EXPLOITATION COSTS IN EXPERT SYSTEMS

Zbigniew Siarkowski, Zofia Hanusz

Akademia Rolnicza, Katedra Maszyn i Urządzeń Rolniczych
Głęboka 28, 20-612 Lublin, Poland
tel.: +48 81 4456141
e-mail: Zbigniew.siarkowski@ar.lublin.pl

Abstract

In a view of the need to search for new energy sources, opportunities of using the plants for fuel production are more and more often considered. Such type of a production is possible, although it requires a thorough analysis of its achievement costs. These analyses may be performed using appropriate expert systems. The paper presents the issues associated with the introduction of exploitation costs for tractors, machines, and devices into the expert systems related to optimize the agricultural production process. Two ways of selecting the best machine (according to accepted purpose function) or device for a tractor in a farm were presented. After selecting proper tractor and indicating technological process, searching for the database with machines and devices applied at cereal production takes place to select machines or devices power demands of which is lower than that of a tractor possessed. As a result, farmer gains an access to a list presenting all found machines and devices. The other way allows for selecting tractor and machines or devices according to multi-criterion purpose function. Dependencies and 3D plots were worked out for mineral fertilizer spreaders; they define the associations between unit exploitation costs, annual utilization, and aggregate's efficiency. Clicking the point corresponding to selected values would result in presenting given aggregate or aggregates in accordance to selected terms.

Keywords: *expert system, tractors, machines, selection, exploitation costs*

Streszczenie

Wobec konieczności poszukiwania nowych źródeł energii, coraz częściej rozpatrywane są możliwości wykorzystania roślin do produkcji paliwa. Taki rodzaj produkcji jest możliwy, wymaga jednak starannej analizy kosztów jego pozyskiwania. Analizy mogą być prowadzone przy wykorzystaniu odpowiednich systemów ekspertowych. W pracy przedstawiono problemy związane z wprowadzaniem do systemów ekspertowych dotyczących optymalizacji rolniczego procesu produkcyjnego kosztów eksploatacji ciągników, maszyn i urządzeń. Określono dwa sposoby wyboru najlepszej maszyny (zgodnie z przyjętą funkcją celu) lub urządzenia do ciągnika znajdującego się w gospodarstwie. Po wybraniu odpowiedniego ciągnika i wskazaniu zabiegu technologicznego następuje przeszukanie bazy danych z maszynami i urządzeniami stosowanymi w produkcji zbóż w celu wybrania maszyn lub urządzeń, których zapotrzebowanie mocy jest mniejsze od mocy posiadanego ciągnika. W wyniku działania systemu użytkownik uzyskuje dostęp do zestawienia przedstawiającego wszystkie wyszukane maszyny i urządzenia. Drugi sposób pozwala dobrać ciągnik jak i maszyny lub urządzenia wg wielokryterialnej funkcji celu. Opracowano zależności oraz wykresy trójwymiarowe dla rozsiewaczy nawozów mineralnych, określające związek między jednostkowymi koszty eksploatacji, rocznym wykorzystaniem oraz wydajność agregatu. Kliknięcie na punkt wykresu odpowiadający wybranym wartościom spowoduje, że system przejdzie do prezentacji agregatu bądź agregatów odpowiadających tym warunkom.

Słowa kluczowe: *system ekspertowy, traktory, maszyny, selekcja, koszty eksploatacji*

1. Introduction

Methods of tractors, machines, and devices selection for realizing the agricultural production process may be divided as follows: indicative, factorial, technological, peaks of uniform works, methods based on linear programming, and complete variant review. Another attempt to the issues of machine selection is presented by the method, in which not every factor determining the selection of machines for plant production is measurable value. It may be accepted that it was a try to define a simplified advisory system referring to support of decisions on purchase the new agricultural machines. That attempt had the shortcoming that no economic criteria could be introduced.

At machine exploitation practice, two general types of machine performance can be distinguished. The first one refers to the production processes requiring application of unique machines that are useless in other processes. It makes that their annual utilization time is limited by extension of works to do within that process and it cannot be prolonged by service or other forms of machine's involvement. The second type of performance refers to versatile machines that can be applied in many processes and thus their annual utilization time can be much longer, and their unit exploitation costs are much lower.

Department of Agricultural Machines and Devices, University of Agriculture in Lublin, has conducted study upon computer advisory systems since 1980 with a main stress on working out the application software for cattle and swine producers. Since 2000, production of fodder plants, namely cereal grains, has focused more attention. Several papers on production process structure have been published, many multi-criterion methods of machines and devices selection to realize the technological process have arisen, and a variety of software rationalizing the application of selection methods has been created.

Changing situation on fuel market opened new challenges of oil plant utilization (e.g. rapeseed) for fuel production. In an effect, a possibility to work out the complex expert system referring to the selection of machines and devices for rapeseed production appeared.

Nowadays, all countries may be divided into three groups. The first group consists of poor countries, where production maximization is main criterion with no respect to the quality of products achieved as well as costs bearing. They are mainly African, part of Asian and South-American countries.

Second group of countries are such where cost minimization is the main criterion, but products must meet given qualitative norms. In agriculture, it is associated with introduction of welfare notion referring both to animals and environment. It makes that minimization of energetic inputs becomes another, equally important, criterion.

The most developed countries introduced additional notion of welfare in reference to people. As a consequence, main production criterion refers to labour inputs minimization as well as improvement of working conditions for a man.

All these above present difficulties in defining the selection criterion for expert systems, in which man participation is limited, and offered decisions may be crucial for further users of such expert system.

2. The aim of study

Methods of tractors, machines, and devices for agricultural production processes can be divided as follows: indicative (Pawlak, 1975), factorial (Pawlak *et al.* 1997), technological (Tomaszewski *et al.* 1980, Wójcicki 2001), peaks of uniform works (Michałek 1978), methods based on linear programming (Wodniak 1884, Marszałkowicz 1986), and complete variant review (Siarkowski *et al.* 1997). Another attempt to the issues was presented by Grieger (2005). He assumed that not every factor determining the machine selection for plant production was measurable. It may be accepted that he tried to define a simplified advisory system for helping the decision on purchase the new agricultural machines. That attempt had the shortcoming that no economic criteria could be included.

The paper presents main assumptions that were considered by the Authors as necessary to effectively introduce changing values of purpose function into the system. Unit exploitation costs of tractors, machines, and devices applied at agricultural production are one of such functions. There are presented assumptions and solutions referring to machine and aggregate exploitation costs as a selection criterion in expert systems for agricultural producers. The main stress was put on the way the costs are estimated for various exploitation conditions as well as form of their introduction into the system. Considerations were presented using the example of mineral fertilization of cereal cultivation.

3. Assumptions of expert system

Unlike the industry where advisory systems began to be applied after technology selection and then expert systems, the agriculture did not go through the stage of computer advisory systems, with some exceptions of course, such as system for supporting the mineral fertilization worked out by IUNG or systems for helping the decision making referring to machines selection worked out at Agricultural Universities in Cracow and Lublin. Recently, several centres undertook the studies (e.g. Weres 2000, Marciniak 2005, Cupiał 2007) upon databases on agricultural production processes, omitting somehow the advisory stage.

Correct solving the issues within the branch of expert systems for agriculture requires activity in several layers of IT infrastructure:

1. Hardware infrastructure. It consists of a computer network, servers, workstations, printers, and other peripheral devices. In agriculture, such network can be built on a base of Centres for Agricultural Advisory. Farmers often cooperate with those Centres, and on the other hand, the stuff well recognizes their needs and possibilities. Furthermore, part of farmers has computers and Centres would help them to get basic and application software.
2. Basic software. Operation systems, database systems, or systems of programming languages compilation for advanced user-farmers or stuff of Agricultural Advisory Centres. Basic software would make possible to use agricultural advisory system, and in future, computer databases on agricultural production process.
3. Application software. Recording of resources and needs for materials in a farm, decision making support, help in farm management, quality control, and management of production process in a farm.

Following rules after Flasiński (2006) are suggested to be accepted:

- Building of expert system should be started at application software, because it determines the purchase of system software, and then the direction of hardware platform development.
- Agricultural experts within given area should be involved in creating the expert system from the very beginning. This rule seems to be obvious, but it is frequently neglected and main system authors are usually IT experts.

Due to the experiences of the Authors and cooperating IT experts along with students at the Department, Delphi environment has been chosen as a basic, because most of previous programs had been written in Pascal 7.0. A farm is the main object of the system being worked out. It concentrates all activity branches and its appropriate projection in databases would be influencing on the quality of advice generated by the system. Earlier Department's publications distinguished definitions of terms accepted in all branches associated with agricultural technology in a farm that is involved in cereal production. At present, those definitions will be adapted to formal requirements of accepted expert system frames. Therefore, the problem of software selection for expert system has arisen. Basic frame expert systems such as PC-Shell or Neurone make possible to build expert or neuron applications enabling some level of validity and ergonomic generalizations. However, in a case of solving the problems that occur in agriculture using various IT techniques in a hybrid form, a tool of different action philosophy is required. Systems dedicated to work with a single particular technology are directed towards operating, and ergonomics of that branch. Here a system, aim of which is to collect data and methods useful at evaluating and decision making on a base of data collected, is necessary. Such system should not replace any system for database management, but only collect minimum amounts of data needed for decision to make. Main stress should be put on the easiness of integration and openness to various technologies operating with the same data within the same system. It would facilitate to free information flow among methods. It will be new attempt that would make possible to achieve an environment for creating technologically advanced applications. The system should be an independent tool in reference to a branch. Using the applications based on that system should include following problem classes: analysis and interpretation of data, classification, monitoring and systems for early warning, simulations, and prognoses. The system's applications will be used in farms to analyze the directions of development and modernization of production process or control over production process as well as at Agricultural Advisory Centres as an auxiliary tool for, e.g. deep analysis of various data that subsequently may be given to farmers. Such terms are met by HybRex system worked out by AITECH in Katowice (2006), and it is going to be used in further works upon the expert system for cereal producers.

The principles of the system are based on the search through the space of states as the most generalized model for concluding realization in symbolic systems. The space of states can be defined for any symbol set meeting the requirement of concluding ability. The *space of states* is the organized four *[S, A, W, K]*, where:

1. *S* is a set of nodes describing the states of a process of problem solution;
2. *A* is a set of steps at problem solution process;
3. *W* is not-empty sub-set of *S* containing initial states of a problem;
4. *K* – states in *N* are described if properties of states occurring at searching or properties of a path formed during searching are given.

Solution path is a path going through the graph from node in *W* to node in *K*. The path assignation requires the searching strategy. Each strategy is useful for slightly different applications depending on initial conditions, the number and quality of data. In general, there are two such strategies: forward and backward (Mulawka, 1996). Each of them has slightly another practical application. Backward searching is applicable when:

- The goal or hypothesis is given in the problem formulation, e.g. proving mathematical theorems, diagnostic systems, etc.
- Number of rules possible to apply gradually increases and early elimination of goals may eliminate searching through some of branches.
- Initial state is not explicite, but it must be recognized. Backward searching may help in control over data achievement (e.g. diagnostics of agricultural machines).

Forward searching is useful when:

- All or most of data is contained in a problem formulation (e.g. interpretation).
- There is great number of potential goals, but only several possibilities of initial facts and information application for a given problem.
- It is difficult to formulate the target hypothesis.

In here worked out system, there are going to be applied different strategies depending on the advice range, future user will expect. For instance, if a user expects an advice on the selection of particular production operation manner, forward searching seems to be more useful. In a case of evaluation of a machine's reliability, backward strategy will be more useful; for example, checking what was the behaviour of a given machine at similar exploitation conditions.

4. Form of purpose function

The solution of the issue of purpose function form in expert system for cereal producers, including rapeseed, is going to be presented on an example of plantation mineral fertilization. Future system's user may select machines and devices in two ways.

The first way is to select the best machine (according to accepted purpose function) or device to tractor present in a farm. After selecting appropriate tractor and indicating technological operation, database with machines and devices applied in cereal production is searched to select those power demands of which are lower than that of tractor possessed. As a result, user gets an access to the list presenting all found machines and devices. Each of them is described in details by parameters from the databases. They are price, power demand, performance period, utilization during the performance period, annual utilization, maintenance costs, and unit exploitation cost. That information would help user to detailed analysis of his decision on a given machine or device selection. Analysis of highlighted information on machines or devices helps user to make a decision, which may be based on other factors than technical or economical ones, e.g. neighbour's suggestions or his own preferences referring to producers or machine's types.

Another way allows for selecting tractor and machines or devices according to multi-criterion purpose function. The 3D dependence for mineral fertilizer spreaders is of the form:

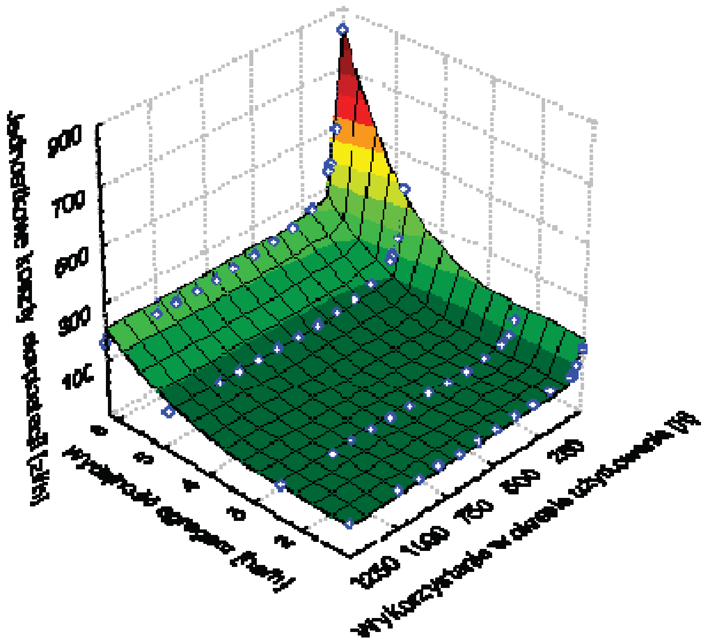
$$z(x,y) = ((18.154)y^3x - 109.18y^2x + 204.713xy + 5932.5)/(6.611x - 141.28), \quad (1)$$

where:

$z(x,y)$ – unit exploitation costs of the aggregate [zł*h^{-1}],
x – annual utilization of aggregate [h],
y – aggregate's efficiency [ha*h^{-1}].

Determination coefficient is $R^2 = 0.96$, and fitting mean-square error is $S_e = 25.09$, which indicates good fitting of the curve to experimental data.

Figure 1 presents plot of unit exploitation costs for mineral fertilization aggregates depending on their efficiency and annual utilization time. The plot illustrates 3D criterion of mineral fertilizer spreaders selection. Achieved results refer to the aggregates optimum from a point of view of unit exploitation costs. The system user has an opportunity to choose the aggregate's efficiency, annual utilization time, and unit exploitation costs for the aggregate from the range on the plot. Clicking on any node corresponding to selected values will result in presenting the aggregate or aggregates meeting selected criteria.



Rys. 1. Zależność jednostkowych kosztów eksploatacji od wydajności oraz czasu rocznego wykorzystania agregatu
Fig. 1. Dependence of unit exploitation costs of an aggregate for mineral fertilization on efficiency and annual utilization time

In addition, user has an access to efficiency plots for particular machines and devices depending on unit exploitation costs as well as utilization during performance period.

The 3D dependence for manure spreaders is of the form:

$$z(x,y)=(4.612x+10.66)*(0.22*y+331.1)/(0.122y+0.000669), \ R^2 = 0.95. \quad (2)$$

Variable descriptions is as Eq. (1).

The 3D dependence for sanitation cars is of the form:

$$k(y)=0.1^{y}-0.92,$$
$$z(x,y) = (78571.1x + 1452.09)y^{k(y)},\ R^2 = 0.99. \quad (3)$$

Equations (1)-(3) have been worked out on a base of own study results.

5. Conclusions

The paper presents assumptions of expert system for cereal producers, including rapeseed, for fuel purposes. The role of selection criterion in expert system was indicated and how that criterion would function in the system. The attempt is of versatile character, although particular technological operations may have different forms of selection function. Attached example refers to the mineral fertilization of cereal plantation and it shows how, on a base of purpose function plot, the initial selection of optimum solution is made.

6. References

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