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OPTIMISATION MODELS AND THE ECONOMICS OF MANAGERIAL DECISION-MAKING

MODELE OPTYMALIZACYJNE A EKONOMIKA PODEJMOWANIA DECYZJI MENADŻERSKICH

ABSTRACT

Making optimal decisions is a process whose aim is to select the best solution from the perspective of efficiency, economy and rationality. This process includes a group of logically related mental and computational operations. They lead to the selection of the best possible decision-making option. To optimize decision-making processes and increase their quality, various methods and techniques based on mathematics and statistics are used. Decision-making is a basic condition for solving management and economic problems in an organization, whether traditional, process-based or project-based.

KEYWORDS: *decision planning, decision making process, managerial decision making, optimization, efficiency, rationality*

STRESZCZENIE

Podjęcie optymalnych decyzji to proces, którego celem jest dokonanie wyboru najlepszego rozwiązania z perspektywy efektywności, ekonomiczności i racjonalności. Proces ten obejmuje grupę powiązanych ze sobą w sposób logiczny operacji myślowych oraz obliczeniowych. Prowadzą one do wybrania jak najlepszego wariantu decyzyjnego. Aby zoptymalizować procesy decyzyjne i podwyższyć ich jakość wykorzystuje się różne metody i techniki oparte na dziedzinie matematycznej i statystycznej. Podjęcie decyzji jest podstawowym warunkiem rozwiązywania problemów zarządczych i ekonomicznych w organizacji, czy to tradycyjnej, czy procesowej, jak i projektowej.

SŁOWA KLUCZOWE: *planowanie decyzji, proces podejmowania decyzji, ja zarządcze, optymalizacja, efektywność, racjonalność*

INTRODUCTION

The essence of economic activity is to meet human needs through production, selection and provision of services. People organizing production must decide how to spend money, what and how to invest it in order to obtain maximum income from the capital employed and at the same time meet the needs of customers. Each of these decisions is an act of choosing between alternatives, i.e. different ways of proceeding. Each choice is accompanied

by an opportunity cost (foregone), called opportunity cost or replacement cost (Griffin 2004, p.34).

Decision making is the process of selecting the best solution that uses methods and techniques based on mathematics and statistics. Economic decisions are the act of choosing between alternatives that have an opportunity cost. The decision-making process consists of six stages: defining the problem, defining the goal, examining the choice options, anticipating the consequences, selecting the optimal option and sensitivity analysis. There are various decision making models such as rational, behavioral, dual process and others that are used in businesses (Stoner, Wanker 2006).

Rational models, where the issue of rationality in the decision-making process is considered in relation to: conditions and assumptions that must be met in order for decisions to be classified as rational, practical recommendations (how a rational manager should act), model approaches to decision-making processes (how decision-making processes should proceed). Behavioral models of bounded rationality. Here, the decision-maker follows the rules of full rationality, but is not *perfect* in his tasks. He is prevented from acting fully rationally by certain limitations: cognitive, motivational, organizational or emotional. Heuristic models – they assume a complete departure from full rationality, present real decision-making processes, akin to the *double process* model – integrate an approach oriented on rational analysis with an approach oriented on intuition (Malewska 2014, p. 127-131).

DECISION-MAKING AS A MANAGEMENT PROCESS

Decision-making is a procedural feature of the management process with multiple economic and psychosociological determinants (Targalski 1985, p. 194, Rebizant 2012). Decision-making can be considered in two senses [3,4]. In the broad sense, it is a complex process that consists of recording and evaluating information, identifying the decision problem and applying the adopted selection criterion, defining and issuing the decision (decision task) and recording information about its execution. In the second - narrow - sense, decision-making is only one of the stages of the decision-making process and

means a conscious act of will by a decision-maker making a non-random choice of one, from a set of possible options for solving the decision problem (these options, of course, must be identified or designed in advance) (Kowalczyk, Roszyk-Kowalska 2016).

System model is a model based on the importance of data and observations in the decision-making process. although this model does not apply directly to managerial decisions at the strategic management level, the process and data waveforms also reflect the waveforms for this category of decisions (Janis, Mann 1997, Dąbrowski, Schumann, Woleński 2015).

The decision-making process consists of the following stages:

- identification of the decision situation,
- identification and design of decision options,
- evaluation of designed variants and selection of the rational variant,
- creation of conditions for the implementation of the decision,
- control of the effects of the decision made.

Each of these stages requires the satisfaction of specific information needs, and a continuous supply of relevant information is only possible with a well-functioning information system. The simplest form of decision-making is a sequence of three stages:

- stage one - problem identification, i.e. identifying causes, effects and probable solutions,
- stage two - decision design, that is, the development of options for the optimal solution,
- stage three - selection of the final decision, i.e. selection of the best of the variants consistent with the previously established criteria.

Decision classification is an important part of the identification of decision-making problems. It is extremely difficult to classify decisions because of their huge number and diversity. The following main types of decisions can be distinguished: strategic decisions, tactical decisions, operational decisions (Morgan 2005, Moroz 2005, Noga 2009, Urbanowska-Sojkin, Banaszyk, Witczak PWE 2017).

With regard to the structure and repetition of decisions, they can be divided into:

- programmed decisions- has a complete structure or repeats with a certain frequency (or both),
- non-programmed decisions- has a not very clear structure, is made much less frequently than programmed decisions.

According to the criterion of the sources of initiation of decision-making problems, decisions are divided into:

- decisions initiated by superior units
- decisions initiated by the manager
- decisions initiated by subordinates

Classifying decisions according to the causes of problem generation, we can distinguish:

- regulatory decisions
- control decisions
- innovative decisions

Due to the amount of information and the conditions under which decisions are made, we distinguish:

- decisions made under conditions of certainty
- decisions made under conditions of risk
- decisions made under conditions of uncertainty

According to the criterion of quantification, decisions are divided into:

- decisions quantifiable
- decisions that are difficult or impossible to quantify

Suggesting by choice options we can distinguish:

- closed decisions (evaluation problems)
- open decisions (exploration and development problems)

With regard to participation in decision-making, we can divide decisions into:

- individual decisions, i.e. decisions made by one person
- individual decisions with collective recognition
- collective (collective) decisions

Taking into account the functions of management, we can distinguish:

- planning decisions
- organizational decisions
- coordination decisions
- command decisions
- control decisions

According to managerial functions we distinguish:

- managerial decisions
- non-managerial decisions

According to the importance of the problem, we divide decisions into:

- key decisions
- standard decisions
- marginal decisions

Suggested by the time horizon:

- short-term decisions
- medium-term decisions
- long-term decisions
- forward-looking decisions

For example, enterprise decisions in the area of costs include: analysis of relevant and irrelevant costs, production costs, issues of economies of scale, optimization of enterprise costs or calculation of the enterprise break-even point. Enterprise decisions in the area of uncertainty include: analysis of uncertainty and risk, quantification of risk, risk propensity, selection of decision-making

methods used under uncertainty, and elements of game theory (Zarządzanie firmą. Strategie, struktury, decyzje, tożsamość 2007, Porter 1980).

Decision categories according to their role in the management process: operational, tactical and strategic. Decisions in terms of degrees of risk include: decisions made under certainty, decisions made under risk, and decisions made under uncertainty. Decisions made in terms of degrees of innovation, are: routine, adaptive, innovative and regressive. And according to the degree of programmability, programmed and non-programmable decisions can be distinguished (Froeb, McCann 2012, Schermerhorn 2008).

OPTIMIZATION MODELS

Optimization models, which are derived from mathematical decision theory and operations research. They are designed to support the process of choosing the right decision and making an optimal decision. Optimal decision in the sense of managerial economics, is one that, under the conditions of a certain criterion of the so-called objective function and constraints, assumes that such quantities are obtained, which allows the model to be optimized by obtaining maximum benefits or minimum losses (Gruszczyński, Podgórska 2004, Panek 2010, Tokarski 2011). If the problem is presented with an optimization model, then for its solution we usually use mathematical programming methods.

Quite a few decision-making problems are solved using simulation models. The simulation process involves the decision-maker trying to describe reality as best as possible using a model. Models of this class are used for such complex situations when optimization methods fail. Simulation modeling can also be used as a complement to optimization models such as linear programming. Then we can test more elements and determine the effects of changing the constraints or the different development of profit and cost coefficients. Simulation as a technique to support planning decisions is used in large organizations with adequate resources. In economic practice in Poland, simulation modeling is used, among other things, for macroeconomic modeling of economic and social processes. Such models are used here for planning, among other things, the state budget and public funds or, public debt, or modeling

of various demographic processes. Simulation models on a microeconomic scale are used in the process of developing and projecting business plans.

Forecasting models are used to make decisions about the future. The basis of these decisions is to determine whether the studied quantity will develop favorably or unfavorably in the future. In the latter situation, we will be dealing with the so-called warning forecast. Forecasts are an important part of planning decisions, both short-term and long-term. Forecasting models are used by both small and large organizations. Models of this type are used for strategic planning, and especially for creating business plans.

Econometric methods are used to solve the most complex economic problems. The tool for analyzing a decision problem is a descriptive econometric model. The process of learning about the mechanism of the decision problem involves building the so-called parameter estimation model and inferring from it. Econometric model is called a formal description of the stochastic dependence of the distinguished quantity, phenomenon or course of the economic process (phenomena, processes) on the factors that shape them, expressed in the form of a single equation or a system of equations. The structure of each equation is determined by: the explanatory variable, explanatory variables (non-random or random) having a fixed economic content, structural parameters, a random variable (traditionally called a random component) with unknown content, and a specific type of functional relationship between the explanatory variable and the explanatory variables and random component. The relationships that exist between economic phenomena are very complex and multidirectional. The decision problem under study is influenced by many phenomena of an economic nature as well as social, demographic, natural, etc., and the impact of these factors varies.

Simulation, is the process of reproducing the properties of a given phenomenon (process) or space, occurring in nature, but difficult to study, repeat. It makes it possible to conduct measurements, research, at a selected place and time; to make - on the basis of a given model and using spreadsheets - appropriate calculations, which then allow you to get an idea of the efficiency of the model or provide a basis for inferring the behavior of the economic system described by the model. The reason for the creation of simulation models is not only the desire to learn about reality, the laws governing it, but also

to explore the possibility of influencing the phenomena around us, to study phenomena in other conditions and in the future (Kulapa 2008, Bednarski 2011, Maciąg 2016, p. 149-150).

A mathematical model is a set of symbols and mathematical relations along with absolutely strict rules for operating them. Symbols and relations refer to specific elements of the reality we study. The model describes a given phenomenon by means of variables whose values can belong to a variety of values, e.g. integers, real numbers, logical values, etc. Mathematical modeling has applications in many areas of life, mainly in those where there is repetition or similarity of events, i.e. in economic sciences (Pawlak 2011, Pawłowski 1981, p. 302-307, Koliński, Śliwczyński, Golińska-Dawson 2018).

Economic decisions are among those whose consequences we consider in terms of profits and losses, so before we make them we analyze the situation, establish criteria for choosing decisions and look for optimal solutions. Methods of quantitative research of regularities occurring in economic phenomena, which could be most generally called econometrics, turn out to be helpful then. A variety of methods are used in economic research, developed by many disciplines of mathematics, primarily mathematical analysis, linear algebra, probability calculus, mathematical statistics, mathematical programming, operations research, stochastic process theory, differential and differential equations, stochastic differential equations, etc. Mathematical modeling is present in macro and microeconomics, business management, marketing, economic logistics, transportation economics, regional management, finance, banking and insurance. In practice, simulation methods can be divided into two major classes (Kłosowski 2011, p. 29-37, Gałązka 2018, Herman 2003, p. 53-57):

- deterministic simulation- the random components of the model are omitted, what in linear models- means operating on the expected values of individual variables,
- stochastic simulation - the random component and the properties of its distribution are taken into account (then an appropriate subroutine generating the realization of the random component and taking into account the actual properties of its distribution must be built into the calculation program).

An economic model is used to get a simplified picture of reality. Trying to represent the entire economic reality is pointless and doomed to failure in advance due to the infinite amount of details. Simplifying assumptions of the economic model can apply to any issue:

- e.g. the earnings of the population (every citizen has a salary equal to the national average),
- foreign policy of the state (the state does not have any economic relations with foreign countries)
- or basic economic categories like price: (the price for a given service will not change in two years) or inflation (it will remain constant over two years).

Conducting simulations makes it possible to analyze the process in various variants, which are verified in a virtual way, and therefore do not affect the real-time operation of the process. However, based on well-developed control parameters that are consistent with the actual state, it is possible to conclude with high probability that the analyzed process variant has a chance to be realized in economic reality. Any simulation requires the definition of basic principles (Pawlak 2012, p. 207-217, Rogowski 2004, p. 193-203, Śładkiewicz 2018, p. 618-624)

REASERCH METHOGOLOGY

Economic sciences use typical methods found in the social sciences and humanities, i.e.: examination of documents (legal acts and administrative court judgments), comparative methods (expert opinions, legal opinions, analyses resulting from linguistic, grammatical and historical interpretation) and case studies. The results of cognitive research are new theorems or theories. On the other hand, research for practical business purposes results in determining whether, and to what extent, the existing theorems and theories on taxation of mine workings are useful in solving specific problems that arise in everyday business activities in the mining industry. In other words, they serve the purpose of clarification and piecemeal verification of existing theorems and theories. Induction was used as the main research method. It consists in drawing general conclusions or establishing regularities on the

basis of analysis of empirically stated phenomena and processes. It is a type of inference based on details about the general properties of a phenomenon or object. The use of this method requires the assumption that only facts can form the basis of scientific inference. These facts are real existing situation (economic & social). Inductive methods include various types of legal acts, analyses, expert reports and scientific documents used in social research.

CONCLUSIONS

Sensitivity analysis is used to assess the economic profitability of the implementation of an investment (business) project, assuming deviations in the values of various variables included in the project (mainly sales values, prices, costs, etc.). It is a kind of tool for reducing the risk of economic decisions, especially in the sphere of profitability of investment (or more broadly of business design, such as the creation of business plans, or calculation of projects for the introduction of new products). The assumption of this method is that the future cannot be predicted and, therefore, the actual values of the various variables taken into account in the investment account will deviate from those assumed. The main task of sensitivity analysis is to calculate the turning point, which marks the equalization of the cost of the product sold with revenue . Sensitivity analysis answers the question: how will the efficiency of the project change with a change in the size of the input parameter? Analysis of the *what if* type - gives an answer to the question *what will happen if...*

This method allows you to study the sensitivity of certain parameters to changes in the value of the relevant influencing factors. Two aspects of sensitivity analysis can be distinguished firstly, the determination of the impact of changes in the values of selected variables, and secondly, the determination of such values of selected variables for which the NPV will equal zero. Examples of variables that can be analyzed: the number of employees, prices for the products and services offered, sales volume, operating costs, or the duration of the project. Note that only one variable should be subject to modification in the sensitivity analysis, while the other parameters should remain unchanged. In

this way, it is possible to determine which of the selected factors affects the investment project to the greatest extent.

Sensitivity analysis is one of the stages of decision-making. This analysis allows you to calculate the limiting level of application of individual factors that ensure the achievement of a certain break-even point. It provides information on what are the permissible deviations of the individual explanatory variables at which the investment venture is still profitable. It can be applied in considering the potential impact of different price and cost structures that may be associated with different production systems or operations. Sensitivity analysis is most often performed using the NPV (net present value) method.

$$ww = \frac{[NPV_i - NPV_b]}{[NPV_b : Z_i - Z_b]} : Z_b$$

where:

ww - sensitivity coefficient of NPV to a one percent change in the value of the explanatory variable Z,

Z_i - the i-th value of the explanatory variable ($Z_i = 1.01Z_b$ or $Z_i = 0.99Z_b$),

NPV_i - NPV value at the i-th value of the Z_i variable,

Z_b - the baseline value of the Z variable,

NPV_b - NPV value for the Z_b variable.

Sensitivity analysis can also include an evaluation of the implementation of the chosen decision option; the goal then is to see if the desired state of affairs has been achieved. If so, management can be satisfied that the right choice was made. If not, on the other hand, the following questions should be asked:

- what were the reasons for this?
- was the decision context correctly identified?
- was the right target set?
- were all options considered?
- would the company have modified its original decision in light of the ex-post evaluation?

In the planning process, the first decisions are made, which are then reinforced and adjusted as necessary. Decision-making in the management process is the foundation of all managerial activity. Deciding also occurs in

other functions such as organizing, leading and modifying, and controlling, existent for the smooth functioning of a company and public organization. The term *decision* has two basic meanings. First, it refers to the result of a particular choice. Second, the term decision can refer to the selection procedure itself. Therefore, the specific economic rationale that determines the making of such a decision and not another is important. The decision-making process [PD] can be represented by the following formula:

$$PD = [P, S, W, H]$$

Where:

P - stands for the decision maker, i.e. who makes the decision (decision maker).

S - the set of decision-making situations (set of conditions).

W - the set of outcomes necessary to make a choice and determine whether the right decision has been made to achieve the right outcomes.

H - a set of hypotheses about future situations shaping the decisions made.

Based on the type of information the decision maker has, we can distinguish the following decision-making situations:

1. Decision-making under conditions of certainty (comfortable situation - we have complete and symmetrical information to make a decision).
2. Decision-making under conditions of risk (the most common situations in managerial economics). Operate on incomplete and often asymmetric information.
3. Decision-making under conditions of uncertainty. In this category fall most of the real situations of the organization especially if they involve issues of strategic decisions. Our information about future economic situations (micro and macro) is subject to a large possible error. Under conditions of uncertainty, our information about the rationale for decision-making is incomplete, not always true and often we do not have it or we use ex post information.

In making decisions process, it is also important to keep in mind that a competitor is modifying its previous decisions and trying to anticipate the

decisions that its competitors (nearer and farther away) are making. The decision-making process in which all its steps are clearly defined is called algorithmic, and the way of its implementation is a typical algorithm, i.e. a set of rules of action determining how to solve the posed problem in a finite number of steps. If the posed problem cannot be solved algorithmically we use heuristic methods. Heuristics is defined as a discipline that deals with methods of solving problems under conditions of incomplete information. In the heuristic approach, the paucity of information is compensated by intuition and experience, for example, business. For the application of heuristic methods, one needs the ability to identify and recognize facts and the relationships between them. Most discoveries, inventions and unconventional methods of operation have been achieved through heuristic problem-solving techniques. In the decision-making process, we also often have to deal with a decision chain. Decision-making can be represented by a finite number of steps (Wołowiec, Szybowski, Prokopowicz 2019, p. 34-42).

So we can identify four fundamental steps in the decision-making process:

- Step one is the result of misdefining the problem situation. The choice is limited by a number of factors that managers are often unaware of (tax changes, credit changes, interest rate risk, etc.). As a result, the assessed situation is incomplete, asymmetrical or false.
- In step two, there are two types of problems. First, the option adopted for analysis is unrealistic or economically disadvantageous (the best solution is to eliminate this option). Secondly, there may have been an incorrect (incomplete) transfer of decision options. As a result, the decision made is not optimal.
- In step three, we evaluate the decision options. Such evaluation is carried out from the point of view of the following criteria:
 - whether the decision can be implemented;
 - whether the limiting conditions will allow it to be applied in practice;
 - whether the resources available are sufficient for its implementation;
 - whether its implementation will not cause negative consequences for the organization (as well as its environment - stakeholders);

- whether the effectiveness, efficiency and economy of the organization will improve as a result of its implementation;
- whether the competitiveness of the organization will improve;
- whether the decision is not too costly;
- whether the decision is efficient from the point of view of the economic calculation.

In the fourth step - the most important from the perspective of economic calculation - the best option is selected. This is the variant that best meets the specified evaluation criterion. In most decision-making situations within managerial economics, we are faced with multi-criteria selection problems. Of course, it is best when we can use single or multi-criteria optimization methods. Then the result is unambiguous, and we can determine by how much the chosen option is better than the others (Wołowiec, Szybowski, Prokopowicz 2019, p. 34-42).

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