selection is partially based on information from the user. In this manner, the tractor selection procedure conforms to the individual's farming operation meeting the individual's desires and perceived needs.

The expert system calculates the comparative tractor index (CTI) for each tractor in accordance with the worksheet in Appendix A. Since this method is to be used as an aid in tractor selection, not to determine a final decision, the results of the CTI calculations are first formatted to a general 0 to 10 rating (with 10 being the highest). The tractor models and their ratings for tractors receiving a rating greater than "5" are presented to the user. If a tractor receives a rating of "5" or lower, it is considered not to be a viable choice and is thus not included in the list of results, although the user has the option of listing all possibilities. The comparative tractor indices for all tractors are also given for further comparison if two or more tractors should tie with the same rating.

At this point, the EXSYS runtime program gives the user several options which are again listed at the bottom of the screen. One important option allows the user to change the answer to any of the questions the computer asked and then see what effect these changes have on the results. All of the options are self-explanatory, but if a question should arise, there is an extensive internal help file to assist the user. When the user is finished making changes, a hard copy may be obtained before continuing.

As with many expert systems, it is apparent that this tractor selection procedure could have been implemented with a "numerical" language as opposed to an expert system shell. The use of an expert system shell to program the selection procedure was based on the following factors: (a) the shell provides easier user interaction, (b) the shell provides an internal help feature, (c) the shell provides the flexibility to change input quickly, and (d) the shell provides the ability for online description of the selection process. The expert system shell also allows the ability to update the tractor data files quickly.

The tractor data files and menu program are available from the authors. However the EXSYS Runtime Program needed to run the expert system is a licensed product and may not be distributed by the authors.

EXPERT SYSTEM EVALUATIONS

The evaluation procedure consisted of having six farmers and one farm equipment dealer run the system and then fill out a short evaluation form. This evaluation form asked the following questions concerning the ease of operation, performance of the selection procedure and improvements needed. The response to the questions asked during the evaluation are discussed below.

Was this program easy to operate and understand? ______. If not please give examples of where the difficulties were encountered:

All seven reviewers answered 'yes' to this question. Even the individuals with no previous computer experience were able to run the program without additional instructions.

Do you agree with the selection decisions made by this program? ______ Why?

All reviewers, except one farmer, answered 'yes' to this question. The most common reasons for agreement were because the system was based on the Nebraska Tractor Test information, which is an independent study, or that the system chose the same tractor that they themselves would have chosen. The one dissenting opinion was given because the best tractor was a four-wheel drive tractor and the user's operation was all row-crop. He did, however, believe that the selection process was correct based on tractor performance. (Note: the second choice was a row-crop model, thus it would be the best choice for his operation and the system still accomplished its goal.)

Do you think this program was helpful? ______ If you were about to purchase a tractor and you had access to a program like this, would you use it? ______ Why?

All the test subjects thought the program was helpful. All but one said they would like to use a similar program if they were in the market for a tractor. The one farmer who was not sure if he would run the program said that his mind was already made up as to what kind of tractor he wanted and thus this program was not that useful to him. The others gave reasons for wanting to run the program that ranged from getting the information at a fraction of the time it would take without the program to the fact that the information provided was unbiased. Additional reasons presented were that the program will help to narrow the choices that should be considered and possibly provide a means for deciding among these choices, or even suggest a tractor that had not previously been considered.

How could this program be improved? What changes would you like to see or what additions to the program are needed?

The most common response was the need to include economic factors in the selection process. Another important suggestion was to tie into a program that calculated the required horsepower to provide the user with a complete evaluation package.

SUMMARY AND CONCLUSIONS

The conclusions of this project are:

1. A user friendly system was developed, based on

a procedure from Rider et al. (1979) to aid the farmer in tractor selection.

2. The expert system evaluated tractors ranging from 75 kW to 300 kW (100 hp to 400 hp) utilizing 113 Nebraska Tractor Tests from 1980 to 1986.
3. The evaluations of the system by six farmers and a farm equipment dealer were favorable. According to the reviewers:
   a. The system was easy to use.
   b. The systems selection decisions were valid.
   c. The system was helpful and worth the time required for its use.

References

1. Barrett, J. R., J. B. Morrison and L. F. Huggins. 1985. Artificial intelligence and expert systems in agricultural research and education. ASAE Paper No. 85-5516. St. Joseph, MI: ASAE.
2. Chen, L. H. 1987. A microcomputer model for selection of machines and tractors. ASAE Paper No. 87-1050. St. Joseph, MI: ASAE.
3. EXSYS, Inc. 1985. *EXSYS: Expert system development package*. Albuquerque, NM 87194.
4. Gaultney, L., S. Harlow and W. Ooms. 1987. An expert system for diagnosing problems in hydraulic systems. ASAE Paper No. 87-1025. St. Joseph, MI: ASAE.
5. Freesmeyer, S. R. and D. R. Hunt. 1985. A farm machinery selection program for personal computers. ASAE Paper No. 85-1022. St. Joseph, MI: ASAE.
6. Hunt, D. 1983. *Farm power and machinery management*. Ames: Iowa State University Press.
7. Jacobson, B. K., J. W. Jones and P. Jones. 1987. Tomato greenhouse environment controller: Real-time expert system supervisor. ASAE Paper No. 87-5022. St. Joseph, MI: ASAE.
8. Jones, P. and J. Halderman. 1986. Management of a crop research facility with a microcomputer-based expert system. *Transactions of the ASAE* 29(1):235-242.
9. Kline, D. E., D. A. Bender and B. A. McCarl. 1987. Farm-level machinery management using intelligent decision support systems. ASAE Paper No. 87-1046. St. Joseph, MI: ASAE.
10. Rider, A. R., K. Von Bargen and P. Jasa. 1979. Selection factors to quantitatively evaluate tractors. ASAE Paper No. 79-1526. St. Joseph, MI: ASAE.
11. Wolfgram, D. D., T. J. Dear and C. S. Galbraith. 1987. *Expert systems for the technical professional*. New York: John Wiley & Sons.

APPENDIX A

TRACTOR SELECTION WORKSHEET
(from Rider et al., 1979)

TRACTOR SELECTION WORKSHEET

Tractor Manufacturer________________________ Model ____________

Nebraska Tractor Test Report Number ____________

FUEL EFFICIENCY — HP-HR/GAL

Drawbar Performance
75% Pull or 50% Pull at Maximum Power ________

50% Pull at Reduced Engine Speed ________

TOTAL ________

FUEL EFFICIENCY INDEX = $\frac{\text{TOTAL}}{3}$ = $\frac{\_\_\_\_}{3}$ = ________ (line h)

LUGGING ABILITY IN RATED GEAR

Increase in % Pull at 90% Crankshaft Speed ______ x 4 = ______

Increase in % Pull at 80% Crankshaft Speed ______ x 2 = ______

Increase in % Pull at 70% Crankshaft Speed ______ x 1 = ______

Total ______

LUG INDEX = $\frac{\text{TOTAL}}{20}$ = $\frac{\_\_\_\_}{20}$ ________ (line i)

TRANSMISSION

Speed Range (MPH)	Number of Gears		
4.0-4.4	____	If 0 gears, enter 0 If 1 or more gears, enter 2	______
4.5-4.9	____	If 0 gears, enter 0 If 1 or more gears, enter 2	______
5.0-5.4	____	If 0 gears, enter 0 If 1 or more gears, enter 2	______
5.5-5.9	____	If 0 gears, enter 0 If 1 or more gears, enter 2	______
6.0-10.0	____	If 0 gears, enter 0 If 1 gear, enter 1 If 2 or more gears, enter 2	______
		TOTAL	______

TRANSMISSION INDEX = TOTAL ________ (line j)

TRACTOR SOUND LEVEL

Maximum Sound Level Measured at operator ear ______dB(A)
a) If measured dB(A) less than 85, enter 10
or b) If measured dB(A) more than 95, enter 0
or c) If measured dB(A) between 85 and 95, enter 95 - Measured dB(A) = 95 - ____ = ______

SOUND LEVEL INDEX = ________ (line k)

OIL CONSUMPTION

	GAL
To Motor	______
Drained from Motor	______
DIFFERENCE	______

Oil Consumption = $\frac{\text{DIFFERENCE} \times 4000}{\text{Maximum Drawbar Horsepower} \times \text{Total Hours Engine Operated}}$ = ______

Oil Consumption Index
a) If oil consumption is 1.0 or greater, enter 0
or b) If oil consumption is less than 1.0, enter 1

________ (line m)

REPAIRS AND ADJUSTMENTS

Repairs and Adjustment Index
a) If significant repairs or adjustments, enter 0
or b) If no significant repairs or adjustments, enter 1

________ (line n)

ABILITY TO SUSTAIN WORKLOAD

Workload Index
a) If good quality manufacturer and good model, enter 2
or b) If either the manufacturer or model has not performed to expectations, enter 1
or c) If either the manufacturer or model has a poor performance record, enter 0

________ (line o)

DEALER LOCATION

Dealer Location Index
a) If dealer is in primary trade center and less than 50 miles from farm, enter 2
or b) If dealer is not in primary trade center and less than 50 miles from farm, enter 1
or c) If no dealer is located within 50 miles from farm, enter 0

________ (line p)

DEALER PARTS INVENTORY
Dealer Parts Index
a) If two dealers within 50 miles from farm maintain adequate parts inventory, enter 2
or b) If only one dealer within 50 miles from farm maintains adequate parts inventory, enter 1
or c) If no dealer with 50 miles from farm maintains adequate parts inventory, enter 0

________ (line q)

DEALER REPAIR SERVICES
Dealer Service Index
a) If service shop with qualified service personnel and equipment is available within the primary trade center, enter 2
or b) If service shop with qualified service personnel and equipment is not available within the primary trade center, but within 50 miles from farm, enter 1
or c) If no service shop with qualified service personnel and equipment is available within 50 miles from the farm, enter 0

________ (line r)

RELAIABILITY AND DEALER SERVICES

Oil Consumption Index	(from line m)	______
Repairs and Adjustment Index	(from line n)	______
Workload Index	(from line o)	______
Dealer Location Index	(from line p)	______
Dealer Parts Index	(from line q)	______
Dealer Service Index	(from line r)	______
	TOTAL	______

SERVICE INDEX = TOTAL ________ (line s)

COMPARATIVE TRACTOR INDEX

				Farmer Weighting Factor 0 to 5		Weighted Index
Fuel Efficiency Index	(from line h)	____	x	______	=	______
Lug Index	(from line i)	____	x	______	=	______
Transmission Index	(from line j)	____	x	______	=	______
Sound Level Index	(from line k)	____	x	______	=	______
Service Index	(from line s)	____	x	______	=	______
					TOTAL	______

COMPARATION TRACTOR INDEX = TOTAL = ________