

EXPERT SYSTEM FOR ECONOMIC EVALUATION OF TECHNOLOGICAL PROJECTS*

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Apart from the technical level, a basic tool for decision making and realization of the technical innovation project is also its economic effectiveness. It is assessed by comparing expenses and effects with respect to all-society interests and standards valid in a relevant period for the areas of technology, economy, ecology, safety of work, etc.

1. INTRODUCTION – BASIC CONCEPTS

In practice, there are usually more development project proposals of scientific and technological, investment and rationalization. It is necessary to choose the proposal that has the greatest benefit both for the society and the investor (Synek et al., 1996). When we compare expenses with benefits, the decisive criteria for economic evaluation are as follows: return time, profitability and risk (Konečný, 1996). Under the evaluation of investment efficiency in a broader context, we understand the analysis of results and benefits of investment, their comparison with social and economic objectives of the society, a complex analysis of data and indicators, and their comparison with comparative bases, an analysis of variances from comparative bases, and

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an analysis of decisive factors, influencing effects and requirements on investment.

Up to now, there were many special terms in the area of economic evaluation (for example - costs: investment costs, production costs, fixed costs, variable costs, independent costs...) which we will not comment here. It is necessary to indicate that when comparing investment projects, it is vital to ensure they are compared at the same level in terms of time, scope, etc. To do this, the following terms have been introduced:

- *Scope of appraisal* – a set of affected objects for which the appraisal must be made;
- *Period appraisal* – investment performance is specified and evaluated in the target year; in investments with a long start-up period, the start-up curve is taken into consideration;
- *A comparable basis* is the state of the analyzed object, characterized by TEI (technical-economic indicators), to which the proposed project is compared during appraisal. The comparable basis may be built-up of:
 - approved TEI,
 - TEI of similar projects with a progressive analysis of developed countries and
 - TEI of sample projects.

It is usually complicated to express investment expenses, but the determination of benefits is much more difficult (especially their quantification). Therefore, we make use of all available instruments (cost formulas, target prices, prescripts, price lists, expert estimations, etc.). Benefits arise from the realisation of innovation, e.g. the increase of production volume, reduction of time, space, material and wage expenses, reduction of circulating capital, but also the decrease in labour, improvement of lighting, enhancement of safety of work, etc. We can quantify most of these benefits and express them in financial units.

The process of evaluation of investment efficiency may have the following stages:

1. Evaluation of purpose and need for investment;
2. Evaluation of technical and economical level of products (representatives of a production program for the suggested plant);
3. Evaluation of interchangeable alternatives;
4. Complex evaluation of the resulting alternative by means of comparative bases with a view of:
 - technical and economical level of investment,
 - production and economic efficiency of investment,

- social effects and
 - incidental requirements and effects;
5. Comprehensive evaluation of investment efficiency.

The first two stages cover basic concepts resulting from the trends in the development of the given industries (need for and usefulness of the investment). Stage three includes the preparation and assessment of mutually replaceable alternatives leading to attainment of the objectives set out in the previous stages. In stages four and five, a complex specification and evaluation of the requirements and impacts, as well as the total contribution of the project is made.

The following stages are included in the economic evaluation expert system:

- evaluation of technical and economical level of investment,
- evaluation of production and economical efficiency of investment,
- comprehensive evaluation of investment efficiency and
- help for quantification of costs and savings.

2. EVALUATION OF TECHNICAL AND ECONOMICAL LEVEL OF INVESTMENT

The technical and economical level of investment is evaluated with the help of group indicators (TEI – technical and economical indicators). With the help of TEI, we evaluate investment projects with a comparable basis (sample projects). Comprehensive evaluation of technical and economical level of investment expresses efficiency rate:

$$r_{ef} = 1 + \frac{C_{ac} - C_{ai}}{C_{ac}}. \quad (1)$$

- r_{ef} – efficiency rate,
- C_{ai} – average costs of projects investment per year,
- C_{ac} – average costs of comparable basis per year,
- *average costs per year* = production costs + transfer expenses + depreciation of machines and equipment,
- *transfer expenses* = i * investment costs,
- i – transfer coefficient (it may be e.g. interest rate).

3. EVALUATION OF PRODUCTION AND ECONOMIC EFFICIENCY OF INVESTMENT

Production and economic efficiency gives us important information about new investment changed profit, income, amount of production... etc. For the evaluation of production and economic efficiency, we use many methods: method of productivity of investment, method of net present value of investment, method of transfer expenses, etc., described in sixth section of this paper. For complement of production and economic efficiency evaluation, we use many TEI, such as productivity of work indicator, efficiency of machines and equipment, etc. The following algorithm expresses comprehensive production and economic efficiency change of production funds rentability:

$$r_i > r_s$$

- r_i – rentability of production fund in year of investment evaluation,
- r_s – rentability of production fund comparable basis.

4. COMPREHENSIVE EVALUATION OF INVESTMENT EFFICIENCY

The indicator of total income from investment expresses comprehensive investment efficiency:

$$I_T = \frac{\sum_{i=1}^n I_i}{\sum_{i=1}^n C_i} \quad (2)$$

- I_T – total income of investment,
- I_i – income in i-scope of appraisal,
- C_i – investment costs in i-scope of appraisal,
- i – number of scope of appraisal.

5. HELP FOR QUANTIFICATION OF COSTS AND SAVINGS

Basic method to determine the costs and savings of an investment project is the calculation algorithm which helps us to express items of costs and income. Using different methods, we determine algorithms for calculation of the most

frequent operating costs (for example adjusting costs of machines, costs for technological energy, costs for reparation of machines etc.).

6. CONCEPTION OF KNOWLEDGE BASE AND EXPERT SYSTEM

A conception of the expert system for the economic evaluation of projects of investment actions is based on the possibility to link the methods of economic assessment with individual types of investment activities. We analyzed the types of investment activities from different viewpoints. Then, the following classification for assessment of the knowledge base was chosen:

1. *restoring machines and equipment (below MaE)* – obsolete and used-up equipment is replaced by the same type of MaE;
2. *restoring and up-dating of machines and machinery* – equipment which is able to operate is replaced with more modern equipment with lower operating costs;
3. *increase of production* - based on the market needs, the production volume increases;
4. *innovation of commodity* – change of function, material and technology,
5. *production of new commodity (innovation of new service)* – linked with a new market territory to obtain;
6. *diversification of production (services)* – expansion of business activity to reduce the trading risk;
7. *reduce the number of refuses* – this can be achieved by the change of MaE, technology or qualification of workers;
8. *machinery common to more users* – introduction of specific, expensive technologies and MaE for common better exploitation by more users;
9. *building-up of infrastructure* - within the realization of general and perspective objectives, it is necessary to build up power distribution systems, modernize flows of materials, information, etc;
10. *ecological activities* – projects to increase safety of work and occupational hygiene – actions with long return time, or action without economic benefits;
11. *other investment activities* – administrative buildings, car parks, canteens, etc.;
12. *combined investment activities* – from the above-mentioned types.

From the methods used for economic evaluation of investment (incl. methods of evaluation of alternatives), the following have been chosen:

1. *Productivity investment* (coef. of economic efficiency):

$$C_{ef} = \frac{P_a}{IC} \quad (3)$$

- P_a = net annual profit,
- IC = investment costs.

(Instead of P_a we can calculate C_{ef} from annual cash flow or savings, which arised from realization of investment);

2. *Return time*:

$$R_t = \frac{1}{C_{ef}} \quad (4)$$

3. *Net present value of investment (NPVI)*:

$$NPVI = PVCF - IC = \sum_{t=1}^n \frac{CF_t}{(1+i)^t} - IC \quad (5)$$

- $PVCF$ = present value of cash flow,
- CF_t = expected value of CF in time t,
- i = business discount rate,
- t = periods (years) 1 to n,
- n = lifetime of investment.

4. *Intrinsic pay-off percentage (i)*:

$$PVCF = IC \Rightarrow i = ? \quad (6)$$

Discount rate is calculated and then compared, e.g. with the bank interest rate.

5. *Transfer expenses* (we transfer the one-shot investment costs into the annual cost by means of coefficients):

$$T = IC \cdot (a_1 + c_t) \cdot c_b + C_o + a_2 \cdot C_w + a_3 \cdot C_e \quad (7)$$

- T – transfer expenses (financial units per year),

- c_t – coefficient of economic efficiency which is assessed for period of economic investment lifetime,
- c_b – coefficient of unproductive blocked resources in build-up,
- a_1 – coefficient which is limiting investment resources,
- a_2 – coefficient which is limiting labour,
- a_3 – coefficient which is limiting fuels and energies,
- C_w – wages and others personal costs,
- C_o – annual operating costs,
- C_e – energy costs.

It is necessary to update coefficients every year, if we want to use this method.

6. *Efficiency coefficient and return time of additional investment expenses (comparing the alternatives):*

$$C_{ef} = \frac{C_{op1} - C_{op2}}{IC_2 - IC_1} \quad (8)$$

- C_{op} = operating costs,
- IC = investment costs,
- $1, 2$ = number of alternatives.

7. *Methods considering risks.*

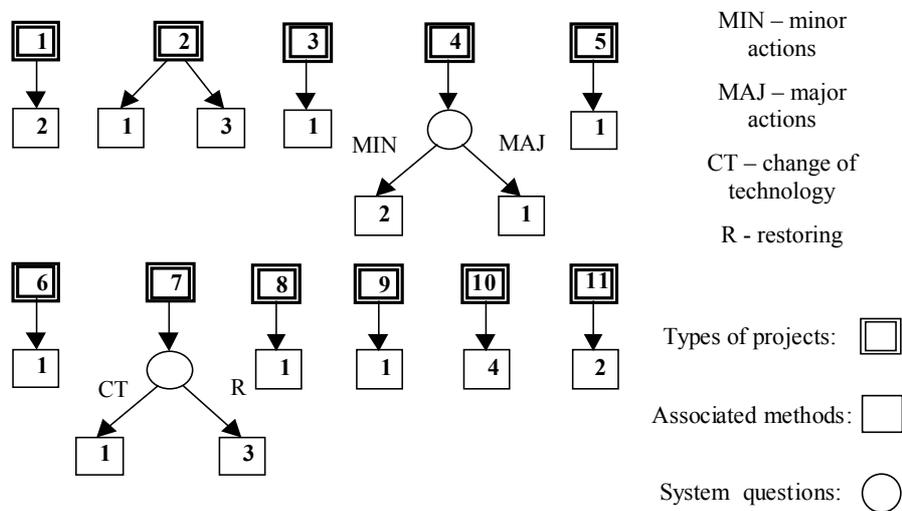
7. INFERENCE NET OF EXPERT SYSTEM

When creating the inference net, the types of investment actions were numbered (see below). Figure 1. illustrates the possible links. The diagram of assignment possibilities was constructed on the base of logical considerations and recommendations, so that for each type of project, the main and possibly additional methods of economic evaluation were determined (this method is not illustrated in the diagram). Microsoft Excel has been selected as the environment of the expert system.

8. DESCRIPTION OF EXPERT SYSTEM

The program falls into the class of software known as expert systems because it is able to select and apply a suitable method of economic investment evaluation, enabling the unexperienced users to work with it too. Every expert system consists of an inference net (inference mechanism) and knowledge base,

which can be modified by the user. However, our program is the user expert system; from the viewpoint of a programmer, it is a pseudo-expert system because the knowledge base consists of source texts of macros. (In classic expert systems, knowledge base is separated from source texts.) User should have a certain knowledge of Visual Basic language in order to modify base (see below). Such a modification is not possible for now, because of the relative calculation method constancy. We can say that the inference net of our expert system consists of a linkage of macros to the basic menu (see Fig. 1) and knowledge base composed of source texts of all these macros.



System questions:

- 1 – Method of net present value and intrinsic pay-off percentage
- 2 – Method of efficiency coefficient and return time
- 3 – Method of transfer expenses
- 4 – Method of return time

Figure 1. Initial diagram for composition of operative net

The core of knowledge consists predominantly of formulae for the calculation of indicators of economic efficiency. Into the variables of these formulas, the program inserts the required data, which describe the actual situation in the enterprise. Certain program improvement is under consideration. After these changes, the user will be able to do some editing of the formulae – e.g. to change some constants. Formulae and their constants would be saved separately – in data file.

9. EXPERT SYSTEM DEVELOPMENT TOOL

The system is drawn as a file of macros (file with suffix “xls”). It is created by means of the Visual Basic programming language, which is a part of Microsoft Excel. The structure of the Visual Basic programming language is similar to Basic or Pascal. The language architecture is based on an object-oriented model with components streamlined for effective and quick development of the user interface. The capabilities of Excel can be extended by using macros to automate tasks and create customer applications in the Microsoft Excel environment. To start our application, one needs to have the Microsoft Excel software installed. The software already features several tools for the appraisal of investments (standard financial functions). After opening a file, macros are accessible from an open workbook (through menus offering different types of projects). The workbook can also be used for standard work with spreadsheets. The reason for integrating the expert system into the Microsoft Excel environment is the advantage of extending the capabilities of a application already popular with a wide customer base.

10. WORK WITH EXPERT SYSTEM

After opening the workbook with macros, a new item – Investment – will appear in the menu toolbar. After clicking on this item, the program displays a main menu containing four items: efficiency rate – global indicator, evaluation of production and economical efficiency according to project type, comprehensive evaluation of investment, quantification of costs. The user selects a type of his or her project from “evaluation of production and economical efficiency according to project type” menu (e.g. “restoring and updating of machines and machinery”). As there are more appraisal methods that can be used for this type of investment project, based on what input data is known, two submenus will be displayed from which one can either choose the “Net Present Value of investment method” or the “Transferred Cost method” (see fig. 1).

Once an item is selected, the program displays a form linked to the particular project type. (A method has been assigned to a particular project type.) The user can now enter all input data into the form required for the method of evaluating the profitability of the selected type of investment. These input data can be e.g.: actual annual cash inflows during the life of the investment, initial capital expenditures, inflation rate expressed as a percentage, and the like. Before starting the calculation, the program checks all values in the entry fields in the form for validity with regards to the given appraisal method.

It verifies, e.g. whether the income is negative or not, the rate of inflation is not below 0% and above 100%, etc. When all the required values are within permissible ranges, the program starts to calculate the profitability indicators attached to the particular evaluation method.

The user can, at any time, change any value in any entry field in the form. A repeated click on the Calculation key will immediately show the changed profitability indicators. On clicking the "Interpretation of Results" key, the program will consider the entered and calculated values and recommend to the user whether to accept or reject the investment, or which alternative (should there be more than one) is the most suitable. The system also displays a brief justification of the decision (e.g. "Because net present value is positive").

11. CONCLUSION

In the market economy, the economic evaluation offers fundamental sub-bases for decisions on realizing an action. The suggested expert system enables designers to process the economic evaluation quickly and skillfully, without specific requirements on economic knowledge. Based on the knowledge of the entrance information, the rate of processing of economic evaluation depends only on time necessary to order the entrance data.

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EKSPERTNI SUSTAV ZA EKONOMSKU PROCJENU TEHNOLOŠKIH PROJEKATA

Sažetak

Osim analize na tehničkoj razini, prilikom odlučivanja i implementacije projekata koji se odnose na tehničke inovacije, potrebno je voditi računa i o njihovoj ekonomskoj učinkovitosti. Ona se može procijeniti na temelju usporedbe trošaka i rezultata projekta, s obzirom na šire društvene interese i standarde koji u danom periodu vrijede za područja tehnologije, ekonomije, ekologije, sigurnosti na radu, itd.