Åbo Akademi University

Nikolai Pavlov

Product Lifecycle Management

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Åbo Akademis förlag | Åbo Akademi University Press
Åbo, Finland, 2016

CIP Cataloguing in Publication

Pavlov, Nikolai.
Product lifecycle management /
Nikolai Pavlov. - Åbo : Åbo Akademi
University Press, 2016.
Diss.: Åbo Akademi University.
ISBN 978-951-765-834-8

ISBN 978-951-765-834-8
ISBN 978-951-765-835-5 (digital)
Painosalama Oy
Åbo 2016

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ISBN 978-951-765-834-8
Painosalama Oy – Turku, Finland 2016

ACKNOWLEDGEMENTS

Many people helped me to accomplish this work.

I would like to thank all my colleagues at St. Petersburg Polytechnic University from my department and my faculty that gave me so much useful advice when I worked on the first, Russian version of this work.

I would also like to express my great appreciation to Professor Claes Gustafsson who instigated the initial idea of my start working at Abo Akademi University.

When I came to Turku, I received great assistance from Professor Kim Wikström, who inspired me to prepare an English version, became my supervisor, and offered the most useful advice; his support has been constant.

Robin Wikström, my next supervisor, gave me considerable help in overcoming all the difficulties in accomplishing this work.

My thanks and gratitude go to Irina Mostovaya and Elizabeth Nyman who translated my thesis into English

I would also like to express my gratitude to my reviewers Ignacio Javier Perez Galvez and Tatiana Nikolaevna Saurenko, who accepted the task of being my reviewers. Further thanks also go to Ignacio Javier Perez Galvez for becoming my opponent, for which I am obliged and honored.

I wish to thank my family for all the support and patience they have given me during this process. My wife inspired me not to give up in difficult situations and my daughter has also been extremely helpful.

Finally, I felt that the atmosphere in Turku was always very warm. For this I would like to thank Magnus Gustafsson and his family, as well as Magnus Hellström and all the colleagues I worked with in Axeila.

ABSTRACT

Small and medium-sized enterprises play an important role in innovation processes in different countries due to their flexibility and ability to easily introduce new processes and products. In EU countries, the USA and China, the share of small and medium-sized enterprises in terms gross domestic product is above 50%. In modern dynamic markets, the need for innovations in the sphere of a product and its lifecycle management is evident. This need for innovation is not only limited to the development of new products but also includes the rationalization of marketing activity in this area and the development of a control system that will take into consideration the characteristics of the manufacturers as well as the consumers and their interactions.

According to the data, from the beginning of 2013 [141], the share of small and medium-sized enterprises in the Russian GDP was only about 20%. It is expected that this number will reach the level of the developed countries by 2020. The Strategy for Innovative Development of the Russian Federation until 2020[166] aims at a transition to a socially oriented innovation economy development model. At the present stage, the lack of scientific efforts summarizing this new experience is evident. For small enterprises with limited financial and human resources, it is important to develop new computer-based systems, which will assist them in using modern methods of marketing and management.

The objective of this research was, therefore, to increase the effectiveness of product lifecycle management. The scientific problem was to develop a theoretical basis for an intellectualized product management methodology.

The research questions were formulated in order to determine an understanding of client-oriented lifecycle management and its various stages. This understanding included the following factors: the role of client- orientated lifecycle management in a company's management and the effectiveness factors for its usage; revealing the specifics and problems of product lifecycle management; summarizing the existing methods of overcoming these problems; revealing areas that have been insufficiently studied; systematizing models and methods of decision making in lifecycle management in order to develop a system for their selection and use in real situations; developing an evaluation a system for the applicability of different methods for product lifecycle management and formulating the task of choosing a method for decision making and allowing its implementation; developing an experi-

mental version of an intellectualized system for checking the correctness of the results obtained; testing this version on real examples, and, finally, developing recommendations for implementing the results in practice.

The following results were obtained.

- A method of decision making was suggested based on situational parameters and including a stage in which the solution to the problem was selected. This is a multi-stage matrix with a fuzzy calculation in the form of an expert system. This system allows factoring in a fuzzy or incomplete knowledge of the situation and subjective preferences of the decision maker. The process chooses the most preferable method for a given situation.
- The method developed was based on a suggested set of fuzzy variable types that described a set of typified situations, which are important for choosing a method of problem solving.
- A complex of methods and models was complemented by a set of newly developed and improved methods to cover a full range of typified tasks.
- A complex of equations for transformation and quality evaluations was developed, as well as adaptation mechanisms to comply with the decision maker's preferences.
- The experimental version of the developed system was tested thoroughly, both in simulated conditions and real life situations, and demonstrated the functionality expected.

The theoretical importance of the research includes the following:

- developing a methodology for creating an expert decision support system for product lifecycle management that helps formalize the representation of management processes;
- suggesting an enhanced system of models and methods that covers all typical product lifecycle management tasks and complements the instrumentality of the situation analysis and the development of optimal solutions;
- suggesting principles for the interactive transformation of fuzzy and incomplete knowledge about problematic situations; these are based

on fuzzy data processing and self-adaptation to real applications that develop methods and facilities for knowledge accumulation.

The practical importance of the research can be summarized as follows:

- the development of a fuzzy matrix, an expert decision support system for product lifecycle management that increases solution feasibility and effectiveness;
- the provision of practical recommendations for implementing such systems in small industrial enterprises;
- the implementation of complex of models, methods, and techniques in the curriculum of the courses “Marketing Research”, “Methods of Decision Making”, and “Product Management”.

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The main contribution is the developing of a methodology for creating an intellectualized, interactive decision support system that can help to find the best method of solving complicated management tasks under conditions of incomplete and fuzzy information about the situation, and the presence of a subjective factor. This was done in the context of product lifecycle management.

The main practical result is the possibility of building a computerized advisor for problem solving a method choice that is based on expert knowledge, for small industrial enterprises that have limited human resources.

The contribution includes the following items.

1 A system of client-oriented product lifecycle management for small industrial enterprises was identified; the tasks to be solved were detailed on the basis of formulated stages of product lifecycle management; a classification of these tasks was suggested. This allowed the use of a wide range of mathematical and other advanced methods in this activity in order to increase its effectiveness.

2 Scientifically sound methodological principles have been suggested for developing fuzzy interactive systems for every stage of product management, pricing, promotion, and distribution. This allows the effectiveness of the functioning of “manufacturer-consumer” systems in small enterprises to be increased.

3 A general procedure of decision making for product lifecycle stages was discovered based on formulated specific features of task formulation and solving. The procedure includes goal definition, description of the marketing situation, method choice, and evaluation and task solving. This procedure is distinguished by multivariance, stage typization, and usage of computerized instrumentation. This allows the usual set of methods aimed at individual features of decision maker to be expanded and facilitates problem solving for different marketing situations by making a real problem more concrete.

4 A classification of methods and models for product lifecycle management has been suggested that considers a specific pattern for their us-

age in small industrial enterprises. Based on this, a set of logical, fuzzy logical variables and possible value sets was introduced. This presented the possibility to define the situation parameters that are important for choosing a problem solving method and, via determination of compliance between these parameter sets, to solve the task of defining the preferability of using every method in real situations. Even incomplete and fuzzy information is fully used to make maximally informed decisions.

5 A complex of methods and models was collected and amplified with new elements:

- a method of developing a qualitative model for new product sales forecast based on the consequent use of complex of models;
- a model for choosing strategic areas of business based on neural networks;
- a formula for the evaluation of consumer segment perspectives when developing a new product;
- a dynamic programming model for the most efficient market coverage with complementary goods. This program expands the possibilities of product lifecycle management under conditions of incomplete knowledge of a situation and the absence of a quantitative model.

6 A problem of method selection was formulated, i.e. a definition of the correspondence between the method parameters and the situation parameters (logical, fuzzy logical and sets of possibilities). The result was the preferability of usage for each method. This allowed the validity of decisions in a manufacturer-consumer system to be increased by the maximal usage of incomplete and fuzzy information.

7 Formulae for the knowledge transformation of the expert systems were developed for matrix rule presentations that are compact and convenient for experts to deal with - as regards the fuzziness and incompleteness of knowledge about the situation and the initial estimates of the decision maker.

8 A system of quality estimators of expert system functioning quality was suggested. It includes:

- a quality estimator for the whole system, which functions in the form of weighted partial indexes, and allows the priorities of the chosen product policies to be considered;
- each matrix has correctness and usefulness estimators that help to check and expertly correct the introduced rule parameters. This significantly simplifies creation and debugging the expert system.

9 An algorithm and formulae for automatic adaptation were suggested that allows the system to install the individual characteristics of the decision maker, the qualifications of the staff, and the changing specifics of clients.

10 Adaptation scenarios for the developed decision support system were suggested that simplify its practical use.

1 INTRODUCTION

In this chapter, economic and organizational problems and ways to improve the efficiency of product lifecycle management are considered.

1.1 The role of product lifecycle management in small-sized manufacturing enterprises

Currently, Russia is overcoming the aftermath of the 1998/2008 economic crisis, and because it is now a member of the WTO, the role of the Russian economy in the global market is growing, and, recently, has also shown a tendency to be less dependent on the import of products. The aim of the Strategy for Innovative Development of the Russian Federation until 2020 [166] is a transition to a socially oriented, innovative model for economic development.

Among the global changes acknowledged by experts in the innovation sphere during the last decades, [237] the following can be distinguished: a decrease in the product lifecycle, including the period of new product development, due to the growth of competition; global specialization and partnerships caused by the increasing difficulties of production technologies; the interdisciplinary character of innovative activity and the need for various competences leading to development of cooperation on different levels; development of knowledge and technology transmitting channels including knowledge transfer on a personal level, which raises the skill requirements for employees; the growing role of social innovations.

In order to overcome problems caused by the dynamics of the global economy and to provide consistent innovation development, the Strategy for Innovative Development of the Russian Federation until 2020offers a number of large-scale lines of development based on the joint efforts of business, science, and the state. The role of the state is expressed not just in the subsidization of those organizations following the path of innovation, but also in the reinforcing of the requirements for ecological compatibility, energy, and the source content of the production. Nevertheless, it is important to keep in mind that the development of products that meet market requirements plays a significant role in ensuring the competitive capacity of domestic goods. The role of Russian businesses can be increased by the use of principles, methods of marketing, and marketing research.

Small and medium-sized enterprises play an important role in innovation processes in different countries due to their flexibility and ability to easily introduce new processes and products. According to the data from the beginning of 2013 [141], the share of small and medium-sized enterprises in the Russian GDP is about 20%, while in EU countries, the USA and China this index is above 50%. It is estimated that the share of small enterprises in Russia will reach 50% by 2020. Currently, trade prevails among the activities of the small businesses and accounts for about 50%, whereas manufacturing activities comprise about 25% (according to the data [141] from 1.01.2013, with a reference to the Russian Federal State Statistics Service). Hence, the evidence from this data suggests the importance of support and development for small businesses [128], as they are an important reserve of innovative development for the country.

The particular problems and risks for small businesses, which are caused by the limited number of resources in organizations of this type, are noted in [16]. Among these risks are the low stability of their market position, frequent dependence on large companies, including the excess of caution exerted by large companies as regards entering into agreements with small organizations; and finally staffing problems.

According to the results of the regular polls, the main problems limiting the development of small manufacturing enterprises, in the opinion of executives [298], are the following (in descending order): heavy taxation (was mentioned by 53% of the executives); demand (44%), lack of financial resources (34%), high commercial crediting rate (28%) and lack of qualified personnel (22%). While the first and partly the third reason can be overcome by state measures, the others are mostly internal reasons. Thus, the main reason for the demand problem is the inadequate quality of the output goods and their inability to meet the market requirements. The fifth reason touches upon the different categories of employees. There are highly-qualified workers and specialists, including marketing experts, however, despite the large number of economic graduates, it not only takes deep knowledge but also extensive practical experience to acquire a qualification that ensures successful activity on the modern competitive market. Small enterprises cannot always afford to hire such specialist. In contrast to the large-scale enterprises, which have marketing departments and services, in small enterprises there is often only one specialist who can hardly achieve a high level of experience due to a lack of cooperative working conditions and skill sharing.

Thus, there is a need for rationalization in the marketing activity of the enterprises under consideration. This fact is also mentioned in the study [172], which addresses the problem of improving the marketing activities of small and medium-sized enterprises.

This type of rationalization offers a wide range of directions. However, in conditions of a dynamically developing market economy the correspondence between the product, the customers' requirements, and manufacturability take on special significance, therefore the opinion expressed in [135] is still relevant.

Modern Russian consumers are currently at a transitional stage from the deficit and low quality of the closed domestic market to a wide variety of goods of different quality and prices. Both extremes have disadvantages. The wide range of choice, according to some scholars, [249], leads to a decrease in customer satisfaction, as they believe that they have not chosen the best product. Thus, the market situation is currently not stable, and customers' needs are still not fully satisfied.

Many Russian manufacturers still cannot satisfy the increased demand of the consumer market. After joining the WTO, the growing presence of foreign products on the market has only worsens the situation. Previous experience [243] shows that government assistance does not solve the incipient problems, and, therefore, the path of development is in the hands of the organizations themselves.

The need to consider manufacturers and consumers as a system is determined by the growing relationship between them through modern information technologies. Questionnaires and observations of consumers' behavior within traditional marketing research are no longer sufficient. It is a question of telecommunication market research [282] implicating customer feedback and a dialog between manufacturers and consumers, as well as between customers and sellers.

There is a common opinion that the marketing approach, as a study of a "manufacturer-consumer" system, began to be researched by Russian scholars during the transition period from socialism to capitalism. During Soviet times, there was a requirement to meet the consumers' needs set by the National State Standard for fast moving consumer goods. Unfortunately, there were no real mechanisms for checking that this requirement had been fulfilled. Therefore, it became necessary to apply foreign marketing achievements in the area of product management.

Currently, there is a wide range of computer-aided instruments for product, lifecycle management support. They are united by the term PLM (Product Lifecycle Management). Another widely used concept is CALS, formerly known as Computer-Aided Acquisition and Logistics Support. Now it stands for Computer-Aided Acquisition and Lifecycle Support [102]. Even though these concepts declare the need for a customer feedback option to be included, this function (if implemented at all) merely supports the relationship with customers, data standardization, and processing management.

Thus, currently there is no integrated methodological support for the relationship between manufacturers and consumers in the cycle, which would include: marketing research - formation of product requirements - manufacturing – modification, with a consideration of the consumers' opinion – phasing out. Moreover, this is a complex aspect of the organization marketing activity which includes a wide range of different tasks.

The variety of the solving tasks at each stage determines an even greater variety of applied tools. Moreover, even within one particular task there is a wide range of methods and models used for its solution. The generalized list of the latter is discussed in [208], [216]. Firstly, the methods of the behavioral sciences, e.g. psychology and sociology, are used. Secondly, different, and sometimes quite complicated mathematical methods adjusted for research in the "manufacturer-consumer" system are applied. Among these are factor analysis, methods of ratio measurement, methods of combined measurements (conjoint analysis), multidimensional scaling, and structural equation methods [209]. Thirdly, methods of artificial intelligence are rapidly being developed. The separation of these methods into individual group is justified in [195], [196]. Finally, non-formalizable, creative, and expert methods are used [247]. All of the above-mentioned methods require the professional skill of the user to be applied. The result is determined not just by the complexity of the methods per se, but also by the most important stage – the choice of the method that fits the current task [198].

In theory, a particular method is usually described, and then its applications are illustrated by examples. In practice, the situation is often the opposite: there is real situation that requires an administrative decision to be taken, and there is a need for the selection of a correct method in order to elaborate the decision.

It is evident that for almost every task there is a wide range of methods and even approaches that can be applied with more or less optimum result being gained by making more or less effort. For example, a new product idea may be created with the use of any of the following methods: intuitively creative methods like brainstorming [151], the Disney Brainstorming Method, the method of Six Thinking Hats [52] etc.; the use of logic systematic methods such as customer survey about qualities and characteristics of a product [135], methods based on a morphological approach [232] (morphological box, method of "negation and construction"). There are descriptions of the successful use of each of them and they can be applied in any real situation.

Among the criteria for the applicability of different methods, there is certainly a subjective element in the form of personal preferences and professional qualities of the person applying them.

Finally, there is almost always a lack of information about a particular situation, it can even be unclear what kind of information is required in order to select a decision making method. When the method is chosen, the situation is clarified to some extent, as the application of particular methods is well described in literature.

Hence, the choice of the administrative decision making method in the "manufacturer-consumer" system is an especially complex task. It has the following features:

- weakness of structure [275];
- lack of full information about the situation;
- often – a lack of clarity concerning the required information;
- the non-uniqueness of the solution;
- different degrees of complexity and effectiveness of the method's application;
- dynamism of the research object: consumer, manufacturer and their relationships;
- influence of subjective factors.

A specifically Russian problem in this area is also the lack of professionals with the necessary qualifications, who are not just graduates with a deep knowledge of the subject, but employees with broad practical experience. Moreover, the above-mentioned types of tasks appear in almost every domestic company dealing with the development and manufacturing of products. Therefore, it is necessary to formulate a generalization and systematization of the research and the decision making methods, and adapt them to modern Russian conditions. It is mostly true that small and medium-sized enterprises have neither a large marketing department, nor the means to finance product research and development.

Thus, the task is to elaborate a mechanism that is capable of ranking decision making methods in the "manufacturer-consumer" system with the help of the characteristics of the situation and the individuals' preferences on the basis of an evaluation of the preferred use of a particular method in a particular situation.

The complexity of the task requires the marketing specialist to have good qualifications and a considerable range of skills (and therefore necessitates a high salary). Unfortunately, small enterprises cannot afford such experts. This research proposes the use of artificial intelligence as a solution for this problem. Artificial Intelligence makes it possible to use the most effective methods for solving current tasks, and therefore improves the effectiveness of a company's marketing activity. In addition, not only does it improve the competitive posture in the market of a particular company, but also raises the competitive capacity of Russia in the global market.

It is evident from the above that the object of the research is a client-oriented product lifecycle management process, i.e. the development of an intelligent system that allows the effective use, in practice, of methods and models for client-oriented product lifecycle management.

The aim of the research is to improve the efficiency of product lifecycle management. To achieve this aim it was necessary to solve the following scientific problem: the elaboration of a theoretical basis of methodology for future use in computerized and client-orientated product lifecycle management.

1.2 Nature and content of a product and its lifecycle management at the present stage

1.2.1 The product and its lifecycle management

Marketing is defined by many scholars as both a theoretical [282] and a practical [135] phenomenon. In the current research marketing is understood as a special kind of human activity (following the authors [111], [265]), within which decisions are made which are not only aimed at solving consumers' problems but are also beneficial for the company [307], [45]. In a broader understanding it is more appropriate to talk about customers, therefore, in this research the term "customer", following [233], will indicate a legal entity or an individual obtaining goods from a company; thus, covering both consumers and dealers.

The activity of the small industrial enterprises under consideration should be based on the important principle of customer orientation [233]. A meaningful goal for a profit organization is to build customer loyalty, which will not only ensure sales, but will also lower marketing costs. This is because customer retention is cheaper than customer acquisition. As mentioned in [233], this is the reason why, at the present time, marketing has become the main controlling function in the activities of organizations.

It is well known [135] that the main success factor for an organization is a good product. Mostly, the role of a good product development is visible in such concepts as holistic marketing, competitive marketing [187], and virtual marketing [268].

Over all, this has defined the main subject-matter of the scientific research.

An economic product [231] is the result of human economic activity in the form of

- a tangible product (goods);
- intellectual property;
- work executed and services provided.

By the term "product management" scholars [149] understand any activity of a product manager that is related to the marketing-mix: product, prices, promotion, distribution, and, inevitably, additional components, if they are required due to product specifications (such as packaging, physical evidence etc.).

However, due to the fact that

- a product as a component of the marketing-mix has its own distinctive characteristics, which are interesting as objects of the research methods,

- other components of the marketing-mix (price and promotion) are widely discussed in both scientific and academic literature,

the current research attempts to bring product management into correlation with a product as a component of the marketing-mix. Hence, the management object is a set of products, produced by a company, i.e. product range, as well as the content, quantity of each item, and the structure of the relationship between them. The development of new items and the phasing out of other items are also taken into consideration.

According to the level of originality, all products can be divided (on the basis of [135], [149]) into the following groups:

1 New products that do not have analogues.

2 Products that are characterized by a principal change in consumer properties, e.g., the addition of new functions, a new practical use, or a new operating principle.

3 Products that have insignificant changes for the consumer or in the technological properties, such as a new design, the reduction of costs, or an improvement in particular consumer properties.

4 Products that have kept their consumer properties while their attributes, packaging or brand were changed.

The mastering of level 3 and 4 products does not usually require much effort and can be limited to product modification and/or production technology. However, the development, introduction, production, and selling of level 1 and 2 products requires the execution of various tasks, such as research and the exploration of ideas to popularize the new product. Creation of type 1 and 2 products incurs the development of new items, while types 3 and 4 are modifications of an existing product. In a number of studies [98], modification is not considered as a stage of product development. In [135] modification is mentioned in the growth and maturity stage, but is not singled out as a separate stage. In [149] modification is considered as a special kind of activity, it is also mentioned in this study that it is practically a continuous process.

The term product modification in this study will be understood as the development of a product with a low originality level, which has been modified using, e.g., new packaging, a new brand name, or new technological properties or materials. In contrast, the development of a new product means either a principal change in the consumer properties and the fabrication method or the creation of a product that has no analogues.

Based on the above, the need for taking the product lifecycle into consideration becomes evident. During its development the product passes through several stages that are characterized by particular duration and transition terms, which depend on the product's distinctive characteristics. It is appropriate to use various standard methods of research and management for each stage [58]. This concept can generally be effectively used.

In this research, we will use system and cybernetic approaches to describe and analyze the management systems in the area under consideration. The cybernetic approach has been researched in [27], [59] and other studies.

The principles of the cybernetic approach are the following:

- The principle of requisite variety means that the complexity of the control mechanism in a system must match the complexity of the controlled system. This can be achieved either through big marketing, analytical, planning departments, or by the implementation of an intellectual administration system that allows the control of such objects as client behavior
- The principle of emergence (the larger the system the greater the differences in size between a part and the whole, and thus the higher the probability that the qualities of the whole can differ from the qualities of the parts) is expressed through the difference in the functions that the company employees carry out. Thus, for the beneficial selling of goods decisions are required in several areas; economics, management, marketing, and marketing research. All these areas require different competences. Computer support exists within product lifecycle management for all these different kinds of competencies.
- The principle of external complementarity or the availability of reserves to compensate for the influence of unaccounted external (client reaction) and internal (personnel psychology, difference in qualification) factors.
- The principle of feedback provides a measurement for the correction of any practically achieved state, as long as it allows the system to self-adjust and adapt to features in the internal and external environment.

- The principle of solution selection must take into account the fact that there is often more than one solution, and that different solutions have different objective and subjective preferentiality.
- The principle of decomposition is used to single out relatively independent subsystems from the company's operation systems, particularly from the marketing subsystem. Thus, in this study, product lifecycle management and its stages are singled out.
- The principle of the hierarchy of management is seen as setting a particular level of organizational consideration as regards the division of strategic, tactical decisions, and company scheduling. In addition, the activity of product lifecycle management is divided into subtasks.

On the basis of the above, Figure 1-1 illustrates the activities involved in customer-oriented product lifecycle management

Figure 1-1 illustrates the information flows (thin arrows) in the "manufacturer-consumer" system, as well as the functions of the company departments working with customers and products. The figure represents the informational aspect of management and therefore the movement of the product from development to disposal is not shown. Furthermore, as long as a product has a set of consumer properties, when it is handed over to a customer the information about its quality is also transferred (thin arrow). Other forms of information include the results of marketing research, plans for company development, orders, and instructions.

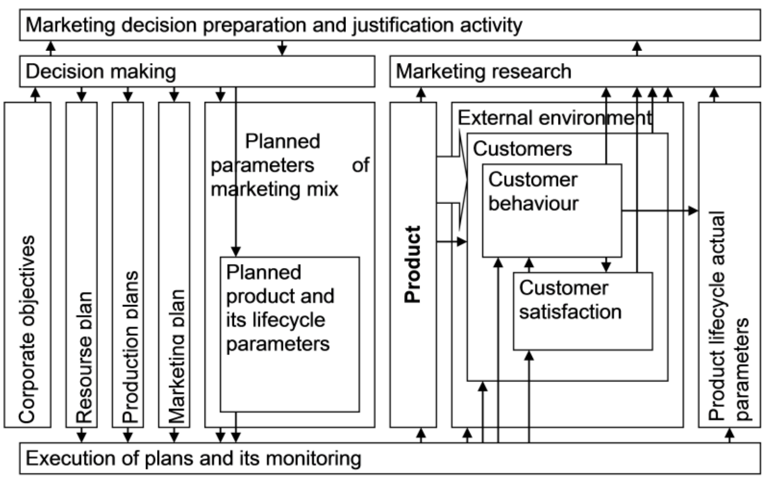

Figure 1-1 Customer-oriented product lifecycle management

The technological aspects are included in the production process, because the focus of the research is on interactions between manufacturers and consumers, and not on the inner production elements.

The literature shows a variety of approaches to the notion of corporate objectives. Scholars mention profit earning and ensuring customer loyalty etc. In [307] the author mentions a “triangle of objectives”, i.e. an interrelation between business, corporate, and functional objectives. The author in [271] discusses the principal need for a use of several criteria to form a final objective function. This approach is based on the possibility of obtaining opposite indexes, such as those that provide both long-term and short-term benefits. Due to the inconsistency of the requirements a compromise in the form of multicriteriality has to be reached.

The general objective is divided, according to the levels, into the aims of the functional departments.

This research only focuses on marketing activity. Its main objective is to fully adopt the market opportunities suggested by [125]. Therefore, the criteria for reaching the corporate objectives may include, e.g. profitability, market management (choice of clients in particular), and customer satisfaction [125]. The priority of the criteria used may vary depending on the situation. For example, in some stages profitability is sacrificed to market penetration.

Marketing activity is conducted through preparation and justification of administrative decisions. It results in drafts of orders, instructions, plans, and programs for marketing efforts, as well as instructions and recommendations for employees designing the programs.

Several publications, e.g. [85], offer the idea that most employees should be involved in conduct marketing activity. Nevertheless, even these scholars would agree that marketing is a special kind of activity, and, in the current conditions, it will probably still only be carried out by professionals for a considerable time to come.

Marketing administration requires information about both the external (shown in Figure 1-1) and internal (not shown) environment. This information is an important source of feedback, which provides data about the results achieved, the current state of the administration system elements, as well as information about the company environment.

This type of information is presented in the form of reports created using of information systems: marketing research reports, interim reports, including office memos, internal documents, and oral reports. Therefore, according to a cybernetic approach the administration system traditionally includes the following: an aim, a control system, control elements, disturbances and their measurement, feedback.

The product takes a special place among the elements of the marketing-mix (product, price, promotion etc.) due to its significance and need for further detailed analysis.

Customers are characterized by their satisfaction (internal characteristic) and by their behavior (external characteristic). Both characteristics are interrelated and affect each other within customer's activity, and both are affected by marketing efforts: advertisement, personal sale etc.

Product lifecycle management has a dual character. On the one hand, it is determined by the behavior of customers purchasing more or less goods. Therefore, the duration of a boost of sale stage can only be affected/influenced by customers. However, on the other hand, particular stages, e.g. the modification or phasing out stages, are initiated by the administration on the basis of justifications provided by marketing departments.

Thus, product management is the part of marketing management that deals with a product as an element of the marketing-mix.

The aim of management is to fully use the market opportunities of a company. The object of management are the details of the product lifecycle, e.g. the transition time.

The agents of management are:

- the marketing departments that prepare the decisions;
- the administration that make the decisions;
- the executive departments of a company.

The product's distinguishing features including the mental elements (expectations and attitudes) represent the controllable variables. As a result, customer behavior is formed and it determines the stages of the product's lifecycle. In particular cases, moments of transition can be set by the administration as can the controlled variables.

Feedback is provided by the research into the company's environment.

The problematic factors are the economic, competitive, and customer parameters, the company's internal environment, and the state of the resources supply.

Without doubt a strong role is played by the subjective and objective human element in management.

1.2.2 Content of product management activity

This issue was discussed in [198].

Product management is a heterogeneous complex activity related to other types of activity in a company. In order to successfully develop a product, release it onto the market, and realize a profit, coordinated guidance is required for the marketing processes; these include: the economic, constructional, technological, organizational, social, and informational processes. Studying each of the above-mentioned groups of processes constitutes a separate complicated task. Product management has to be carried out during all stages of a product's lifecycle: from its development to its phasing out.

In this sense, product management has an important feature – it is related differently to the other activities within the organization. Firstly, there are activities that can be considered product management, e.g. searching for ideas for a new product, and test marketing.

Secondly, there are activities closely associated with product management, but also include other activities, e.g. product modification. Apart from the marketing objectives (e.g. choice of modified parameters and their new values, promotional support) the non-marketing objectives can also be reached (e.g. converting of a manufacturing process). Thirdly, product management can be weakly connected to such kinds of activities as new product development. This is usually carried out by the design department, whereas any general innovation management is carried out by the company administration. In addition, marketing departments can coordinate activities carried out by other departments, although this feature requires further analysis of marketing functions.

There is a broad list of departments working in collaboration on product management. This list is based on the data provided in [149] with some corrections and additions, which are determined by both domestic specifics and differences in the approach to the notion of product management. The list includes:

- marketing departments: advertisement, sales promotion, marketing research departments;
- sales and distribution departments;
- departments working with business partners, e.g. advertising agencies;
- economic, financial and planning departments;
- design and technological departments;
- manufacturing departments etc.

An important task of the study is an elaboration of a general scheme of product management as a sequence of phases and stages, which are adjustable to a particular situation using elimination or change of order elements, as well as the possibility to return to previous steps. The same approach has already been applied in a wide range of standards and regulations, e.g. in [99]. Despite the absence of a joint sequence for all situations, this scheme will certainly be useful for better orientation in product management and for the systematization of the methods used at different stages of the process.

The scheme is to be based on the following concepts:

1 The product lifecycle according to the sales and profit volume. The stages of product management are typically separated based on the sales volume and, sometimes, the profit margin [307], [135]: introduction of the product (its release onto the market), growth, maturity, and decline. This approach allows the marketing efforts to be well-coordinated. For instance, it is advisable for the product modification to be performed at the growth stage, while product development and introduction normally start at the maturity stage. However, in this scheme the innovation process is not sufficiently considered.

2 Marketing management. The most widely used product management scheme is described in [135]. It is based on a sequence of implementations of the management functions as regards the organization, and includes the following stages: research; development targeting; creation of novel product concepts; idea selection; embodying the idea; supervision. In this scheme, idea development takes the central role, while little attention is given to the production and organizational elements of product management.

3 Product lifecycle according to the National State Standard [98]. This approach sets out 10 stages of the (physical) product lifecycle: research; development; design preproduction; technological preproduction; organizational preproduction; pilot production of a newly-designed product; launching of a product; manufacture and sales of the product; product usage; disposal. In this sequence, the marketing efforts are missing and such important elements of product management as product modification and elimination are not addressed.

4 Unified system for design documentation. The National State Standard for a unified system of engineering drawings [55] determines the following stages for the design documentation: development of requirement specifications, draft proposal, draft design, engineering design, documentation on prototyping, documentation on serial or mass production. This standard does not fully consider the product lifecycle; in particular, it does not include an analysis of the sources of the novel product idea.

5 Intellectual product development methodologies; software development is used as an example.

The possibility of formalizing the intellectual product development is different for different kinds of products. For example, in some cases, such as in the creation of a novel idea, creativity takes the leading role. This is why the creative component must be taken into consideration in the scheme of product development. On the other hand, development of other types of intellectual products, e.g. computer programs and databases, often follow a highly formalized process, which requires a wide range of methodologies, as suggested in [195]. The role of creativity in this case is not important. In [99] the development of software is considered as a unit, addressing a particular aspect of software management. Therefore, software is characterized by a set of specific stages, e.g. software maintenance.

The drawbacks of the above-mentioned lifecycle scheme may be eliminated by a new sequence of product management stages that use a more general approach.

The scheme below takes into account modern marketing tendencies.

1 The initial phase of product management is a capability check of the product development. It is the result of the following stages:

1.1 External environment research: condition and prognosis of the technical and technological development level, market conditions, the standard of well-being of the population, legislation. Nowadays, most consumers needs have already been satisfied [308], therefore a product and its demand develop simultaneously. This process is called holistic marketing [135], [218]. According to this approach sources of a novel product idea are to be found in the external environment.

1.2 Internal environment research: the present condition of the employees' qualifications and a future prognosis, the resources procured the organizational objectives. Due to the growing complexity of modern technologies and their impact on economics, the internal capabilities of the organization become simultaneously an important source of novel product ideas and a limiting factor.

1.3 Consumer research: the present condition and a prognosis of future needs. In the modern stage of this activity there has been considerable change. The computerization of marketing activity has lead, among other consequences, to observation methods, such as the collection and analysis of search engines inquiries [307], [308], [80], as well as market monitoring [31], [44]) becoming the main instrument of marketing research. This has helped to identify consumers' needs more accurately than using traditional marketing research techniques such as surveys, because the latter almost unavoidably cause data errors.

2 The following phase is the developing of a novel product idea, which is the essence of innovation. This process traditionally follows the following scheme:

2.1 Generation of alternative ideas.

2.2 Evaluation of an alternative idea on the basis of the amount of resources needed and the effect gained. This is followed by decision-making.

3 This phase of research may be required in order to evaluate the practical product marketability phase. Due to its growing role, technology can become another direction for the research.

The reason for the inclusion of the research phase before the idea generation is justified by the following:

- The idea generation only takes into account general information about existing inventions. The research results may indicate that licensing or a patent purchase is required in order to use a particular piece of intellectual property when developing a chosen alternative of a novel product;
- Quite often the research has practical or an experimental character and deals with search for a solution of a particular problem determined by the chosen product idea.

In this phase product management consists of the following stages:

3.1 Determination of the research procedure.

3.2 Setting the requirements for the principle used in the product operation.

3.3 Setting the requirements for the product fabrication method.

4 When the need for a novel product and its marketability has been justified, a concept of the product is created in a form that is understandable to the consumers [308].

The concept definitions include:

- who will use the novel product
- in what situations it will be used
- what the consumers' benefit from using the product;
- how to attract customers.

The concept development has similar features to the idea development.

4.1 Generation of alternative concepts.

4.2 Evaluation of the alternatives followed by decision-making.

Concept evaluation requires the use of special methods such as test marketing on model markets [46], which consists of surveying potential customers who have already been introduced to the novel product concept.

5 During the phase of design and development work, the characteristics of the novel product and its production technology are determined.

The phase is divided into the following stages (one should keep in mind that we are talking about activities conducted by the marketing departments of a company, rather than by the construction and technological departments).

5.1 Determination of the characteristics of a novel product: its functional characteristics, size, weight, design, estimated production price etc.

5.2 Determination of the characteristics of the production technology: production volume, estimated level of costs etc.

6 The pilot production includes its preparation, the production per se and the analysis of the results.

6.1 The role of the marketing department is visible at the stage of the pilot production development. They determine the time and procedure of the production, find suppliers, and decide what to do with the output goods.

6.2 Test marketing is often conducted in this phase [46], [45], product samples are introduced and distributed among customers. Test marketing is conducted in a limited market (one shop, one city, etc.) in order to determine sales volumes, possible improvements of the product, and to acquire basic data the for development of further marketing efforts. This phase also includes product prototype testing, when customers express their opinion as regards their experience with a trial product.

7 The next phase is the management of the income-generating commercial production. Time frames and procedure are developed in this phase.

8 Product Sales. This is the main objective of the marketing activity of a company. Decisions about the content of the marketing-mix are elaborated: price formation, promotion, distribution, personnel training, physical evidence, and other components, if they are required due to the type of product.

Although this activity should be carried out throughout the process of product management (e.g. public relations), and particularly for novel products it should start after the novel product concept development (with advertisements such as "Coming soon…"), it is included in this sequence in a post-production phase for the following reason. Many of the marketing parameters of a novel product (such as price, quality, rules of transportation etc.) are created after the successful management of the commercial production has been attained.

A traditional decision-making scheme for the components of the marketing-mix is

8.1 Choosing the components to be developed in the marketing-mix.

8.2 Generating alternative components.

8.3 Evaluation of the alternative components and decision-making.

8.4 Coordination of partial solutions.

9 Product modification. Modification is the development of a product with a low level of novelty, and generally starts with new packaging or brand image, and ends with change of materials, production technologies, and particular product specifications. Modification methods differ from those used for the development of a novel product. For instance, CRM (Customer Relationship Management) is a database, which includes customers' individual characteristics; in particular, customer needs [109]. It is well known [23] that when interviewed customers rarely present ideas that can be used for the development of a novel product. Nevertheless, although novel ideas require creative activity, a CRM analysis is useful for product modification.

Modification often takes place at the growth stage and its purpose is to prolong this stage of the product lifecycle. Decisions about modifications are usually a one-step decision concerning the use of new material, a new design etc. This is why the phase follows the traditional decision-making scheme: generation of alternatives, evaluation of the alternatives; decision-making.

10 Product elimination is a separate kind of activity. It requires making a decision that affects not only customers, but also all the other immediate relationships of the company, from distributors to competitors.

11 Other kinds of activities that can be considered as marketing include: establishing of product support, conducting of marketing research, production planning on the basis of demand forecasts etc. Other activi-

ties can be referred to as an extension of operational decision making consisting of the following stages:

11.1 Detection of problems.

11.2 Preparation for decisions and decision-making.

The distinguishing features of the task types in product lifecycle management ?????

Each stage of product lifecycle management has a set of tasks. Although they are interrelated, the main groups can be identified on the basis of their content.

- The "Management" (MG) group includes administrative tasks: planning of work packages, execution of decisions, and the organizational aspects of the activity under consideration.
- The "Economics" (E) group includes economic tasks, mainly the justification of proposed decisions.
- The "Marketing" (MK) group includes marketing tasks such as development of decisions and decision-making.
- The "Research" (R) group consists of marketing research tasks dealing with the reception of the initial data for decision-making.

The list below includes the phases of marketing product management (first number), the stage of each phase (second number) and the group of tasks (letter). The key feature of this classification is that the main accent is placed on problematic tasks, which presents difficulties in their accomplishment. For instance, a set of methods has already been developed that can be used at the stage of environment research; their procedure is depicted in detail. The fundamental problem is choosing the most suitable method at any stage. For example, the forecast method is not practical during a period of seismic qualitative changes caused by the introduction of new computer technologies; in such a case expert methods are more applicable. Accordingly, the task of method selection, which means conducting the appropriate research and analysis of its result, is the reason why the MG group consists of decision-making tasks, while group E includes tasks such as the cost estimation of each type of work. The list of generalized tasks is justified using the same reasons.

The suggested classification of management tasks according to the various stages and their content is as follows:

1 Identification of Product Development Capability.

1.1 Research of external environment.

1.1.MG. Identification of the important external environment factors necessary for decision-making.

1.1.E. Identification of the economic parameters of the external environment that need to be analyzed.

1.1.MK. Identification of the marketing parameters of the existing strategic management areas (SMA).

1.1.R. Identification of the methods for monitoring the external environment indexes.

1.2 Research concerning the internal environment.

1.2. MG. Identification of the important internal environment factors necessary for decision-making. Choice of strategic management areas on the basis of the internal and external situation evaluation. Making decisions on the preservation of existing strategic management areas; their elimination and or the need for generating new ones. Selection of new strategic management areas that provide a balance as regards the company's opportunities and market needs.

1.2. E. Identification of the economic indexes in the internal environment that need to be analyzed. Identification of a model of the internal environment that corresponds to the tasks. Identification of desirable and possible range of indexes (costs, sales, profits, effectiveness etc.)

1.2. MK. Identification of a list of internal environment marketing indexes for analysis and an identification of their value. Evaluation of the appeal of the existing strategic management areas. Development or adjustment of product strategy. Generation of alternative strategic management areas and their evaluation.

1.2.R. Identification of the monitoring methods and research for the internal environment indexes.

1.3 Consumer research: identification of consumers' preferences and behavior.

1.3. MG. Selection of the target segment.

1.3. E. Identification of the economic factors affecting customer behavior.

1.3.MK. Identification of a customer behavior model for strategic management areas.

1.3.R. Identification of a research method for motivation and other mental factors. *A priori* segmentation. Evaluation of the appeal of the segments.

2 Development of Novel Product Ideas.

2.1 Generating Novel Product Ideas

2.1.MG. Obtaining a set of ideas for selection.

2.1.MK. Identification of methods for idea generation. Generations of alternatives for the novel product ideas.

2.1.R. Specification of target segment characteristics.

2.2 Evaluation of the alternatives and idea selections for further work.

2.2.MG. Decision-making about novel product ideas (usually there is a wide range of ideas made available for development [135]).

2.2.E. Calculation of the range of the production capacity, primarily the cost and price of the product, which provide target indexes for the company's activities as regards the implementation of each idea.

2.2.MK. Justification of the selection of a novel product for development and the choice of the idea from which to create the product.

2.2.R. Forecast concerning the development of relationships with business partners.

3 Conduct of research on product development (due to practical constraints, this paper cannot provide a comprehensive review of improvements to the marketing methods).

3.1 Selection of researchers and the planning of the research for the novel product development - in order to provide the results within the time and cost limits.

3.1.MG. Selection of researchers

3.1.R. Obtaining information about the researchers.

3.1.E. Derivation of estimates of the labor-intensiveness of the design. Calculations of the amount, time frame, and costs of the research work. Calculations of the work costs involved and their monitoring. The possibility of long-term work with each potential researcher etc.

3.1.MK. Search for potential researchers and their evaluation.

3.2 Setting of requirements for the results of the research on a novel product.

3.2.MG. Research management.

3.2.E. Assessment of the risks of obtaining negative research results.

3.2.MK. Development of a research task, taking part in the acceptance of the result.

3.2.R. Primary data acquisition for risk assessment.

3.3 Setting the requirements for the method of product fabrication.

3.3.MG. Technological research management.

3.3.E. Assessment of risks for obtaining negative technological research results.

3.3.MK. Development of a technological research task, and participation in the acceptance of the result.

3.3.R. Primary data acquisition for the risk assessment.

4 Product Concept Development.

4.1 Generation of alternative concepts

4.1.MK. Identification of methods for the generation of alternatives. Development of alternative concepts.

4.2 Evaluation of the alternatives and decision-making about the concept.

4.2.MG. Decision-making about the concept of the novel product and a method for positioning it on the market.

4.2.E. Cost-estimating for the concept positioning.

4.2.MK. Identification of the models concerning the perceptions of the novelty by the customers and consumers, and their evaluation of the concept. Identification of the means of concept positioning. Identification of the elements of the concept of the marketing mix, and the objectives of each component.

4.2.R. Identification of the models concerning the perceptions of customers and consumers.

5 Design and Development Work.

5.1 Specifications of the product characteristics.

5.1.MG. Management of product development activity.

5.1.E. Identification of the economic parameters of the product. Calculation of the amount, time frame, and costs of the development work. Assessment of the risks of obtaining negative results for the development.

5.1.MK. Refinement of the technical parameters of the product in collaboration with technicians.

5.1.R. Primary data acquisition for risk assessment.

5.2 Specification of characteristics of the production technology.

5.2.MG. Management of the production technology characteristics.

5.2.E. Identification of methods in the pre-design as regards the need for resources and prime cost. The pre-design need for resources and prime cost in order to identify the requirements for the technology.

5.2. MK. Refinement of the technical tasks as regards technology - in collaboration with technicians.

5.2.R. Collection of information about technologies used by competitors and advanced development.

6 Pilot Production.

6.1 Planning and implementation of pilot the production.

6.1.MG. Pilot production management.

6.1.E. Calculation of the amount of work, time, and resources required.

6.1.MK. Identification of time frames depending on the market situation. Planning of the test marketing based on the use of prototypes.

6.1.R. Refinement and forecast of the market situation.

6.2 Test Marketing: Refinement of demand and the content of the demand generation activities.

6.2.MG. Test marketing on test, regulated, and real markets.

6.2.E. Calculation of the production capacity of each period.

6.2.MK. Planning of the test marketing as an experiment. Concept evaluation of the test marketing on the test and regulated markets. Identification of the list of product variations, based on the results of the test marketing on the regulated and real markets.

6.2.R. Conducting research within the limits of the test marketing.

7 Scheduling of the management of the commercial production.

7.MG. Development of a plan for commercial preproduction.

7.E. Identification of the factors affecting the prime costs: output effect, experience effect, etc. calculation of the product's prime costs.

7.R. Evaluation of the indexes of the required parameters.

8 Product Sales. At this stage, the development of other marketing-mix components, in addition to the Product takes place.

9 Product modification.

9.1 Generating of alternative modifications for the product.

9.1.MG. Obtaining the modification alternatives for selection.

9.1.E. Identification of lines of goods that require modifications on the basis of economic parameters. Calculation of the indexes for marketing analysis.

9.1.MK. Analysis of the range of goods as a whole, according to the product line, and the analysis of each product. A posterori segmentation and pre-selection of segments. Profiling of selected segments. Selection of target segments. Development of alternatives to the modification ideas. Development of modification concepts for each alternative idea.

9.1.R. Use of the customer relationship management system for posteriori segmentation.

9.2 Evaluation of modification alternatives and the selection of an alternative.

9.2.MG. Making a decision on the product modification.

9.2.E. Identification of changes in the economic indicators of the company for each modification alternative. Identification of the amount of work, time, and cost of each modification alternative.

9.2.MK. Development of partner relationships and a competitors reaction forecasts for each modification alternative . Evaluation of each modification alternative for the product.

9.2.R. Data collection on the possible consequences of modifications.

10 Product elimination.

10.1 Generating elimination alternatives.

10.1.MG. Obtaining a set of alternatives for selection.

10.1.E. Identification of products requiring elimination based on economic indicators. Calculation of parameters for marketing analysis.

10.1.MK. Analysis of the product range as a whole by product lines, and an analysis of each product.

10.1.R. Obtaining initial data for forecasts and calculations.

10.2 Evaluation of elimination alternatives followed by decision-making.

10.2.MG. Making a decision on product elimination.

10.2.E. Identification of the amount of work, time, and cost of the action.

10.2.MK. Development of partner relationships and competitors reaction forecasts for each elimination alternative.

10.2. R. Data collection for making forecasts.

11 Elaboration of the product management operational decisions

11.1 Identification of progress deviations.

11.1.MG. Obtaining information on the need for operational decision-making.

11.1.E. Identification of the analyzable economic indicators for each area of activity and method of analysis.

11.1.MK. Identification of marketing indicators in order to monitor the situation and the methods of the analysis.

11.1.R. Monitoring of selected environmental indicators.

11.2 Development and making decisions on the operational product management.

11.2.MG. Making of an informed decision on operational management.

11.2.E. Calculation of alternatives for the consequences of each decision.

11.2.MK. Evaluation of the consequences of operational decisions for partners, competitors, and consumers. Adaptation of standard solutions to a specific task.

11.2.R. Search for standard solutions for deviation correction. Registration of a decision and its consequences for further reference.

Within the current research we will consider the tasks as the essence of marketing research, because they play a defining role in customer-oriented product lifecycle management. We will consider solution methods (found in the literature and proposed by the author) for every task, the features of their application, and the factors determining the selection of methods.

The structure of the problem of customer-oriented product lifecycle management is shown in Figure 1-2. This figure presents both the methods researched in the paper and those newly developed.

It is necessary to make some clarifications.

1 The scheme of product development is rather generalized due to the wide range of products under consideration. Development of a particular product may require some changes in the scheme, e.g. some stages may be omitted, some tasks may be reformulated, and other changes may be required.

2 The role of the strategic management areas has increased over the last few years [12]: customer value and manufacturing technology are to be considered as inseparably connected to each other.

3 The stages of product development and modification should be clearly separated. Development of a new product is either the creation of a product that has no analogues or a principal change in its consumer properties or fabrication method. On the other hand, product modification is the development of a product with a low originality level, using, e.g. new packaging or brand imaging, technological properties, or materials. Modification usually takes place during the stage of mature? growth or market saturation and its role is to prolong these stages of a product's lifecycle. Decisions about modifications are usually a one-

step decision on the use of new materials, new designs etc. Modification methods differ from the ones used for the development of a new product. Modifications are often based on the results of customers' reviews that show their needs have not been met. It is recognized [23] that customers' reviews rarely offer ideas that can be used for a novel product development as novel products require methods of creative activity.

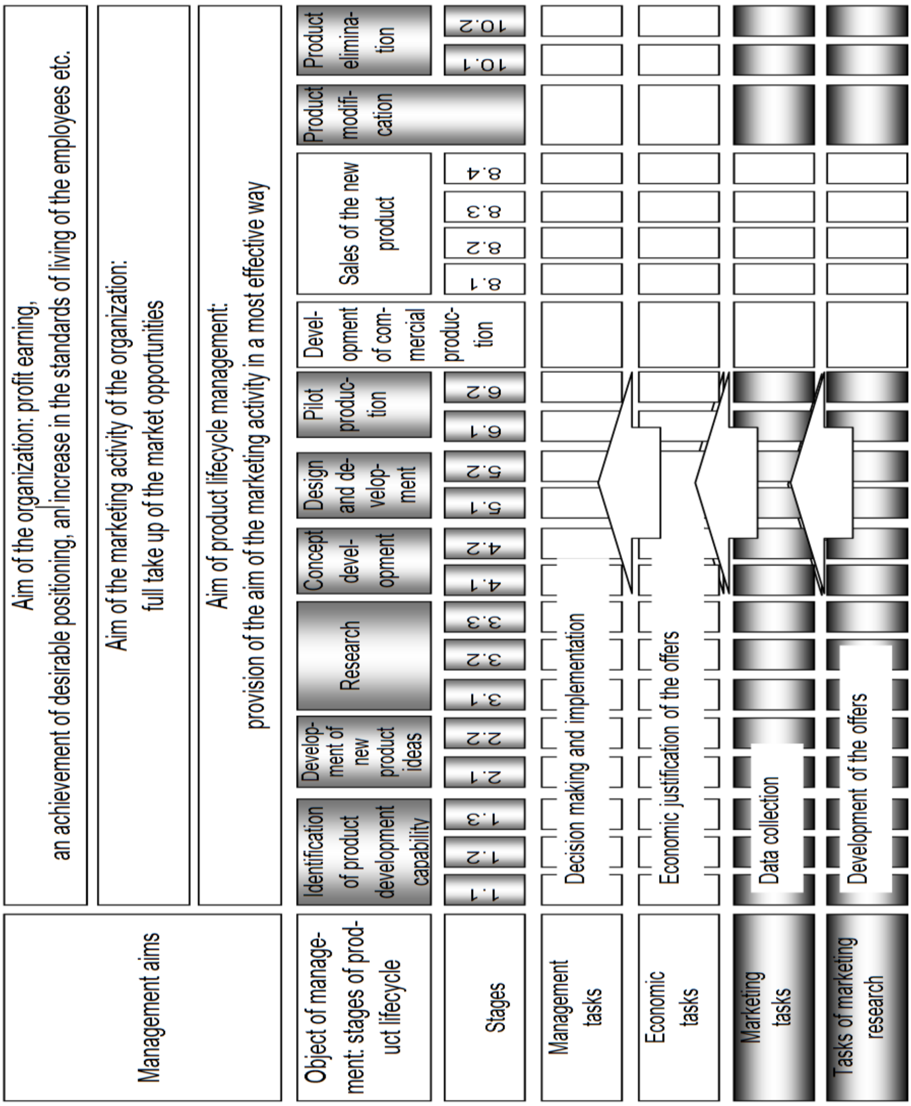

Figure 1-2 **Structure of the problem of customer-orientated product lifecycle management**

4 The role of segmentation also differs between the development and modification stages. Some authors indicate that there are 2 types of segmentation: macro segmentation (also known as a priori segmentation) and micro segmentation (a posteriori segmentation) [143], [133].

- *A priori* segmentation takes place before product development and defines a targeted category of customers: young people, women, people who watch their weight, dog owners etc. The main criteria are demographic, social, behavioral, and geographical. A new product is developed and positioned with consideration for each criterion.
- *A posteriori* segmentation is conducted at the stage of product modification based on attitudes towards the existing product, customer satisfaction, and receptivity to marketing strategies. After segmentation is complete, the segment's profiling starts, i.e. identification of important demographic, socio-economic, or behavioral features. For example, the segment of customers who are dissatisfied with the battery-life of a digital camera would mostly consist of tourists.

A considerable range of tasks are included in the term evaluation. The complexity of these types of tasks is determined by the complexity of the evaluated objects and insufficiency of the available information.

Based on the above-mentioned list, the following conclusions can be drawn.

1 The administrative decisions necessary for product management are decision-making, the management of the work, and the adaptation of standard solutions for specific tasks. In general, decision-making follows the following scheme: generation of alternatives→preference evaluation→choice. This research will only consider the stage of decision preparation: the generation of alternatives and their evaluation.

2 The economic problems involved in product management are generally limited to the choice of economic indicators for the analysis, the choice of models relevant to the task, making calculations for the economic evaluation of primary costs, price, costs for the new product design, calculation of the cost-efficiency of the decisions, etc.

Detailed analysis of these tasks is beyond the scope of the research.

3 The tasks of the groups "Marketing" and "Research" also have different aims and need to be discussed further, in detail in this research; this is due to their close relationship and their common problems.

The main types of marketing problems for product management are shown in Figure 1-3. These research results are summarized in [213].

It is evident that the tasks in the groups "Marketing" and "Research" are heterogeneous and require a set of special methods. The following equation will represent the variety of marketing tasks in product management in the research for the purposes of problem formalization.

$$\Phi=\{\phi_f\},$$

where $f=1\ldots n_\Phi$- task number, n_Φ- number the tasks.

Therefore, tasks are formulated and standardized that will be discussed in the current research.

Thus, a system of customer-oriented product lifecycle management in small-sized manufacturing enterprises has been identified, the management tasks have been detailed according to the formulated management process stages, and a standardization of these tasks offered in order to apply a wide range of mathematic methods to the activities under consideration. In addition, a human factor has been considered as regards both the objectivity and subjectivity of management.

1.3 The efficiency of computerized product lifecycle management and its promotion

There are two approaches to the definition of efficiency.

Firstly, efficiency is considered as the ratio of the result to the effect [255]. However, this approach is more applicable to either economic efficiency, or to cases with only a one-goal criterion.

Secondly, efficiency is considered as productivity, i.e. as an effect [14]. This approach is more applicable to complex cases with multiple goal criteria, i.e. in the system under consideration. An additional advantage of this approach is the possibility to grade the results and to create a results ranking, which is important for a generalized analysis, e.g. to evaluate the applicability of the methodology in solving a wide range of real tasks, in contrast to the justification of an economic decisions in a particular situation.

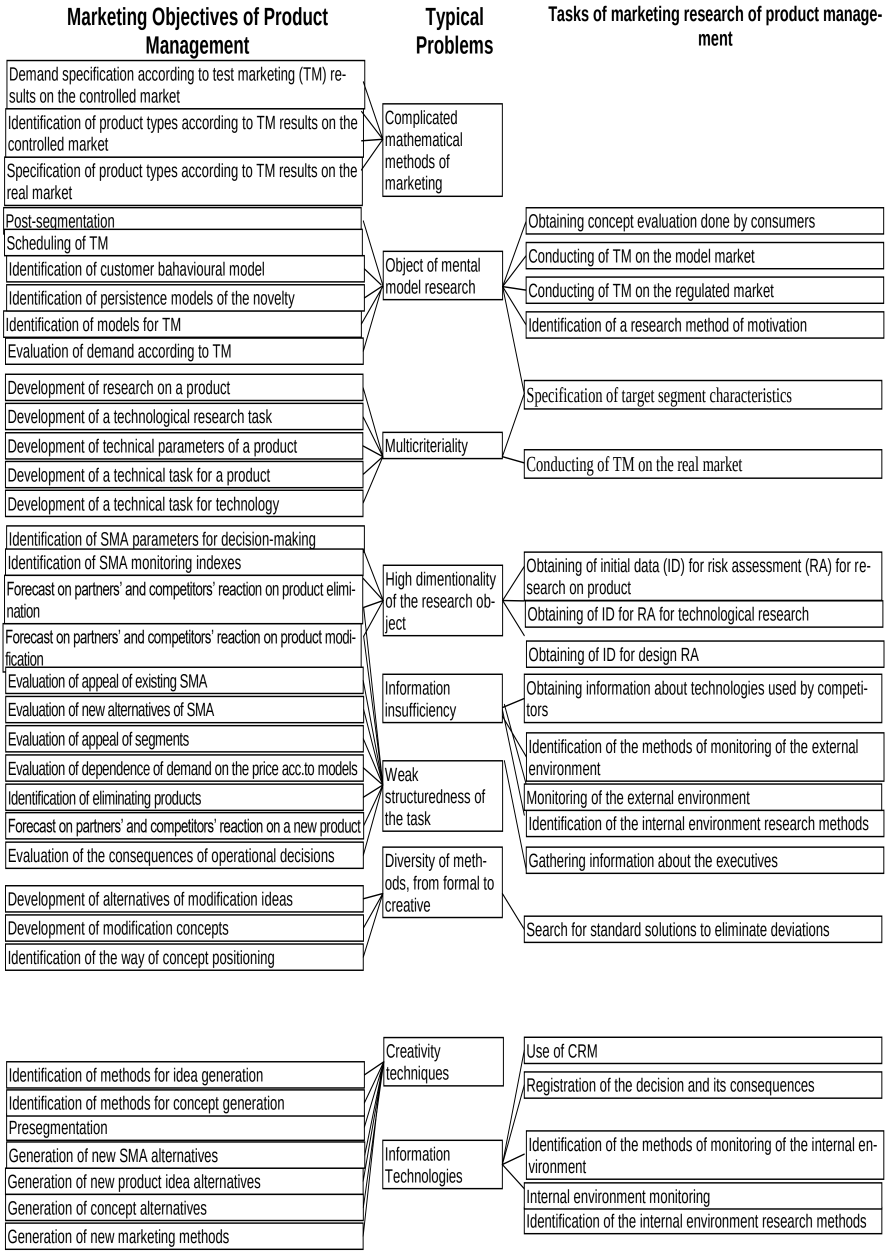

Figure 1-3 Identification of typical problems (in the middle column) based on the objectives of product management and marketing research

Both cases require an evaluation of the effect. However, an evaluation of the costs of an implementation of a client-oriented product lifecycle management is also required. For the purposes of the research, these evaluations will be done separately [203].

Evaluation of the efficiency of the marketing efforts is a challenging task. Thus, in order to use a multiple regression analysis for the quantitative modelling of the influence of the marketing strategy, an attempt was made to use the PIMS (Profit Impact of Market Strategy) approach, described in [304]. This attempt was not successful due to the high complexity of its objective and the wide range of factors affecting the marketing strategy.

The quantitative parameters of the companies, where the results of the current research will be introduced, varied, therefore we used qualitative and in some cases comparative assessments for both the effect and cost items.

For analysis, it was found convenient to use the approach suggested in [120] and thus the following aspects were taken into consideration:

1 The purpose of the assessment. In this research we developed an expert support system for the selection of the methods used to accomplish the tasks in product lifecycle management. Based on this, the purposes of the assessment were:

- the justification of the advisability of introducing such systems as a result of scientific developments; this purpose can be reached with the use of a comparative evaluation of the traditional execution of marketing functions and various alternatives of marketing activities improvement;
- a quantitative assessment of the economic effect will be required later on, when the possible price of a commercially distributed system will be defined. This assessment is required in order to be compared with the assessment of the company's costs after the license price and the costs of introduction of the system have been taken into account.

2 The function of the results. At the initial stage of development, the purpose is to determine the advisability of establishing a computerized product management system. In the future, these results will be used for decision-making and planning of measures in order to improve the marketing practices of small-sized manufacturing enterprises.

3 The users of the assessment results are the managing directors of companies and heads of IT-departments. For the former, not only are the quantitative indexes significant but also the qualitative indexes, as they will help to assess the long-term outlook and create a positive attitude towards the system. For the IT-department the quantitative indexes of costs, required computing power, etc. are more significant due to their task of the introduction and further use of the system.

As a solution for these complex issues, the research offers the following task formulation for an evaluation of the efficiency of the suggested innovations in marketing.

In order to assess the impact made by this system on the costs of an organization, we suggest the use of a comparative assessment of the various alternatives for marketing function implementation.

A traditional scheme of marketing for small and medium-sized enterprises is taken as the bases of the approach, i.e. one or two highly qualified economists and some general purpose software, such as:

- productivity software;
- a data-based management system (DBMS);
- statistical software, containing nearly all the necessary tools for marketing analysis, including Data Mining techniques;
- online software Collecting and Analyzing Data, such as http://mailchimp.com used for analysis of effectiveness of email newsletters, http://www.ianketa.ru/ for electronic survey, https://metrika.yandex.ru/ for web counting analysis and so forth. Almost all of these services are free of charge.

As an alternative the following can be considered:

- outsourcing of marketing consulting;
- outsourcing of marketing activities;
- introduction of a computerized system of product management.

Consulting is a possibility that can be used to occasionally address an issue. However, the cost of specialists is very high because in order to develop a recommendation the consultant has to carefully examine the situation, and has to do repeat this every time. That is why this option appeals to companies with a low level of marketing activity, whose products are stable and the competition in the market where they operate, is low. These types of organizations do not play any important role in the innovative development of the country, and therefore will not be addressed further in the research. Consequently, consulting as an option will also not be considered either. In comparison, outsourcing to a third party, as a part of the marketing activity is more advantageous for companies with relatively intensive marketing activity. Therefore, in the research we suggest companies consider only three alternatives for the organization of marketing activities in small and medium-sized enterprises.

We suggest companies evaluate the effect on the basis of the following elements (based on [125]):

- reduction of costs;
- revenue growth (both activities cannot be merged into one - profitability - as the revenue growth and cost reduction have different grounds and mechanisms);
- customer satisfaction;
- competitive position.

Evaluation of the elements that determine the cost factors for each implementation is given in Table 1–1. For each factor, the preference ranking of the three organizational alternatives of marketing activities is presented. Justification of their values is given in the respective cells in the table. At the first approximation, the factor loadings are not taken into account.

It is evident that from the point of view of costs the traditional scheme cannot compare with the other alternatives. The most preferable alternative is outsourcing (which is supported by [1] and other publications that mention its far-reaching prospective on the Russian market). At the same time, outsourcing requires high labor costs and one should keep in mind the role of the wage factor. On the other hand, software costs are usually lump-sum costs and overall this price is not as high as the labor costs. Taking this fact into account, the computerized management system is almost identical to the outsourcing costs. The effect of other parameters is shown in Figure 1-4.

It is evident that factors and indexes included in the effect are interrelated and the introduction of an intellectual decision support system will positively affect all the components.

Factor	Traditional marketing organization in small-sized enterprises	Outsourcing of marketing activity	Computerized Decision Support System
1. Main functions of the employees in a company that define their quantity	Whole complex of marketing activity (3)	Mainly – coordination of work carried out by the executives. Price of work done by a third-party includes prime cost and profit (1)	Whole complex of marketing activity (2)
2. Professional skills of the labor force of a company which define the wage rate	Must have a high level of professional skills, difficult to achieve (3)	The work monitoring requires a certain level of professional skills (2)	A high level of professional skills is not required. (1)
3. Professional skills of the executives	Must have high level of professional skills, difficult to achieve (3)	High level of professional skills, but customer effort is not required. (1)	High level of professional skills is not required. (2)
4. Wages	The time-rate system for the salaries of highly qualified specialist(s) while the workload is unbalanced inflicts heavy expenses. (2)	Costs include the profit received by the executive company (3)	Low-skill requirements, low labor costs (1)
5. Workload balance	The workload is unbalanced, especially if the staff of the company includes experts, such as interviewees, focus group moderators, analysts, advertising specialists, etc. (3)	The workload is balanced, because usually there is only one member of staff. (1.5)	The workload is balanced due to the possibility of increasing the diversity of the tasks carried out by one employee. (1.5)
6. Software costs.	The whole software package is required. (2)	Only productivity software is required. (1)	The whole software package as well as the computerized decision support system are required. (3)
Total ranking	16	9,5	10.5

Table 1–1 Evaluation of the factor costs for implementation of various organizational forms of marketing activity in small-sized enterprises (ranks of preferentiality are given in brackets)

Hence, on the qualitative level, the expediency of introducing an intellectual decision support system in the area of customer-oriented product lifecycle management can be seen to be justified.

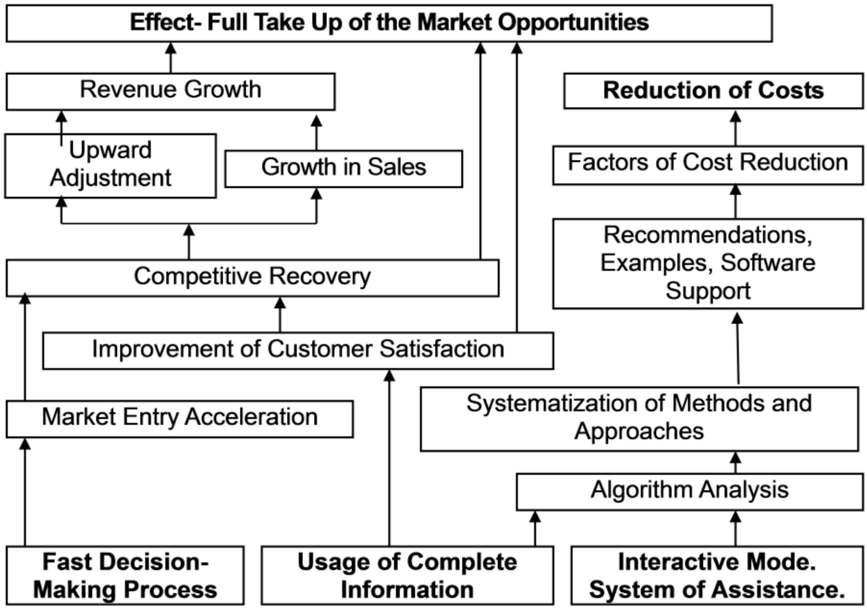

Figure 1-4 Interrelation of the factors determining the efficiency of using a computerized decision support system

The required effect of the system will be achieved if the development facilitates: the selection of a method that corresponds with the task on the basis of both the available information and the often insufficient information; provide the required tools (mostly consisting of computer support for the task execution); support the activity under consideration with corresponding methodical recommendations. These tasks require a methodology and an intellectual knowledge-based system.

These issues will be addressed in this research.

1.4 Current state of product lifecycle management and its computerization

1.4.1 The practical problems of product management

Due to the fact that the research is focused on product lifecycle management, a topic closely related to marketing, there is a need to also analyze the above-listed marketing problems of product management and marketing research. These marketing problems can be divided into several groups (see Figure 1-3):

- Sophisticated special mathematical methods of marketing. There is a variety of methods for marketing research and data analysis [256], [19], [45]. They can be classified into three large groups.

  - "Classic" methods (contingency tables, factor and discriminant analysis, etc.). Applying these methods, the researcher firstly puts forward a hypothesis about the relationships between the variables, then gathers and processes the data, and finally tests the hypothesis.
  - Methods determining the relation of variables in the process of analysis (e.g., online analytical processing (OLAP) [19], [189], some types of cluster analysis, and regression analysis to certain extent). Here the researcher discovers the relationships between the variables or identifies the groups of researched elements by applying various processing techniques.
  - Methods of Data Mining [19], [17]. These methods use the computational capabilities of modern computers and in some cases allow the detection of automatically non-trivial relationships between the variables, which is useful for solving marketing problems (e.g., to determine what products are often bought together). However, these methods require deep knowledge as regards the methods of Data Mining (a decision tree, genetic algorithms) as well as related topics (storage and retrieval of information from information systems).

The main problem here is the variety and complexity of the methods and the small number of academic publications by marketing specialists.

- The methods of mental model research. Although this issue can also be subsumed under marketing techniques, its main feature is the fact that mental processes are still not fully researched. Their study is being conducted on the borderline between marketing, psychology, and sociology with the help of testing methods, depth interviewing, structural equation modeling, etc. Each of them has its own specific features, which makes the study of marketing techniques a difficult task.

- Multicriteriality. The problematic task of decision-making in the context of multicriteriality has been studied for quite a long time; however, in this case it is necessary to deal each time with the identification of a certain set of criteria, assignment of their importance, and assessment of their values, which is a difficult and time-consuming task. Quite often there is an element of subjectivity in the marketing objectives of this kind. Numerous publications [64], [145] have researched the issues of the derivation of consistent subjective estimates in high dimensional tasks, the development of the principles of choice based on multicriteriality, and corresponding these tasks to the process of decision-making (e.g., the use of utility function [113]).
- High dimensionality of the research object. This issue is associated with the problem of multicriteriality. A high dimension sets the task of the selection of the important parameters for the analysis, as well as the interrelations between the parameters that are difficult to record (e.g., multicollinearity and identification of a set of significant independent variables in multivariate regression analysis, selection of the significant independent variables in the method of classification tree).
- Insufficient information. Many markets in modern Russian conditions, B2B in particular, lack sufficient information. They work in conditions of deficient and inadequate information. Under these circumstances, indirect assessment methods and expert methods are applied [258].
- Weak structuredness of the tasks. Many marketing problems cannot be solved with the use of traditional methods such as, the initial data identification – the problem statement – the method choice – and obtaining the solution. Often it is necessary to use a method of trial and error in order to refine the problem statement while in the process of solving it.

- Creativity techniques. There are a number of techniques that help to solve creative problems. These are, for example, the theory of inventive problem solving (TIPS) [6], and the previously mentioned Walt Disney and de Bono methods, etc. Their specificity lies in the fact that they organize creative processes
- Information technology, which includes the data collection, storage, processing, and output.

From the brief overview above it is clear that product lifecycle management is performed with the help of different methods. However, their use meets a number of challenges.

1 In order to solve a particular problem a whole range of methods and tools can quite often be equally applicable. The method is often chosen subjectively. This is the reason why a Decision Support System (DSS) for product lifecycle management must be developed. One of the system functions should be to rank the decision-making methods on the basis of an evaluation of the methods preferential usage in a particular situation.

2 It is often difficult for marketing experts to navigate with a variety of methods, because each will have its own specifications, often making the methods rather diverse. In general, every analyst only uses some part of the available techniques, which do not always fit the task well.

3 Another phenomenon noted by both foreign and domestic researchers, is that managers do not often understand the intricate mathematical methods of analysis and decision-making, that is why they are not likely to use the results obtained with the help of these methods. Therefore, the mathematical methods are often omitted.

4 Method selection is influenced by many factors, including subjective and non-comparable ones, which makes it rather a difficult task. Low formalizability is typical in the rapidly changing conditions in Russia: these "special" situations must be taken into account when a decision is to be made contrary to the theoretical calculations.

All these challenges require a systematization of the selecting process for the decision-making method for product lifecycle management.

Computerization of product lifecycle management

Currently, intensive work is in progress on the automation of the control of product lifecycle management. The concepts of CALS (Computer-Aided Lifecycle Support) [102], PLM (Product Lifecycle Management) [37] are presently being developed. Within the framework of these concepts, there is a variety of support software for product lifecycle management. The generalized structure of this support software is presented in [37], which constitutes the base for Table 1–2.

Stages of product lifecycle	Software	Type of System
Marketing research	CRM (Customer Relationship Management)	ERP (Enterprise Resource Planning)
Designing	CAE (Computer Aided Engineering)	
	CAD (Computer Aided Design)	
Preproduction	CAM (Computer Aided Manufacturing)	
	CAPP (Computer Aided Production Planning)	
Manufacturing	MPM (Manufacturing Process Management)	
	MES (Manufacturing Execution System)	
	SCADA (Supervisory Control And Data Acquisition)	
	CNC (Computer Numerical Control)	
Operation	IETM (Interactive Electronic Technical Manual)	
Disposal		

Table 1–2 The structure of the software according to the product lifecycle stage

There is various auxiliary software, e.g. PDM — (Product Data Management) [3]. Sometimes an electronic document management system and other systems are considered as means of PDM.

It is evident from the table that the main focus is placed on manufacturing, i.e. the preproduction, technology, maintenance, and supervision. Marketing research, operations, and disposal are supported as auxiliary functions. However, successful operations on the market require additional functions.

In addition, there is a wide range of tools that have been especially developed for solving marketing problems. These include statistical packages such as Statistica, SPSS, and a domestic analytical platform Deductor [186].

Numerous software programs have been developed to conduct research on customers, e.g. survey software, programs for the analysis of the effectiveness of emails and newsletters, and for web counting analysis, etc.

Finally, a considerable role is played by the information systems of the companies working with customers. Sales using bar codes, Electronic Documents and Record Management Systems, and the gradual transition to the use of data warehouses represent very large databases, the capabilities of which are not fully used. The fact that software is often updated and expanded and new software developed makes it impossible to develop detailed recommendations for the use of each piece of software. Therefore, the recommendations describe the principles of the methods applied.

Overall, it is possible to say that all the elements presented are not fully integrated, however, their use as a complex would be able to fully satisfy customer demands and consequently achieve the aims of manufacturing enterprises.

Theoretical problems of customer-oriented product lifecycle management

For several years, great effort has been devoted to the study of customer research. Analysis of the applied methods will be provided in a further section of the research. A key limitation of these studies is that they do not fully address the problem of the selection of a method and approach to solving practical tasks. The scope of a particular application method is often illustrated with examples, nevertheless, even in similar situations it is not always clear whether a particular software or method are applicable to the task that a manager is dealing with.

Another problem arises at this point, that of the transformation of a real task into a task that is solved with the use of a certain method. Assumptions analysis is often labor-intensive and requires a highly-qualified researcher. In practice, it often becomes either a shallow analysis or it is not conducted at all. Moreover, some significant parameters of the task may be omitted, which makes the solution ineffective and in some cases even detrimental.

As a result, the selection of a solution method for marketing tasks is often based on individual knowledge, preference, and experience.

Thus, the existence of the specific problem of selecting a solution method for a particular product management task is evident. The solution of this problem can be considered a metadecision (selection of a solution method is separated from the task solution). A decision support system will allow an increase in the efficiency of the decisions and their correspondence with the task, which, in turn, will increase the efficiency of the product management activity.

This problem of selecting a solution can therefore be solved on the basis of the accumulation of collective and individual knowledge, taking into account the specifics of the situation, and this has led us to the conclusion that a set of tools of knowledge-oriented artificial intelligence would be useful in order to build a decision support system.

The main problem is the development of a precise mechanism that is capable of ranking the decision-making methods in a "manufacturer-consumer" system with the help of the situation parameters and personal preferences based on an evaluation of the preferential usage of a particular method in a particular situation.

This task is so difficult that its solution requires using artificial intelligence techniques. This issue is researched in [215].

A rather full list of the artificial intelligence methods and techniques can be found in [239]. The following methods and techniques are the most powerful, universal, and in-depth.

Neural networks [83]. The advantage of this technique is that it is based on learning. "Supervised learning" is the most productive method. For the system under consideration this means that the neural network receives the specific details of a situation as input information and then generates its output, e.g. the degree of preferability for each solution method or even a preference ranking for the whole set of methods. The presence of a teacher means that there is a solution for every situation. The teacher provides the network with the answers, in cases where they are not identical to the ones generated by the system. Answers generated by the system make adjustments according to certain rules. Gradually, the parameters of the network develop so that all the existing situations give correct solutions. After this the network is used for generating solutions for new situations. The great number of examples of existing situations makes using this method a favorable solution. The correct solution usually becomes evident not only after the successful completion of the task, but also after a mistake. These examples can be generalized as <specifics of a situation>→<correct solution>. The main advantage is that it is not necessary to know the parameters that are really significant for the decision-making process. All the available data is gathered assuming that it is sufficient for making the right decision, even though the method of decision-making is uncertain. After the learning process is complete, the network will independently determine the significant parameters and their effect on the decision. It is not necessary for a user to be familiar with the structure of the effect, as the user has received a ready solution.

Technologically, supervised learning is a well-elaborated method. Modern software, e.g. the latest versions of Statistica, is based on improved algorithms that allow the difficulties that occur in the process of learning to be overcome.

For example, the change of parameters does not occur only for a particular case, but for the whole scope of situations, which makes the learning process considerably more stable than in cases where "classic" learning algorithms have been used based on the alternate application of descriptions of every existing situation. Moreover, modern computers have sufficient computational capability to implement multi-layered networks with a large number of neurons, taking into consideration the complexity of the relationships between variables. These networks provide a flexible configuration, and the nonlinearity of these networks [83] makes it possible to model comparatively flexible and complex decision-making situations.

The following disadvantages of the method have to be recognized. The education process for neural network training is not yet always stable, it requires some fine-tuning, as well as the testing of various types of neural network structures, and neuron functioning. The methods used for automated stall prevention in local extrema, such as a random change in the network settings, only solve the problem to a certain extent. This especially concerns the complicated vector estimates as in the case of solving a formulated task, but not the simple dichotomous keys of the Yes / No type. It is also nearly impossible to check the decisions at the content level. However, the main disadvantage is that the network is adjusted to current situations, and its actions for any new ones are difficult to predict.

The fact that the learning process is very slow (a set of situations usually has to be presented to the system tens of thousands of times) is not a significant disadvantage, because the system adjustment is not a real-time task.

Decision trees [82]. This method determines the if-then decision rules of a particular situation that are related to a particular class based on a set of measured parameters. For example, in a typical case, one can determine which group of bank customers has the highest probability of paying off a loan without any problems, and which has the lowest probability. For the “manufacturer-consumer” system, one has to build a decision tree for each method to determine the rules of its preferential use.

The advantages of this method are similar to the previous one.

The disadvantage of decision trees is the difficulty of its application to tasks that require ranking a large number of alternative solutions.

Limited enumeration algorithms [19] are also designed primarily for dichotomous decisions. The method is not widely used, as can be seen from the literature.

Structural equations [185]. This method allows a linear model to be constructed of the complex relationships between variables. Using this method, it was expected, for example, that a statistical model of consumer behavior would be constructed that could be determined by using a model of the actual behavior of buying customers on the basis of surveys and testing of consumers psychological attributes, including internal variables. The additional correlation and variance analysis allows the accuracy of the solution to be evaluated and the influence of any unaccounted factors. There is a set of techniques for the application of the method. For example, it is included in statistical packages (Statistica 6 and later versions). However, the method is rather complex: it requires a deep knowledge of statistical calculations, and the mastering of a highly coded language. The main argument against this method is the small number of positive examples of its application, even in the help desk software of the statistical packages, which explain the features of the methods.

Expert systems [87]. On the one hand, this method is the most powerful, but on the other hand, it is the most subjective. The application of expert systems should be based on a fact base. For the problem addressed in this paper, the fact base provides the specific details of a situation. For example,

Fact A: Current task = Generation of a new product idea;
Fact B: = Method applied = Survey.

Moreover, there is a rule base, which in the simplest case looks like

IF Fact A, THEN Fact B

In more complex cases, the facts in the IF-clause are combined with the use of the logical operation AND. The task of the system is to check the conditions of application for each rule. Thus, if Fact A is the antecedent and the above mentioned if-then rule is applied, then Fact B is added to the rule base while the search for a rule that contains Fact B as a consequence continues. As a result, the fact base is updated. The conclusion is not always obvious, so one can mention knowledge production as one result.

While these expert systems are conceptually simple, they represent a powerful tool that allows rather complex problems to be solved from car diagnostics to medical diagnoses.

The advantages of the use of expert systems for the tasks under consideration include the following:

- they represent a system of human knowledge - expert knowledge;
- they allow the rules that have been applied to be viewed, which makes their work understandable for decision-makers;
- they allow working in reversed order, i.e. from the consequent to the antecedent, which allows the information required for decision-making to be known;
- it is easy to input the quantitative parameters into the system, such as degree of fact reliability or alternative solution preferences.
- certain difficulties may occur while implementing such systems:
- in reality the number of rules is redundant, that is why it is extremely difficult to make such systems complete and consistent;
- expert systems are rather difficult to debug, the decisions concerning the system operability is made by a human expert.

The researchers had great expectations for the expert systems, but optimism about their application systems has considerably reduced these expectations due to the above-mentioned difficulties. This is particularly obvious when searching for information on the topic in information retrieval systems. There is a clear lack of recent studies on the subject: mostly there are only publications about dedicated application of the systems, e.g., [126], and some information about the use of expert systems in agriculture is available at http://www.akn-agro.ru.

However, taking into account the positive aspects of these systems for solving the task of choosing the product management method, the study suggests their use. The following features of the current problem define the features needed for the implementation of the expert systems now under development.

1 The expert systems use a fuzzy magnitude of fact possibilities. For example, the fact:

$$\text{Method applied} = \text{Survey}$$

has a fuzzy evaluation of alternatives in a range from 0 (impossible) to 1 (absolutely certain). In this case, the possibility is interpreted as the solution method corresponding to the current situation. The same applies to those cases where the information about the details of a situation is incomplete. In these cases, the solution is dependent on the level of confidence of the analyst as regards the available facts. Fuzzy expert systems are researched, for example, in [8], [301].

2 One of the disadvantages of the expert systems is their high dimensionality. A rule system should be complete, which means recording all the possible combinations of the facts implications. In this case, an unordered set of production IF THEN rules requires a great effort to fill in, and is hard to debug. Frames and semantic networks, which are used for knowledge systematization, do not always facilitate the task of developing and debugging the expert system [87]. Thus, it is not a technical problem, but a problem of the interaction between a human and the software system.

Furthermore, as long as the system under development generates qualitative information it is considered to be a multivariate rule-building expert system. These systems have been well known both in Russia and abroad for a long period of time [301], [152].

A convenient way of determining the rule input for an expert would be a matrix representation. For example, a rule that allows the way of receiving data to be determined (secondary data, survey, observation, etc.) depending on the current task (identification of parameters for analysis of external environment, new product ideas generation, target segments selection, etc.) contains a matrix with all possible value combinations. These are then interpreted as estimates of a preferred application of each data collection method for each of the current tasks.

The initial values of the matrices-rules can be formed based on the analysis of the literature. For example, in order to generate ideas, the secondary data is nearly unusable, and observations provide little information, therefore the most applicable method is a survey.

3 Ability to self-learn (adjustment) and adapt. The first characteristic allows the expert system to be debugged during the process of operation. Unfortunately, little research has been done in this area. We can only mention the publications that describe the general principles, such as [235]. While a common program of real complexity requires time-consuming debugging (there are special tools for this, among which single-stepping is the simplest), expert systems are formed on the basis of expert knowledge, debugged by experts and the decisions as regards their performance are also made by experts.

The second characteristic – adaptation – is considered in relation to the changing operating conditions and, to a greater extent, to the subjective preferences of the decision maker. This is important due to the possibility of ambiguous choices being made by the product management method. Fuzzy inference rules are subject to adjustment.

(Self) learning and adaptation are the properties of the neural networks, which is why, in order to select a decision-making method in product management it is suggested that a specially modified expert system be developed - a self-training fuzzy expert system.

4 The term «hybrid systems» usually refers to systems that combine expert systems with application programs (statistical packages, database control systems, etc. [266]. The other denotation of the hybrid system is used in [20] and other publications describing the projects of the same authors. The focus of their research is the integration of expert subsystems and neural networks that interchange information, into a single system.

The system under development is also a hybrid one, but it has features of both expert systems and neural networks.

5 Finally, another important feature of the system under development is interactivity. The expert system can operate in a data collection mode. In this mode, the operator inputs all available data in response to questions from the system. It is important to admit that the input data may also be fuzzy. Stepping (one inference rule is used at each step) allows

the settings to be adjusted at the stage of system setup. The result of all steps is a column of preference evaluations for each of the decision-making methods for the analyzed situation. The decision-maker selects a method based on this data. This decision may be taken into account in the changes in transformation matrices singular values, which leads to the adaptation of the system to the particular experts in a particular company. This issue does not present any theoretical difficulties, but adds flexibility to the system under development.

The task is to combine the above-mentioned heterogeneous feature in a single software tool and methodology based on the computerization of product lifecycle management.

Thus, product lifecycle management involves the application of a number of various interrelated methods; the problem is the selection of the correct solution method. Various procedures and tools are used for the correct selection and implementation of these methods [213]. All these facts represent the elements of the methodology.

1.4.2 Conclusions

1 A system of customer-oriented product lifecycle management for small-sized enterprises has been identified; the tasks of the management according to the stages of its process have been detailed; for the typification of these tasks it has been suggested that a wide range of mathematic methods are applied.

2 It has been demonstrated that in order to evaluate the efficiency of a system implementation, the effect, i.e. the use as regards market opportunities and the cost saving on the performance of product management tasks, i to be researched on a qualitative level.

3 On the basis of the task typification, the importance of the problem of the selection of a solution method for the product management tasks has been demonstrated as being a meta-decision. The expediency of a decision support system based on artificial intelligence has been determined. The features of the tools for the computerization of the activity have been described.

2 METHODOLOGICAL BASIS FOR THE PRODUCT LIFECYCLE MANAGEMENT COMPUTERIZATION

2.1 Introductory notes

2.1.1 General approach used in this work

The area of research includes methods, models, and algorithms of computerized decision-making in client-oriented product lifecycle management, namely – the development of methods and algorithms for decision-making tasks and the development of methods for information collecting and processing.

General philosophical principles. This research is based on and develops previous achievements by Russian and foreign scientists. Theoretical findings are checked by their practical use.

General approach used. The research is based on the situational approach in management developed by [225], [236] and other authors. This approach is used to control complex technical and organizational system and is based on the ideas of artificial intelligence. According to this approach, the management cycle process starts with collecting data about the real situation, formulating a problem, generating solutions, making decisions about the various solution choices and implementing the solution.

This approach was used both in performing the research and in the decision support system that was developed as the result of the research.

2.1.2 Theoretical and methodological basis

The theoretical and methodological basis for the research is fundamental works by Russian and foreign scientists on marketing, marketing research, product management, decision-making theory, control systems and artificial intelligence.

Elaboration on the extent of the problem.

Concepts, approaches, methods and models of product management, and product lifecycle management are reflected in the writings on marketing and product management of G. L. Bagiev[1], E. A. Vikulenko [289], [290], [291], E. P. Golubkov [93], [94], G. Y. Goldstein, E. V. Popov, D. Aaker, R. S. Wiener [149], And J. J. Lamba, D. R. Lehmann [149], F. Kotler [135], N. Malhotra [158], G. Churchill [45] and others.

Questions of innovation effectiveness in product management are revealed in the works of T. G. Brodskaya [35], A. N. Gerasimov [86], I. N. Evstafiev [72], V. A. Zavgorodnaya [307], V. A. Kolemaev [127], Yu. L. Muromtsev [169], B. I. Kuzin [140], V. N. Yuryev [140], N. B., O. A. Tretyak [273], Yu. G. Uchitel [278], [279], G. P. Fomin [78], L. M. Chistov, H. Albert [165], F. Kotler [135], D. Liker [153], M. Mescon [165] and others.

Principles and methods of decision making, mathematical methods and modeling in economics are considered in the works of A. V. Andreychikov , V. G. Anisimov [10], [11], V. V. Glukhov [88], [89], [90], [91], [92], V. M. Glushkov , V. P. Koniuchowsky [129], [130], [131], G. B. Kleiner, B. I. Kuzin [140], O. I. Larichev [145], B. G. Litvak, M. D. Mednikov [92], V. N. Sokolov [258], [259], I. M. Syroezhin , R. Ackoff, F. Emery, J. Forrester [79], H. Reif and others.

Problems of artificial intelligence based systems and expert systems can be found in the works of A. N. Averkin, N. A. Amosov, V. N. Vagin [281], V. M. Glushkov, V. Duke, A. P. Eremeev, G. S. Osipov, E. V. Popov, D. A. Pospelov [224], [225], F. Rosenblatt, and V. V. Toporkov, I. B. Fominykh, A. B. Frolov, V. F. Khoroshevsky and others.

Works on uncertainty, fuzzy values, cognition modeling and other similar methods used in marketing were created by V. I. Maksimov , A. N. Melikhov, V. B. Silov, E. A. Trahtengerts, A. Kofman, L. Zadeh, D. Dubois, A. Prada, E. Mamdani, F. S. Roberts and others.

The above list of scientific works reflects a wide range of research directions and different aspects of product lifecycle management.

2.1.3 Information base of research

The research is based on the national standards of the Russian Federation, ISO standards, data from the Federal service of state statistics, monographs by Russian and foreign authors, articles by Russian and foreign authors pub-

[1] No references for the authors whose results were used in previously published articles of the author.

lished in scientific journals, data on information agencies, Russian and foreign Internet sites, dissertations.

The validity of the results is proved by the fact that the research ideas are based on a summary of best practices and the analysis of practical situations. The theory is based on known principles and correlates with the published experimental data and experimental data obtained by the author. A comparison of solutions obtained with the help of suggested methodology and expert recommendations were performed. In some cases, the obtained solution was compared with that given in literature. System analysis, modern economic statistical simulating, analysis methods, modern methods of collecting and processing incomplete and fuzzy data were used.

The accuracy of the findings and the conclusions of the research is proved by their correspondence with results obtained with the help of the developed expert system with those taken from the literature; specially those obtained from the test cases, expert solutions, and the positive effect of the solution realizations.

2.2 Analysis of the current approaches and methodologies applicable to product lifecycle management

2.2.1 Approach selection and evaluation of the current methodologies in the area of product lifecycle management

Some general approaches to the issue of product lifecycle management have been researched in [62]. Among them ([205]) are the following:

1 System and cybernetic approaches. These are general approaches used for the identification of an administration system. The development of the software under consideration is based on these approaches (Chapter 1).

2 The Complex approach takes into account different aspects of the problem. This approach is over generalized, despite its efficiency. All available data as well as relations between phenomena and processes are considered.

3 The Dynamic approach considers the dynamics of a particular situation. This approach is used in the functioning of an administration sys-

tem as well as in particular methods of lifecycle management such as the dynamic process.

4 The Quantitative approach. All the estimates are quantitative indicators. However, this is impossible as regards complex socio-economic systems.

5 There are some more restricted approaches that are used in management.

6 The Command-administrative approach. The disadvantages of this system were demonstrated by the history during the collapse of the Soviet Union.

7 The Functional approach. All the employees perform a particular set of assigned tasks. This is a traditional approach; its main disadvantage is failing to focus on results.

8 The Process approach. This is oriented towards the results of business processes in a company. In practice, it does not result in any sudden change of efficiency, especially in Russian conditions.

9 The Situational approach [90]. This approach is one of the most promising ones. It is applied to the method selection task depending on the characteristics of the situation and its main idea is acting according to the situation.

A successful modern marketing activity should be based on a specific methodology. In turn, the methodology based on a particular approach or approaches is aimed at organizing the market activities into an integral structured system.

In the literature on marketing, research is quite often conducted on methodology, however, the publications often consider only the methodological approaches, the approaches to methodology, and the main principles, while integrated research on the elements of methodology and their interrelations can only be found at a higher general scientific level, in theoretical works on conducting a scientific research and learning methods. Many scholars agree on the definition of the term "marketing methodology", as an operation based on marketing principles and methods. Additionally, there are detailed methodological designs for particular elements of marketing activity, e.g. marketing research or development of a particular type of product, such as software. Finally, the groundwork has been done for the methodologies of various types of marketing, e.g. project management. One should note that these activities are also applied outside of the marketing processes.

At the level of the marketing mix components (product, price, promotion, distribution) there is a smaller number of integrated methodologies. In the area of product management, there are mainly methodologies for project management aimed at the development of particular types of products (engineering developments, medical products, etc.) [262]. The issues of methodology of software development as intellectual property have been addressed in [195], [196], [192], [202], [207], [193], [191], [204], [200], [201].

There is a clear lack of integrated methodologies for product lifecycle management, especially one that would consider the customer and manufacturer as a system.

2.2.2 Description of an intellectually interactive methodology of lifecycle product management

Generalizing the problem definition and the overview above, it is possible to articulate the essence of the methodology required in order to successfully solve the identified problem.

The list of basic methodology elements is based on [181]. It has been slightly changed in order to correspond to the topic of the research.

1 Methodology Characteristics.

1.1 Features.

- Field of application: management of the lifecycle of different product types at the company level.
- Purpose. The developed decision support system (DSS) assists in the selection of marketing task solutions based on incomplete information about the characteristics of a particular situation. The objectives of the DSS are to consolidate and systematize the knowledge about the use of the whole set of product management methods. Then to introduce them in the same vein that would allow the selection to become more objective and justified, and take into consideration the task factors and the assumptions. At the same time the selection recommendations should not primarily deal with the specifics of a certain tool application (mostly, software), but the specifics of the methods themselves.

- Functions

  - Selection of the product management marketing task. This is a separate significant meta-decision that is determined by a broad set of factors. Cognitive models are often used for understanding situations. The application of creative methods is determined by the task of generating new product ideas. Selection of a linear-programming technique is determined by the linear dependence assumption in the model. The complexity of a particular situation and the absence of a model may require expert evaluations; while a combination of solution examples for a variety of similar problems, an absence of a model, and insufficient data for building a model make the use of neural networks the most expedient action. It is evident from the list that the selection of a method is determined by its specifics together with the task of the product management, and the aim of the researcher.
  - Evaluation of the choice selection quality. In order to make the final decision it is necessary to evaluate whether the decision is unambiguous, and, if not – to what extent it helps to make the final decision, i.e. how close it is to being unambiguous.
  - Providing the subjects of a marketing activity with a study guide on the application of a selected method.

1.2 Principles.

- The ambiguity of the choice should be taken into account. For a specific task one can sometimes equally well and sometimes with varying degrees of success use a wide range of methods and tools. As a result, a measure of probability (preferentiality) of method application is introduced, which represents an analogue quantity from 0 (impossible) to 1 (absolutely certain) [238], [245]. This measurement facilitates the final selection for a decision-maker as it gives an order to the various methods under consideration, starting with the ones with the higher application potential. Thus the developed system is considered to be fuzzy.

- The incompleteness of the information available for marketing specialists should be taken into consideration. Evaluation of the potential can be applied even in cases where the description of the current situation is uncertain.

- Any available data that affects the decision-making process should be considered.
- Consideration of the subjective factor, the experience of a particular decision-maker and the time factor. The adaptation should be anticipated for a real application
- Interactivity: the possibility to add or update any available information at any stage of the operation.
- The above mentioned principles facilitate the use of a computer environment as an integral part of the methodology.

1.3 Achievement conditions.

- High speed of decision-making.
- Low labor-intensity of the situation analysis.
- Providing the marketing specialists with all the necessary information on the decision implementation procedure.

2 Logical structure

2.1 Users (subject): The methodology solves the task of providing marketing specialists with practical help: marketing analysts solve specific practical problems, and the researchers develop new methods for product management and generalize the experience of the applications in the existing ones.

2.2 The object: the process of product life cycle management.

2.3 Forms of data processing. The form of the data processing is determined by the method used for solving a particular task. We will study these methods later on in the research.

- In order to attain a solution (selection of a decision-making method) based on the initial data (characteristics of the situation) IF-THEN rules have been formed.
- Some characteristics of the situation can easily be determined (presence of experts, availability of the examples of similar solutions), while the identification of others is a matter of some difficulty (the possibility of linear programming model application) requiring in-depth analysis of the situation. Therefore, method selection DSS can-

not be built as a one-step Task→Method or Aim→Method transition. The selection of a method based on the characteristics of a particular situation is a multi-step action. The fuzziness of the system is another argument in favor of a multi-step transition, because a one-step transition, without considering the specifying characteristics of the situation, gives considerably broader recommendations.

These features (multi-step IF-THEN transition) corroborate the need for an expert system.

- As a result, the DSS is classified in the category of fuzzy expert systems.

The available data is input as a description of a situation, which is a set of facts for the expert system. Even if the data is only indirectly related to the task, incomplete or not completely reliable, the available information is used to facilitate the selection of a task-solving method. The major part of these characteristics tends to be general in nature. Thus, the aims of the task-solving include: an understanding of the situation, parameterization, and evaluation of the alternatives, etc. The specifics of an object domain are included in the list of product management tasks compiled in [213], [198]. The list facilitates the collection of the facts.

The form of the presentation of the facts is fuzzy, i.e., the information is expressed as probabilities of each parameter value. The absence of any data on the specifics of a particular situation is allowed.

2.4 The methods applied as part of the methodology.

- Methods of life cycle management. These methods will be discussed in the next chapter.
- Methods of decision-making procedure selection for a specific task. The initial data is processed according to the principles of an expert system with the use of fuzzy IF-THEN rules. Every rule of this type is presented in the form of a possibility matrix. At this stage, it is appropriate to introduce the mechanisms of how the expert system operates, without the use of rigorous mathematical tools.

As an example, one step of the expert system operation can be discussed: the selection of a method based at the stage of product management. Under this transformation a row of possibilities for each set of methods is formed based on: the column of probabilities for the product management stages, the help of a possibilities matrix, the number of rows which correspond to the number of stages, and the number of the rows which correspond to the number of methods.

For each stage of the product management various sets of methods can be used with different degrees of preferability. For example, for the stage of idea generation TIPS/TRIZ methods are most suitable. The possibility to apply TIPS/TRIZ methods for the stage under consideration (the cell at the intersection of the row corresponding to the stage of idea generation and the column corresponding to TIPS/TRIZ) is set as 1 (a perfect match). Expert opinion can also be used for idea generation. The applicability of this method is set as 0.9 (the cell at the intersection of the row corresponding to the stage of idea generation and the column corresponding to the method of expert evaluations). The methods of the focus-groups are less suitable for idea generation, according to the weighty opinions of the scholars in the area of marketing research, as in focus-groups truly new ideas are rarely proposed. Therefore the applicability is set as 0.2. Finally, application of neural networks at this stage is not justified; their applicability is set as 0.

In a similar manner, the other elements in the possibility matrix for the applicability of the methods, depending on the stage of product management, are completed.

Thus, if a decision-maker inputs the information that the current stage is the idea generation stage, the result of the rule application will be the applicability of the methods. For TIPS it is 1, for neural networks it is 0. The fuzziness of the situation definition leads to an increase in the fuzziness of the method selection process.

Similar transitions occur for each rule determining both the final result (applicability of a method) and the intermediate outcome, e.g., Need for consideration of the process dynamics→Applied model.

The final result for the probabilities for every value of every parameter is defined as a combination of a priori subjective representation and is based on all matrix transitions determining the possible values of a particular parameter. For example, the selective method can be chosen based on the a priori representation, the above mentioned transition Stage→Method, the required accuracy of the Result→Method transition and others that will be described later on in the research.

The work can be carried out in an automatic or single-step mode. The former allows the result to be estimated immediately, while the latter allows the available information to be input at any step in the solution process.

- Methods of result evaluation. As a result, the decision support system outputs the final evaluations of the applicability of each method. The first type of evaluation is based on the specifics of a situation with the help of the series of transitions previously explained, and these ultimately determine the accordance between a chosen method and the situation. Moreover, an implement a group of evaluations of the method itself is offered, without regard to the situation. These give an indication of the method value per se as well as its correspondence to the hands-on experience of decision-making in a company. We suggest using the following estimates: O_1 for adequacy of assumptions; O_2 for credibility of the result; O_3 for decision utility; O_4 for usability for one time tasks solution; O_5 for usability within a decision support system. The higher values of the estimates are more preferable.

The second type of estimates begin to play a great role when the information about a particular situation is limited, and here the method selection is mainly based on general assumptions.

All the estimates are in a range between 0 (impossible) and 1 (perfect match).

A general evaluation is also given to the Decision utility. If the results of the four methods of applicability are presented as a row 1; 0.9; 0.2; 0, it can be seen that the first two form a group of preferred methods, as they are highly applicable; while the other two are less appropriate. It is evident that this recommendation is fairly useful even though it is not perfect. In an ideal case, there is a certain level of confidence in the application of only one method, while all the others are completely rejected. This is why the utility estimate for the decision as a whole is introduced. This estimate is also in a range between 0 (absolutely useless) and 1 (perfect match).

2.5 Implementation techniques.

- Technology determines the product management functioning and is expressed in manuals, instructions, guides, etc. Recommendations on particular methods of application as well as an expert system on their selection will be provided below.

• A computer environment expands the opportunities of an individual.

The temporal structure of the methodology consists of stages and phases.

3 The stages and phases of product lifecycle management have been discussed earlier in the research.

3.1 The stages of application for the suggested methodology are discussed in the fourth chapter of this work.

4 Organization. Theoretical and practical recommendations on the application of the methodology are discussed later in the research.

Thus, the basic provisions of a customer-oriented methodology for product lifecycle management have been identified. Based on main features of this methodology, it can be called intellectually-interactive.

2.3 The decision-making procedure in product lifecycle management

2.3.1 Study of the general decision-making outline

The general decision-making outline is formed on the basis of universally recognized stages of management; the contingency approach to decision-making described, e.g. in [89], [62], [248], is widely and successfully used for solving a wide scope of marketing tasks with regard to the above suggested notion of meta-decisions (Figure 2-1).

Figure 2-1 includes three sets of blocks that will be discussed in more detail later in the research.

The solution purpose is to obtain a particular result within the limits of the product management process, e.g., to select a product for elimination, to accomplish the generation of new product ideas, to select a concept among the available alternatives, etc. More precise settings for the marketing task (criteria of optimality, containment, admission) are determined by a decision-maker with regard to a particular situation. However, the real task in each particular case has certain nuances, which makes creation of an exhaustive list of tasks impossible even for management of a particular kind of product. This is why the research suggests concentrating on more generalized tasks, which are easier to articulate for each situation, such as; learning the value of variables, gathering data about previous decisions and their accuracy, obtaining evaluations of the alternatives (e.g., fuzzy ones), selecting the best or the most reasonable decision, reflecting on the essence of the decision and its progress in ordinary language, etc. An exhaustive list of the tasks can be compiled after a detailed examination of each stage's tasks and their solution methods.

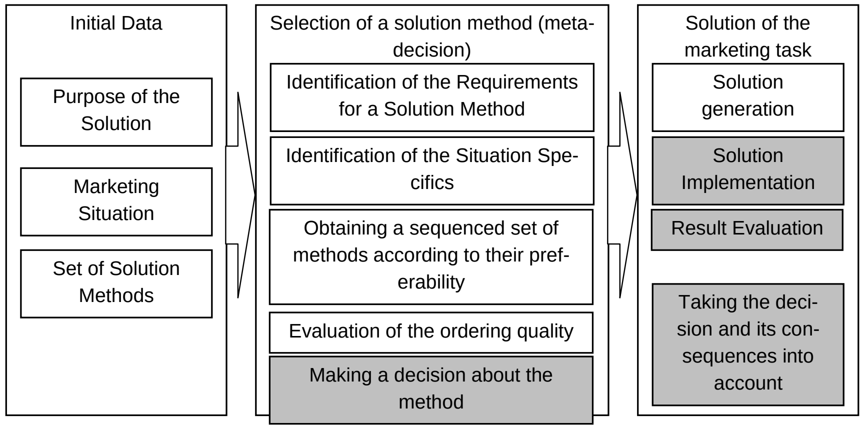

Figure 2-1 Decision-making outline in product management (white boxes represent the object of the current research)

The marketing situation is characterized by a wide range of parameters. For example, by the product management stage, alternate decisions or a need for decision generation will exist due to the stochastic nature of the processes under consideration, etc. The selection of the researched parameters for a marketing situation depends on the task and – to a certain extent - on the method. A decision support system should help to identify which parameters are to be measured, in which cases and how this will be done. A separate difficult task is to compile a list of quantitative and qualitative parameters for a situation, which will then determine the application of a particular method. This task is solved on the basis of the analysis of the method's parameters per se. Consideration of this task is beyond the scope of the current research.

In order to form a set of decision-making methods, the marketing tasks used in product management have been identified [198] and their typification has been carried out [213]. A detailed analysis of this task will be discussed in more detail later in the research. We have exemplified the various groups of methods in the following paragraph.

The mathematic methods include the rather universal methods of hill-climbing, dynamic simulations, factor and discriminant analysis, operational research, etc. as well as methods specific to marketing in general and for product management in particular, e.g., performing BCG and the GE / McKinsey matrices, etc.

Most of the instrumental methods can be considered universal. Among these are OLAP (On-Line Analytical Processing), Data Mining methods, methods of artificial intelligence (neural networks and expert methods). Almost all require a corresponding computer environment. However, there is a group of instrumental methods that is mostly used for marketing tasks. For example, this includes, among others, the method of classification trees.

The creative techniques are, e.g., the Walt Disney method, the method of six thinking hats by de Bono, and a wide range of methods employing creative activity.

In order to research mental phenomena in the marketing methods of allied sciences are applied (testing for psychological attributes measuring, building structural equations of their interrelation) as well as specifically marketing methods (methods of joint analysis, multidimensional scaling used in order to identify the preferences and perception of the product attributes). A separate group consists of marketing experimental methods, which test marketing in particular, and are used for new product performance refinement and demand forecasting. Surveying methods form another large group.

Such methods as identification of chaotic behavior and simulation are applied when complex objects are examined.

For a better understanding of a situation it is possible to use methods of cognitive model construction, deductive, inductive and traductive reasoning. Methods of collective discussion, such as brainstorming, expert evaluation, TRIZ / TIPS, constitute separate subgroups.

In situations where the available data is insufficient or inadequate, methods of risk analysis and work with fuzzy values are applied.

Identification of requirements for a solution method as a result of a metadecision is often carried out not on the basis of the task features, but according to a company's strategy, the stage of product management, and the content of the task. A solution method should meet the following set of requirements:

1 **Adequacy of assumptions**. The application of nearly every method imposes comparatively serious assumptions in order to simplify a situation. Correspondence of the applied solution method to a real situation should be achieved on both quantitative (correct conclusions) and qualitative levels (satisfactory accuracy of a solution). The task of product management is exemplified in [62] by demonstrating that achieving an application adequacy with the Monte Carlo simulation method can require a rather complex model. Similar examples are illustrated by the linear-programming technique. Thus, the transformation of the problem of goods optimization in a shop into a task of linear-programming techniques requires a set of assumptions. As regards the dependence of sales volume on the size of the shelf where the product is displayed in the shop, the assumptions made in this case are rather adequate. However, in some cases minor assumptions conflict with others and this is more serious. For example, the task of the range of goods optimization in a shop is simplified by making the assumption that by the end of a particular period the number of unsold goods should equal zero. This is not a very serious assumption, but it can impose a chain of more significant ones. If a product is fully sold out over a particular period and sales process has a random nature, it can mean that in the end some customers will not be able to buy the desired product due to its absence, which does only mean that they themselves will not come to this particular shop anymore, but they will also relate this fact to a wide range of customers. These consequences can become significant enough to skew the results of model calculations. Therefore, the adequacy level of the linear programming model is not especially high.

A range of product management tasks do not require high solution adequacy. One of these is the pre-selection of new product alternatives for development. The application of an expert evaluation can be sufficient. However, in order to determine the sales volume according to the sales forecast, the level of solution adequacy should be high. This can be achieved with the application of methods such as test marketing on regulated and real markets[2] [45].

[2] This method is considered to be experimental.

2 **Result validity** (degree of confidence in the obtained results). Usually, the validity of the sampling research e.g., of the level of customer satisfaction in a new product, can be evaluated with some assumptions. Publications on marketing research note that the validity level decreases as the number of respondents grows. This decrease in validity is determined by a lack of conscientiousness from the interviewers and unsatisfactory supervision of their work. However, it must also be mentioned that the validity of an expert evaluation is not the subject of an a priori estimation.

As a rule, the tasks that require a high level of accuracy simultaneously require a high level of validity.

3 **Decision utility.** The method of joint calculations provides recommendations on a range of goods and determines which product models will better satisfy customers' needs; therefore it has a high level of utility. Cluster analysis techniques help to divide customers into particular groups, which can have both the potential to become the basis for segmentation or be absolutely useless. Thus, cluster analysis has a medium utility level.

Decision utility requirements should be applied with regard to other requirements, and first of all to the ease of application of a particular method.

4 **Usability for one-time decisions**. The frequency of a particular task solving can have a strong impact on the solution method selection. Usually, it is not difficult to determine how often a particular product management task will be solved; such tasks as the mastering of a fundamentally new product production are rather rarely solved. Others tasks, such as customer survey, monitoring of attitude towards a particular product, are solved on a regular basis. The product management methods can be divided into:

- Methods for a one-time application. The main reason for this is the high labor-intensity, which causes the impracticality of frequent applications. For example, organizing a series of focus-groups in order to identify the positive and negative features of a new product[3];

[3] Application of this method is mainly carried out by research organizations rather than by manufacturing companies.

- Methods for applications used on a regular basis. The typical examples of these methods are methods of artificial intelligence, such as neural networks that are used, e.g. for the selection of new product ideas, and expert systems that can be used to select models of customers' behavior. Both of these require a complex development process. The former requires the collection of a significant number of examples and a time consuming adjustment; the latter, the development and debugging of the rule and fact bases. After these stages neural networks and expert systems are able to promptly find answers for the questions that arise.
- Universal methods. The method of measurement as regards attitudes towards a particular type of product is conducted according to the standard procedure (using Likert's or Thurstone's scales). A model questionnaire is prepared for a certain class of products. Processing of the collected data is easy and can be done manually. This method can be equally used both as a one-time application and applied on a regular basis.

5 **Usability of the computerized decision support system**. This index takes into consideration the introduction of computerized tools as well as other matters concerning the regular application of a particular method. In order to be developed, an expert system requires adjustment and- to a considerable degree- the expenditure of a large amount of highly skilled labor. In order to create a neural network, enormous volumes of data are required; however, the latest achievements in this area give the hope of a simplification of the development, adjustment, and application of neural networks; this is confirmed in [221].

For a quantitative assessment of the above-mentioned requirements in a range from 0 (poor) to 1 (excellent) we introduce

$$O_{mj},$$

where m is the number of the method (general number of methods will be specified later on in the research), j – the number of the assessment.

In the context of the current research, a set of the previously mentioned requirements is considered as an invariable. For various applications it is convenient to modify the relevance of each characteristic. The assessment is based on the experience of various application methods in a particular company. The research will further suggest preliminary, average assessments on the basis of the analysis of the advantages and disadvantages of the various methods carried out in the literature, as well as analysis carried out by the author on the basis of personal experience. However, similar to nearly all average assessments, they may not correspond to the real conditions in a particular company. In such cases, the assessments can be modified later in the process of the operation of a decision support system.

Identification of the situation parameters that are taken into consideration for the method selection. The situation parameters should be easily determinable. It is assumed that a computerized decision support system will establish certain correspondence between the situation parameters and parameters of various methods, which, in turn, will allow a method (methods) to be selected that correspond to the situation. For example, the availability of similar demands for a particular service to be rendered, requires the application of methods of simulating queuing systems or Markov chains. The need for classification of homogeneous objects (e.g., candidates for obtaining a bank loan) required the application of methods targeted at regular applications, such as neural networks, discriminant analysis, and classification trees.

Identification of a full set of significant situation parameters that allow the successful selection of an appropriate solution method is a separate task that will be addressed later on in the research.

Acquiring a set of methods ranked according to preferability. The preferential application of a particular method is determined by its correspondence to a situation and the decision requirements. We suggest using the following equation for the method evaluation:

$$A_m = B_m + \sum_{j=1}^{5} o_j O_{mj} ,$$

where A_m is a general assessment of the m-th ranking method; B_m - evaluation of the correspondence between the m-th method and the task, carried out by a decision support system on the basis of the input situation parameters (the idea of the system operation is described in [213] and in Chapter 3 of this research); o_j – evaluations of significance of each of the above mentioned evaluations, reflecting, in general, principles of product management activity accepted in a company (e.g., orientation towards one-time or regular decisions); O_{mj} – evaluations of each of the applied methods are made a priori on the basis of the experience of their application.

Assessment of quality ranking. A decision-maker should know the quality level of a decision suggested by a system. One can argue that a qualitative decision is a confident application of only one method and the rejection of the others. However, several methods are often almost equally applicable, and only a particular method subset can be rejected. The issue of selection quality is addressed in [213].

The decision about a particular method is made by a decision-maker on the basis of the results of the two previous stages. This part is difficult to formalize, and requires separate research that is beyond the scope of the current paper.

Application of a selected method to the solution of the initial task. Despite the fact that solving a task by different methods has its own features, the basis of the process of solution generation has an almost universal nature. Execution of this stage is based on the classification of decisions according to their types [62]:

- decision - generation, when the essence of the task is to develop a solution (e.g., to find the extrema of a function by the value of a derivative);
- decision - selection, when it is necessary to select the best option among several alternatives;
- decision - classification, when a situation is classified so that a particular decision corresponds to each potential class.

The type (class) of a decision is denoted as;

$$K=\{k_1, k_2, k_3\}.$$

The outline of solution generating should be divided into task levels that are comprehensible to decision-makers, who are the marketing specialists. This means that the goals of each subtask should be attainable as the result of standard actions, e.g., obtaining the parameter values, creating a situation model, acquiring the evaluation of alternatives. The solution to each subtask provides a particular result and accelerates the achievement of the ultimate goal.

Taking into consideration the increasing role of the human factor, the research suggests differentiating the generalized stages of the process of marketing tasks solving in the context of a contingency approach. These generalized stages are represented in Figure 2-2. The stages are named according to their main goals.

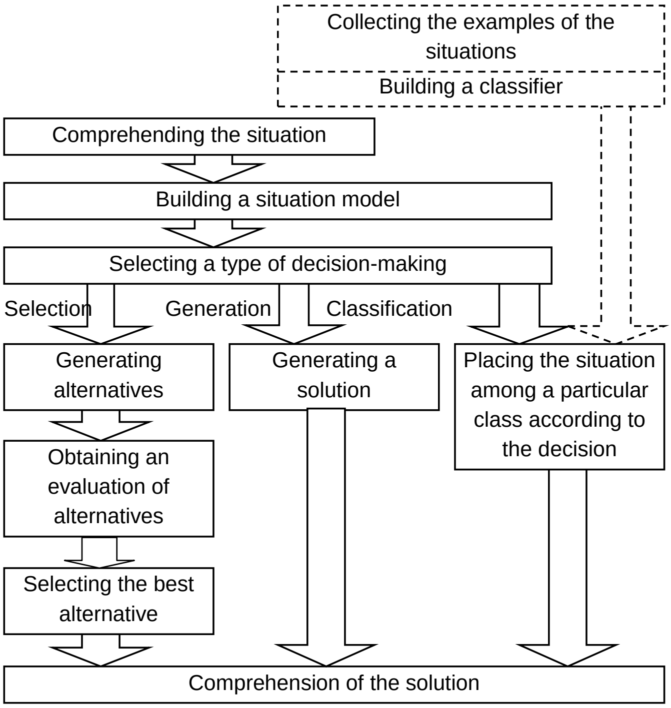

Figure 2-2 A general outline of the generation of solutions for product management marketing tasks

An outline of solution generation for a product management marketing task

Solution generation has the following stages:

1 Comprehension of a situation. At this stage the data acquisition and analysis takes place.

2 Building a situation model. By the term model we understand a prepared set of information about a research object collected for the purpose of studying this object.

3 Selecting a type of task for decision-making. A decision-selection, decision-generation or decision-classification is selected (in the picture from left to right).

4 Generating of solution alternatives (creative part).

5 Evaluating the alternatives on the basis of one or several criteria. The criteria set may require establishment.

6 Selecting the decision alternative best-suited to a particular task.

7 Decision generating. This stage is inherent in the decision as a form of generation. However, at the same time, it requires two preliminary stages: collecting situation examples and building a classifier.

8 To place the situation among a particular class is the essence of a decision-classification.

Classification requires the fulfillment of two auxiliary subtasks: collecting examples of situations with the correct solutions and building a classifier. This is the reason why the use of decision-classification requires preliminary preparation. The application of these types of solutions for one time tasks is rather limited.

9 Comprehension of the solution. The difficulty of comprehending the solution generation process, especially with the use of mathematic methods, is often the reason for their rejection by the administration. This is reason why this stage should be recognized as obligatory.

The multitude of solution stages of a marketing task is denoted as

$$Э=\{э_e\},$$

where $e=\overline{1,\ n_Э}$ is the number of the solution stage, and $n_Э$ is the number of the identified stages.

The decision implementation and the evaluation of the results often requires the application of special non-marketing methods either alone or alongside other marketing ones.

Taking into consideration the decision and its consequences for further activity (for method selection system learning) is beyond the scope of the current research.

Thus we have distinguished the standard features of the settings and the product management tasks' solutions, the general outline for the product management tasks according to the stages of its lifecycle including the goal-setting, the marketing situation description, and the selection and evaluation of a method; a solution for the marketing task has also been developed. In the solution, the typical product management task stages were noted and the application of a corresponding tools recommended.

This has significantly improved the solution of tasks in various areas of marketing activity, e.g., in marketing communication, and allows a problem to be defined that has appeared in a real situation.

2.4 The principles and methods for the computerization of product lifecycle management

In order to select a solution method for a product lifecycle management task corresponding to a particular situation, one should analyze the peculiarities of the application of various types of methods corresponding to the stages of the product lifecycle management tasks. These peculiarities are expressed through a set of qualitative parameters.

According to the suggested idea of a decision support system, in order to select a method for the solution of a product management task, one should determine a particular set of qualitative parameters of a marketing situation in the context of the task being solved. On the basis of these parameters a decision support system will offer one or several applicable methods.

In order to know what parameters should be determined, the important parameters of the solution methods should be decided and, on their basis, a uniform description should be compiled for the whole multitude of methods. Thus, selection will be carried out by comparing the situation specifics with the existing methods' parameters and the identification of the most suitable method. The probability measures of each method for each parameter and the specifics of each situation will be applied for the comparison. The result of this comparison is the applicability of each method to the assessed situation.

2.4.1 List of the applied methods' parameters

The list of parameters characterizing the various methods of application is determined on the basis of analysis of a rather broad set of the most commonly used methods of marketing tasks' solutions, provided in [62], [214], [206].

A broad review of the literature describing the various methods in the area of product management and examples of their application has been provided for the following set of parameters.

The aims of marketing research or the solutions for a marketing task can lie in conducting test marketing, the selection of a product for elimination, accomplishment of the generation of new product ideas, and making a selection among the existing concept alternatives, etc. However, in each particular case the real task has certain nuances that have to be considered, which require the marketing specialists to have high qualifications. That is why we suggest using more general objectives, which are easier to articulate for each particular situation as early as possible in the first stages of the task consideration. We suggest selecting such objectives as learning the value of the variables, employing fuzzy evaluations of the alternatives, selecting the best or the most reasonable decision, reflecting on the essence of the decision and its progress in everyday language, etc.

The type of model (TM). By the term "model" in the current research we will understand a set of knowledge about an initial system collected for the purpose of studying the latter. This is one of the broadest definitions of a model. There are various types of models offered in literature, such as descriptive, numeral, analytical, dynamical, cellular automatons, cognitive maps, etc.

The predominate type of relationship in a situation model or in a model required for decision-making (TR). The literature review resulted in identifying the following types: a general type of mathematical relationship (Mt); those including magnitude and its rate of change (MR); a linear (Ln); cause-effect (CE); a stochastic (St), a numerical (Nm), an algorithmic (Al), an unpredictable (Up), and an undetermined (Ud).

The predominate type of situation parameters (TP). A range of types was detected: quantitative continuous (QC), quantitative discrete (QD), fuzzy (Fz), scoring (Scr), comparative (Cm), qualitative (Ql).

The predominant methods for defining task parameter specifications (MS). The use of secondary data (SD), measurements, including conducting surveys and observations in the context of marketing research (Msr); evaluation of the parameters with the use of a computational model, e.g., extrapolation

(CMd) with the use of a simulation model (SM), standards (Std), and expert evaluations (EE).

The desired precision of the initial data estimate. Unlike expert evaluations that sometimes only require approximate parameter values, in linear programming the precision (Prc) of the parameters should be rather high in order to solve the tasks. The value of the parameters can be: high (H), average (A), and low (L).

Additional parameters. A set of special parameters exists for particular methods; they are listed in the last columns of the following tables.

2.4.2 Parameters of situation comprehension and methods of task-solving

The methods of situation and solution comprehension have many common features and are presented in Table 2–1. The different methods are characterized by the same value of their parameters, which supports the opinion that the method of choice for solving a particular task is ambiguous. For example, cause-and-effect relationships can be researched with the use of various methods.

While the issue of situation comprehension is quite well researched, e.g., in the context of a contingency approach, the issue of solution comprehension has been given much less attention in literature. The most difficult to comprehend are the decisions made as a result of the application of analytical models. In contrast, heuristic methods are easier for understanding. Expert evaluations are often accompanied by an explanatory note that helps to give the reasoning for the decision to some extent, but they are often taken as read.

The most comprehensible results are those of the expert system operation, because the system can save the sequence of the deduction of the new facts and present all the applied rules to a decision-maker.

The possibility to reflect on the progress of the decisions in ordinary language is one of the characteristic features of expert systems.

2.4.3 Parameters of simulation methods

The following stage of a marketing task solution is building a situation model. Simulation, in the form of data collection about the initial system is nearly always necessary. In some cases, the model can be a component of the method. For example, finding of extrema by determination of a derivative zero value implies an analytical model, while the linear programming method implies linear model. However, there is a range of models that it is more convenient to separate from the others, because they either have intrinsic value (e.g., knowledge representation model), or determine a method of operation (e.g., simulation model of queuing systems determines the operation method as Monte Carlo simulation experiments). The particularly important model classes are represented in Table 2–2.

Methods	Research objective	TM	TR	TP	MS	Prc	#
Pilot marketing research	Building a situation model Collecting data about the earlier decisions and their accuracy	No QI	-	QI Cm	SD Msr EE	L	
Non-experimental methods of causal research	Building a situation model Learning the interrelationships between the variables[4]	Cg QI IT	CE	QI Cm	SD Msr EE	A	
Experiments[5]	Learning the value of variables Learning the interrelationships between the variables	No Dn SM Cb	CE Mt	Qc QD QI	Msr	H	1
System analysis	Building a situation model Learning the interrelationships between the variables Generating the decision alternatives	Cb Ant Nmн Cg QI	Mt MR Ln CE Al	Qc QD QI	Msr CMd EE	B	
Expert systems	Obtaining an explanation for the decision obtained	Eт	CE	QI	Msr	L	
1 - Possibility to manage the value of variables: high - for real experiments; average - for pre experiments; low – for quasi-experiments.							

Table 2–1 Methods for situational comprehension, decision comprehension and their parameters (#- is a column for comments on the special parameters of particular methods)

Apart from the parameters introduced in the previous section, parameters typical of particular simulation methods or their groups have been added.

Process examination (P).

---

[4] Use of the term "interrelations" is determined according to the following reasoning. Firstly, sometimes a cause-and-effect relationship creates a causal loop; therefore the relationship between variables can be bilateral. Secondly, the structure of the cause-and-effect relationship between the variables has not been studied well-enough at the first stages of the research.

[5] Only the field marketing observations have been addressed in the research. The model experiments are related to simulations.

Model Type	Objective	TR	TP	MS	Prc	P	D	Hmg
Descrip-tive and qualitative	Learning the interrelationships between the variables Obtaining the qualitative evaluations of the decision's consequences Obtaining the qualitative system dynamics after the decision implementation	CE Ud	Ql	SD EE	L	0	0	0
Analytical	Obtaining the qualitative evaluations of the decision's consequences Obtaining the qualitative and quantitative system dynamics after the implementation of the decision	Mt St	QC QD	Msr CMd EE	H	0	0	0
Numeral	Learning the interrelationships between the variables Obtaining the qualitative evaluations of the decision's consequences	Nm Al	QC QD Ql	Msr EE	H	0	0	0
Knowledge repre-sentation	Creation of a knowledge formalization system	Any	Any	Any	Any	0	0	0
Cognitive maps	Learning the interrelationships between the variables Obtaining the qualitative evaluations of the decision's consequences Obtaining the qualitative system dynamics after decision implementation	CE	Ql	Msr EE	L	0	0	0
Consumer motivation	Learning the interrelationships between the variables Building a situation model Obtaining the qualitative evaluations of the decision's consequences	CE Nm Ln	Ql QC	Msr EE	L	0	0	0
Causal models of consum-ers' be-havior	Learning the interrelationships between the variables Building a situation model Obtaining the qualitative evaluations of the decision's consequences	Ln	Ql QC	Msr EE	L	0	0	0
Dynamical	Obtaining the qualitative and quantitative system dynamics after the decision imple-mentation	MR	QC	Msr EE	H	1	0	0
Lag mod-els	Obtaining the qualitative and quantitative system dynamics after the decision imple-mentation	MR	QC	Msr EE	H	1	1	0
Markov chains	Obtaining quantitative evaluations of deci-sion's consequences	St	QD Ql	Msr EE	H	0	0	1
Simulation models of queuing systems	Obtaining the qualitative evaluations of the decision's consequences	St	QC QD	Msr EE	H	0	0	1
Cellular automata	Obtaining the qualitative evaluations of the decision's consequences Obtaining the qualitative system dynamics after the decision implementation	Al St	QC QD	Msr EE	L	0	0	1

Table 2–2 Simulation methods and their parameters

Simulation with differential equations is oriented towards a consideration of the dynamics of the processes occurring in the simulation object. In numeral models, as a rule any temporal change of variables are not considered.

Discontinuity of the sampling instants and the formation of control actions (D). This type of discontinuity is typical, e.g. when planning marketing expenses as the distribution of profit. Discrete-time models are applied for this type of task. Other models do not have limitations of this kind.

The presence of homogeneous events or actions (Hmg) is a characteristic of queuing systems (arriving requests), but is not considered in, e.g., cognitive models.

The table assists the selection of the most suitable type of model for solving a particular task.

2.4.4 Parameters of the alternative generation methods

These methods mostly belong to creative techniques. Their common feature is that they are not used in decision support systems, but are meant for human performance. The parameters in most cases correspond to the parameters of the situation comprehension methods.

Creative methods and their characteristics are presented in Table 2–3. It is evident that nearly all of them have similar parameters, which makes selection of a particular one a difficult task and makes the choice subjective to a significant degree.

<table>
<tr><th>Method</th><th>Research objective</th><th>TM</th><th>TR</th><th>TP</th><th>MS</th></tr>
<tr><td>Inventions (the theory of inventive problem solving)</td><td rowspan="3">Creating the alternatives</td><td rowspan="3">None
Ql IT</td><td rowspan="3">Ud</td><td rowspan="3">QC
QD
Nm
Cm Ql</td><td rowspan="3">Msr
CMd
SM Std
EE</td></tr>
<tr><td>Model techniques of inventive activity</td></tr>
<tr><td>Morphological analysis</td></tr>
</table>

Table 2–3 Creative methods and their parameters

2.4.5 Parameters of evaluation and alternative selection methods

The evaluation of alternatives, as a task, can be divided into two parts:

In a situation, determination of the parameter values required for solving a particular product management task is done by conducting research that results in obtaining the initial data for the calculations and decision-making.

Determination of the preferability evaluation of the solution alternatives for the marketing task. Calculations of generalized estimators for each solution alternative for a product management marketing task according to one or several criteria also occurs here as a selection of the most appropriate alternative.

Due to the abundance of research methods for evaluating the task parameters this paper will only consider: a) methods related to the tasks of product management and b) model methods for each class.

Among the wide set of methods for alternative selection this research will only consider the models that represent different classes of the selection task solution.

2.4.6 Solution parameters - generation methods

It is important to comment on the reasons why operational management methods are included in this group. Generally, they refer to the stages of pre-production, operation, disposal, and – to a certain extent – the modification stage. This class of tasks is not directly associated with product management; they are typical for various types of management activity. Accordingly, these tasks do not require special marketing approaches and methods.

The very nature of the marketing tasks of operational management in the area of product management is the identification of the current problems and the responses to them. Usually, the alternatives are not taken into consideration and the decision is made on the basis of experience or according to an instruction or other management directive.

According to these features, the marketing tasks of operational management are considered a form of solution-generation.

The methods applied for the decision-choice, decision-generation and decision-classification are presented in Table 2–4.

Method	Research objective	TM	TR	TP	MS	Prc	P	#
Descriptive marketing research	Learning the value of the variables	Different	Any	QC QD Cm	SD Msr	H	0	
Joint analysis		Q	Ln	QD Ql	Msr	A	0	
Multidimensional scaling				QC QD				
Assessment of Psycho-logical Attributes		Ant Nm	Ln	QD	Msr	A	0	
Chaos identification	Obtaining the qualitative system dynamics after the decision implementation	Dn	Up	QC	Msr	*	1	
Expert evaluations	Finding the value of the variables; interrelationships between the variables; obtaining the qualitative and quantitative evaluation of the decision's consequences	-	Ud	QC QD Nm Cm Ql	O	A	Ud	
Monocriterial selection	Selecting the best in a certain sense solution; selecting a feasible solution; ordering the alternatives	Nm	-	QC QD Nm Cm Ql	CMd SM	A	Ud	
Multicriterial selection	Reduction of the number of options							
Mathematic techniques of hill-climbing	Obtaining either the best or acceptable solution	Ant Nm MPr Dn Pr[6]	Mt Nm Ant	QC QD	Msr SM CMd EE	H	0	
Non-optimized mathematic techniques	Learning the value of the variables; their interrelationships; building a situation model; obtaining the qualitative and quantitative evaluation of the decision's consequences	Ant Nm ND MCh Im	Mt Ln St Nm Al	QC QD	Msr CMd EE	H	0	
"Modern" factor analysis[7]	Building a situation model; learning the interrelationships between the variables		Ln	QC QD	Msr CMd SM EE	B	0	
Control systems with feedback	Building an automatic or automated control system	Dn Cb	MR Al	QC QD	Msr[8]	B	0	1
Fuzzy control systems		Dn Cb IT	MR AL Ud	QC Fz	Msr EE	B	0	
Search for solution in knowledge-based systems	Finding a multi-step solution	KnR	Sm	QC QD Scr Cm Ql	Msr CMd SM Num EE	Any	0	2
Expert decisions	Obtaining the best or acceptable solution; inventing alternatives; obtaining qualitative and quantitative evaluations of the solutions	Cg Ql	Ud	Scr Cm Ql	EE	L	0	
Deductive reasoning	Obtaining new knowledge	IT LP[9]	Scr	Scr Cm Ql	Msr EE	H	0	
Operational management methods	Elimination of the current problems	-	Any	QC QD	Msr	H	0	3
Cluster analysis	Defining the class of the current situation; building a classifier for new situations according to the solutions	An	Mt	QC QD	Msr CMd SM EE	H	0	

Table 2–4 Parameters of the methods applied at other stages of the product management task solutions (# - is a column for comments on the special parameters of particular methods)

6 Dynamic Programming.

7 So-called "modern" factor analysis is the building of factors according to the criteria of the dispersion maximization of the factor values for the elements of the research.

8 In the current research, in order to avoid an over-detalization, the managing part is presented as a non-divisible data converter.

9 Logical Propositions.

2.5 Procedure for the intellectualized selection of a method for solving product lifecycle management tasks

2.5.1 Initial data for method selection

Some of the parameters characterizing the methods are determined by the situation. In order to use a decision support system, a decision-maker should determine the degree of probability of all or some of the values of each parameter value, and input them into the system as initial data.

The list of the parameters that are determined by a situation consists of the following groups:

The purpose of the task solution from multitude P (see section 2.2);

The product management task from multitude Φ (see section 2.2);

The predominating type of situation parameters or the type of the most significant situation parameters: quantitative continuous, quantitative discrete, fuzzy, numerical, comparative, qualitative.

The multitude of parameter types is denoted as

$$T=\{\text{т}_t\}, \text{ where } t=\overline{1,\ n_T}.$$

The predominated types of dependence in the current model situation or in a model required for decision-making are: a general type of mathematical relationship; those including a magnitude and its rate of change; linear; cause-effect; stochastic; tabular (numerical); algorithmic; unpredictable; undetermined.

The multitude of dependence types is denoted as

$$З=\{\text{з}_z\}, \text{ where } z=\overline{1,\ n_З}.$$

A decision-maker may not always be completely certain of the above mentioned parameter's value. On the other hand, the situation can be irreducible to a unique value of a particular feature. To consider this peculiarity, the above-described variables should be fuzzy. This means that the textual meaning of each of the variables should correspond to the possibility rate for this value, subjectively input by a decision-maker in a range from 0 (impossible) to 1 (absolutely certain). “?” (unknown) is also an assumed value. Thus, the set of input valuation strings is as follows:

$$[B_{Ц,c}],\ [B_{Ф,f}],\ [B_{T,t}],\ [B_{З,z}].$$

String data allows the consideration of the uncertainty of the decision-makers. If they are certain, e.g., about the objective of the solution of a certain task, then all the values of the valuation line $[B_{Ц c}]$, except for one, will equal 0, and one value will equal 1. Whereas, when a decision-maker is uncertain about the solution objective of a certain task, then there will be few non-zero values in the line. Finally, if a decision-maker is incognizant of the objective at this stage, all the values in the line will be signified as “?”. Therefore, this concept of flexibly reflects the real situation, from complete uncertainty to complete certainty.

A set of logical characteristics is presented, obtained from the review of the applicable methods (see section 2.4), as well as the general outlines of the decision-making and solution to the marketing task (Figure 2-1 and Figure 2-2): $л_1$ – availability of solution alternatives; $л_2$ – availability of solutions for model situations; $л_3$ – discreteness of sampling and control instants; $л_4$ – discreetness of values of command variables; $л_5$ – availability of homogeneous demand; $л_6$ – the need for a process to be examined; $л_7$ – multi-step solution; $л_8$ – availability of several optimality criteria; $л_9$ – availability of uncontrolled events with several possible outcomes.

These variables can be denoted as 0 (no), 1 (yes) or “?” (unknown).

The multitude of logical variables is denoted as follows:

$$Л=\{л_l\}, \text{ where } l=\overline{1,\ n_Л}.$$

A set of fuzzy-logical quantities are the quantities introduced in section 2.4 with the values set as “high”, “average” and “high- low??”. In a general case, these variables are presented as analogue quantities from 0 (impossible) to 1 (absolutely certain). Some rough intermediate values are: 0.75- a rather high value of possibility, 0.5 – average value, 0.25 – a rather low value, 0.1 – very low value.

Another assumed value is ”?” – unknown. Values are subjectively input by a decision-maker on the basis of their knowledge of the situation: $н_1$ – high complexity of customer support process; H_2 – availability of off-the-shelf solutions for various situations; H_3 – a large number of experts; H_4 – high recurrence; H_5 – the possibility to manage the value of variables; H_6 – accuracy of introduction of the parameters' value.

Denotation for fuzzy-logical magnitudes is as follows:

$$H=\{H_n\}, \text{ where } n=\overline{1,\ n_H}\ .$$

The last variable, in contrast to the others, is an intervening variable. On the one hand, it is useful for method determination; but on the other, as a rule, a decision-maker will find it difficult to learn its value. It is convenient to determine this variable on the basis of a product management task. For example, if the task is to clarify demand for a new product, precision of determination of the parameters should be rather high. Whereas, if the pilot study is conducted in order to identify ideas for a new product, the precision of the parameter's determination can be much lower. Thus, it has been demonstrated that the selection of a method is not conducted directly from the situation parameters to the method parameters, but requires the use of interim steps.

A set of methods:

$$M=\{M_m\}, \text{ where } m=\overline{1,\ n_M}\ .$$

The methods described in section 2.4 will be used as an initial set.

We also suggest introducing a number of intervening (internal) variables that would:

- assist in obtaining cross-validation of the input evaluations and the process of achieving a result,
- facilitate the obtaining of expert evaluations,
- simplify the transition of the initial parameters into result.

One can assume with certainty that the best decision is obtained by dividing the search for a final solution into as many logically relevant parts and clear expert steps as possible, because this allows consistent initial expert evaluations to be achieved.

The difference between internal variables and situation parameters is as follows:

- the former are more difficult to determine according to the situation parameters. For example, determination of a model type (an auxiliary variable) requires deep knowledge of the applicable methods;
- the internal variables are derived from the situational parameters. For example, decision generation (the solution type is the auxiliary variable) is applied in cases where solution alternatives are available (the parameter of a situation).

The research introduces the following auxiliary (internal) vector-like variables:

Solution class (C) (see section 2.3);

Stage of decision-making S (see section 2.3)

Method of parameter determination: according to a design model, including the application of extrapolation methods; according to a simulation model; secondary data; measurement; measurement data; expert evaluation.

Denotation of the parameters' determination method and the evaluation of the method probability is respectively;

$$\text{C}=\{\text{c}_s\}; \quad [\text{B}_{\text{C},s}], \quad \text{where} \quad s=\overline{1,\ n_{\text{C}}} \ .$$

Model type: analytical (Ant) ; numerical (Nm); dynamical (Dn) (differential and difference equations); mathematical programming (MPr) (linear, integer, convex); simulation queuing system; Markov chains (MCh); interrelations between psychological attributes; network diagrams (ND); non-optimized operational research; decision tree; knowledge representation (KnR) (semantic (Sm) or object-oriented network); statements, if-then rules (IT), if-then rules of management; cognitive; qualitative (including verbal description); game; dynamic programming; cybernetic (with input, output, disturbing influence, feedback and/or control of disturbances); morphological; cellular automatons; model type absent.

The denotation of the model type and the evaluation of its applicability is respectively:

$$\text{Д}=\{\text{д}_{\text{d}}\}; \quad [\text{B}_{\text{Д},\text{d}}], \quad \text{where} \quad d=\overline{1,\ 20} \ .$$

2.5.2 The result of method selection

As a result of the method selection an evaluation matrix should be built in order to assess the degree of applicability of each method to a particular situation. Five requirements for the solution methods have been examined earlier in the research. Moreover, a generalized estimator of the methods' applicability should be prepared. All the estimates should belong to a range from 0 (application is impossible) to 1 (application is absolutely appropriate). Thus, the final evaluation matrix should have a column for the generalized estimates and a column for each partial estimate. The denotation of the result is:

$$[O_{mj}].$$

Unlike the denotation introduced in section 2.3, an additional column j=0 is added denoting the general estimator of the expediency of the application method.

2.5.3 Evaluation of the ranking quality

The tables presented in section 2.4 confirm that the characteristics of various methods often concur. This means that different methods can be applied to the same situation. Consequently, the generalized estimate of method applicability in a general case will have several nonzero values.

Ideally, one method has a probability value 1, while the others have zero probability. Result that presents equal probability for all values is not very useful, though it proves that the application of the methods is possible.

Cases where some of the values have a probability value 1 while others have zero probability can also be considered useful, because they limit the choice to several options and make the selection easier for the decision maker.

However, cases where the probability gradually lowers are considered unsuccessful, because they do not allow a confident choice to be made.

The quality of method selection in the decision support system is provided by:

- the maximum use of available information about a situation;

- the possibility to adjust the parameters for a specific application, e.g., on the basis of real method selection carried out by the decision support system.

Quality measures for selection will be examined in detail later in the research.

The final solution is a multi-step transformation of masses of initial data into a result.

Thus, the task is formulated as is shown in Figure 2-3.

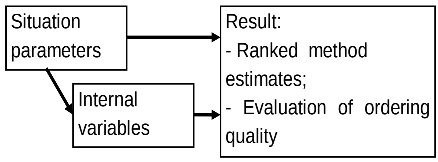

Figure 2-3 Selection of a solution method for product management tasks

Mathematical formulation of the problem

$$<В_Ф, В_З, Л, Н, П_М> \rightarrow <В_М, О_М, \alpha>,$$

where $В_Ф$ is a row of the probability of a situation occurrence on one of the possible stages (tasks) of the product management process; $В_З$ is a row of the probability of interrelation types between variables; Л is a row of logical variables values; Н is a row of fuzzy-logical variables values; $П_М$ is a row of methods; $В_М$ is matrix of method applicability; $О_М$ is matrix of method estimates; α is evaluation of selection quality on the basis of a generalized estimate.

The solution is provided through the determination of auxiliary variables: a row of probability that a particular situation will occur in each class of decision-making tasks: $В_К$; rows of the probability that this situation corresponds with a particular stage of decision-making task $В_Э$; rows of the probability that the parameters are determined in a particular manner $В_С$; rows of the probability applications of a particular model type $В_Д$.

Finally, the task solution is a multi-step transformation of masses of initial data into a result.

$$\langle В_Ф, В_З, Л, Н, П_М \rangle \longrightarrow \langle В_М, О_М, \alpha \rangle$$

$$\searrow \langle В_К, В_З, В_С, В_Т, В_Ц, В_Д, н_5 \rangle \nearrow$$

2.5.4 Conclusion

10 A scientifically proven methodological theses has been presented on the formation of a complex of interactive-intellectual systems for all stages of product management, price formation, promotion, and distribution. This will allow an increase in the efficiency of the "manufacturer-consumer" system functions in small-sized manufacturing enterprises.

11 A general outline has been developed for the decision-making in product management tasks according to the stages of its lifecycle. It has been developed on the basis of the revealed standard features of the settings for solving product management tasks. It includes, aim setting, selection and evaluation of the method, and a solution for the marketing task. This outline is notable for a multi-choice and a typification of the stages of product management task solutions, as well as the application of the intellectual tools. These features broaden the usual set of methods orientated towards the subjective qualities of the decision maker and facilitate the task solving process for various aspects of marketing activity; they also provide clarification of the problems raised in real situations.

12 A substantial and mathematical statement has been provided for the method selection problem for product management tasks. Its essence is the determination of the correspondence between the method parameters and the offered list of fuzzy situation parameters. The outcome type is a degree of preferability of a particular method application. This allows an increase in the reasoning concerning decisions in the "manufacturer-consumer" system by the means of fuzzy and incomplete information about a situation.

13 A new classification of management solution methods has been offered for product management tasks. It considers the purpose of the simulation, the type of dependences, the type of situation parameters, the method of parameter identification, the dynamics of the processes that occur in the model-based object, the discontinuity of sampling instants

and formation of control actions, the availability of homogeneous events and actions. On this basis, a new set and list of variables types have been introduced. They describe the parameters of the product and the market situation: logical, fuzzy-logical, row vectors of probability. This has provided an appropriate representation of a situation and the maximum use of information, including incomplete data, in order to obtain more reasoned decisions.

3 SYSTEMATIZATION OF THE METHODS AND MODELS FOR COMPUTERIZED PRODUCT LIFECYCLE MANAGEMENT

The suggested methodology consists of two main parts:

1 A set of methods and models for client-oriented product lifecycle management. They provide for the management per se, and their successful application requires development of the recommended practices and examples.

2 A tool (expert system) for the selection of a method or model appropriate to a situation. This tool is the main element that combines the methods and models into a unified methodology.

In order to build a method selection system, various methods and models should be reviewed. As a result, the applicability of a particular method for each stage of the product management and for a possible multitude of situations can be determined.

3.1 Purposes and principles of the systematization of the methods and models for product lifecycle management

In order to determine which method can be applied to solve a particular marketing task, a detailed study of concrete examples of application of various methods should be conducted, and combined in a uniform system in order to compare their preferability for solving particular product management tasks.

The literature on the methods applicable to product management is rather extensive (references are provided as the methods are examined later on in the research). One should note that there is a fairly common tendency to describe a method before stating its possible application. However, in order to solve real tasks it is more useful to start with a particular task and select a particular method to solve it. In the current paragraph, an interim step in the transition is reflected on when searching for a method on the basis of a particular task; the methods are grouped according to the stages of product management activity. Within the stage, the examination starts with a method, followed by a determination of the possible modifications, and examples of tasks that can be solved with the use of this method.

The current chapter facilitates the determination of the main component of selection of a solution method for a marketing task: a set of methods applicable for each of the earlier examined stages of product management.

In addition, the conducted overview will later facilitate transition to the determination of the applicability of each method based on a set of values for the parameters addressed earlier in the research.

This study is unable to encompass the entire set of applicable methods in detail due to their extensiveness; therefore, the following approach will be applied in order to obtain a rather full picture of the applied methods.

Some methods that are widely described in detail in the literature and are applied in the allied sciences (economics, management, psychologies, statistics) will be only mentioned in the current research and will not be further addressed. These methods will be indicated by the number 1 in the column Cmt (Comments).

The application of the methods that are is discussed and exemplified in the literature, will be referenced indicated by the number 2.

Methods and tasks that are still insufficiently used and researched in literature are not examined in the paper. However, they can have great potential in future. This group of methods is indicated by the number 3.

Methods and tasks that play significant role in product management will be closely examined in the following paragraph.

There are some methods that are characterized by high complexity and labor-intensiveness and require expert knowledge, e.g. the development of expert systems. Examples of the application of these types of methods also fall outside the scope of the research. They will be indicated by the number 5.

Finally, there are universal methods that can be applied to different tasks. They will be examined by an example of a particular situation, and for other possible tasks, they will be indicated by the number 6.

3.2 Analysis of various methods and models applied in the area of computerized product lifecycle management

The methods applied at different stages of product management and examples of the tasks that can be solved with the help of these methods are as follows:

Identification of SMA parameters for decision-making

Given: a set of economic indices of the external environment and their value (measured by monitoring or only once); the model is selected after the indices have been forecast	→	Required: determination of a set of indices required for decision making

Method	Types	Task examples	Cmt
Calculation of the indices' significance	Numerical methods	Universal methods[10]. The SMAs are the research elements.	6
Cluster analysis		Typification of the SMAs according to a set of features	1
Discriminant function analysis		The SMAs are divided into two groups on the basis of a linear discriminator: perspective and not perspective. The significance of the parameters in this case is determined by standard methods.	1
Competitiveness of a product or an SMA	Numerical methods	Universal methods. In order to evaluate available SMAs	2
Matrix methods (here and later in the research a review of the matrix methods provided in [206] is mostly used])	Cooper's matrix	Analysis of the appeal of the industry and business force [163]	1
	Shell/DPM matrix	Analysis of the appeal of the resource-intensive industry depending on the competitiveness [67]	1
	Strategy matrix of business in a declining stage	Analysis of the competitive advantages in the sectoral environment [163]	1

[10] Universal methods are described at the end of the review.

	Matrix of the parameters of data acquisition methods (depth cost, data acquisition time)	The list of researched parameters [178] is determined by their dependence on a situation (financial performance, required speed of decision-making, resources)	2
OLAP	Interactive cross-tabulation	Data about sales is available as a table with the following fields: Time, Class of goods, Product, Region, Seller, Customer, Sum Total, Amount[11]. Conducted: -analysis of the sales structure in order to identify the main components from the required angle (e.g., knowing sales leaders in each region); -identification of tendencies, seasonal movements according to products and regions; -identification of the dependencies of some variable on other variables, e.g., the number of expensive goods purchased might reliant on regions or months; -comparison of groups of products or SMAs according to a set of factors. Making a decision on whether working with the goods or SMAs is possible. [144] 2. The structure of the demand is determined according to the data on sales and retrieval requests. [158]	2
Classification trees		Determination of the features of an SMA that are significant for its success based on the available description of the SMA with a set of features	4
Neural networks		Development of a classifier for the SMA according to the available examples of the SMA and the correct solutions for them (e.g., to develop an SMA or to leave it)	4
Expert systems		Feeding into a computer the expert experiences of the selection of an SMA for future decisions, and to demonstrate the reasoning	5,6
Expert conclusion	SWOT-analysis in order to identify opportunities and threats	To identify positive and negative factors of the external environment of a SMA [2], [279]	2

[11] This data can be found in invoices.

Analytic calculations [118], [162], [140]	Evaluation of market size	According to the absorption of the market in the reference period, demand at a particular reference period, forecast, demand forecast	2
	Market saturation factor	This is determined according to the following parameters: -potential demand at the moment of market entry; -change of demand during different periods of time (function of promotion factors, service life, the number of customers, purchasing performance); -sales volume in the different periods of time.	2
	Evaluation of a market segment - considering elasticity	An analytical function is applied as regards the level of product quality, the price, the effective advertising expenses, sales promotion, the demand elasticity coefficient according to the quality, and price and advertising [290]	2
	Analysis of the changes of market conditions with the use of Markov chains	The probable states of the market are known as well as an evaluation of the probability of transition from one state to another, the result (profit or loss) of this transition under the implementation of each strategy from the given set. The strategy for each state of the market is determined according to the maximum economic efficiency.	2
Chaos identification		Evaluation of predictability of the external environment	4
Cognitive maps		Understanding the main mechanisms of the external environment, building a qualitative model [71]	4
Knowledge engineering		Systematization of the knowledge about the object domain, the SMA in this case.	4

Identification of the internal environment indexes for analysis

Given: 1) results of analysis of the external environment: significant indices, their current and predictive values 2) standard set of indices of the internal environment for analysis	→	Required: determination of a set of indices of the internal environment for further research

Method	Types	Task examples	Cmt.
Calculation of the significance of the indices	Numerical methods (universal)	Determine the variables that influence the competitiveness of a company [240], [241]	2

Expert conclusion	SWOT[12]-analysis in order to determine the weaknesses and strengths of a company	Identification of the strengths and weaknesses of a company [2], [279]	2

Evaluation of marketing indices of a company

Given: economic and marketing indices of a company	→	Required: obtaining integral estimates of the company's features (strengths, weaknesses, competitiveness, etc.)

Method	Types	Task examples	Cmt.
Expert evaluation	Universal method		2
Numerical methods	Calculation of the indices of market attractiveness	Available indices of the technological level of the analogue goods in the markets, their prices in each market, their relative utility indices in each market. The index of each market is calculated as a sum of the deviation of particular indices from their best values in the markets [140]	2
		Evaluation of the SMA according to the weighted total of the indices [104]	2
Matrix methods	SWOT matrix	Analysis of the weaknesses and strengths of the SMA, as well as opportunities and threats [2], [279]	2
	Boston Consulting Group matrix for SMA	Classification of the SMA into types according to which the following decisions can be made: developing activities, leaving, changing activities, obtaining profit [12]	2
	MCC[13]	Analysis of the correspondence between the mission of a company and its main capabilities [175]	2
	Vector matrix of Economic growth	Analysis of statistical data [291], [55]	2

[12] Analysis of Strengths, Weaknesses, Opportunities, Threats

[13] Matrix of Core Competencies.

Development or adjustment of a product strategy

Given: 1) company objectives; 2) company marketing strategy 3) results of the analysis of the available SMA 4) results of the research on the internal environment of a company	→	Required: formation concerning the principles of pursuing the company's objectives in the product area with the proviso that the external environment can change

Methods	Types	Task examples	Cmt.
Expert conclusion	Universal methods	Determination of the methods for achieving significant goals in the area of product policy	2
Cognitive maps		Examination of the qualitative consequences of the application of a particular strategy	4

Generation of alternatives of new SMA

Given: name and concise description of a new SMA	→	Required: evaluation of the new SMA according to attractiveness (from dichotomous to quantitative estimation)

Method	Types	Task examples	Cmt.
Expert evaluation	Universal methods		2
Matrix methods [206]	Competitive position improvement matrix	Analysis of the differentiation and business reach [55]	2
	"Differentiation / relative cost efficiency" matrix	Identification of the dependency of the relative cost efficiency on the differentiation in a particular market [75]	2
	"Productivity-innovations / differentiations" matrix	Demonstration of the dependency of the productivity on a particular business unit for the implementation of the innovation. [75]	2
Numerical methods		Evaluation of the SMA with the use of the weighted total method according to the suggested indices [251]	2
Multicriteria selection	Universal methods	Evaluation and selection of an SMA or a new product according to the suggested criteria [274]	2

Monte Carlo simulation of queueing systems		For a service company – determining the service parameters (e.g., average service time) depending on the usage of resources (e.g., the number of service lines) and their method of organization [65]	2
Game theory [4], [61]		1. A new company makes a positive or negative decision on whether or not to enter a monopolistic market. The market leader can be friendly or hostile towards the company. The quantitative outcome of each alternative is known 2. Two organizations that have different technical equipment decide on a technical upgrading. The amount of investment required by each of them (several alternatives are possible) and the expected result for every possible action of the associates are known.	2

Determination of consumer behavior models for SMA

Given: proposed new SMA (name and concise description)	→	Required: 1) determination of a consumer's behavior model 2) evaluation of the adequacy of the model (from dichotomic to quantitative)

Method	Types	Task examples	Cmt
Expert conclusion	Universal method		2
Examination of the psychological characteristics	Testing and building of the structural equations	There is available data on consumers, collected by means of surveys and observations. For example, a survey on risk tendency and an observation of the purchasing process. A hypothesis is advanced that there is a certain interrelation between these parameters with the possible inclusion of internal variables that cannot be measured, e.g., credulousness dependencies are considered linear. The computer selects the quantitative parameters of the linear dependences of the behavior characteristics (purchases) of the survey results in order to predict the behavior in the best way according to the survey results. The adequacy estimates are statistical.	3[14]

[14] Useful examples are lacking in the literature, which can probably be explained by the fact that modern conceptions of the reasons behind human behavior have not been fully examined as yet. This area is researched on a qualitative level.

Matrix methods	The Foote, Cone, and Belding involvement grid (matrix)	Products are typified according to the level of involvement of the consumers in the process of selection, and the approach to selection. The type of product determines the consumer behavior model: training, emotionality, routine, hedonism [143]	2
Knowledge information processing [241]	Enumeration, deletion, addition of features, depth-first and breadth-first search, genetic algorithms	A set of features that can be used for model building is available. Building of the best model in a given sense is required	2
Expert systems		Formalization of expert knowledge. Model adequacy estimates are the expert ones.	6
Cellular simulation		Simulation of the qualitative dynamics of consumers' preferences depending on the preferences of "neighbors" [222]. A similar task for electorate's preferences has been researched in [26].	2
		Building a diffusion model of innovations among consumers. An individual's state: whether the novelty is accepted or not. The probability of acceptance depends on the state of the nearest neighbors [222], [36]. The concurrence with observed processes is checked	2
Cognitive maps		Determination of the factors and the way in which they influence consumer behavior. Adequacy is evaluated with the use of expert conclusions on a qualitative level.	6
Numerical simulation	Indifference curves	Determination of the consumer's choice between two products in the market [168] Determination of the consumer's behavior in terms of indifference curves [54].	2

A priori segmentation

Given: a new SMA	→	Required: identification of the consumer segments (to target (or not to target) a particular product at variety of consumers)

Method	Types	Task examples	Cmt.
Expert conclusion	Universal method		2
Creative methods	Universal methods		1
Factor analysis	VALS2, iVALS	Determination of the psychological types of consumers based on the questionnaire survey results. The questionnaire is included in the meth-	2

		ods used in [63], [70]	
	Methods of differential psychology	A typification of personalities is conducted, and the factors of intelligence are distinguished: speed and flexibility of perception, memory features [170]. Methodologies of psycho-diagnostics are developed.	1

Evaluation of segments' attractiveness and selection of a target segment

Given: a multitude of proposed segments based on the demographic, geographic and socioeconomic characteristics	→	Required: evaluation of the attractiveness of the segments (from dichotomous to quantitative)

Method	Types	Task examples	Cmt.
Expert evaluation	Universal methods		2
Numerical methods	Weighted sum of estimates	A set of product indices for industrial-engineering use is proposed, the numerical scores of segments are calculated. [71]	2
Integer programming	Segment optimization	There is a set of segments with the following characteristics: the number of goods that can be sold, the production and disposal costs per unit in each segment, the production and disposal costs not dependent on the sales volume, the proceeds of sales, the total number of segments needing development, the minimal target profit. Minimization of the segment development costs is necessary [140]	2

Identification of methods of idea generation

Given: 1) A set of methods for the generation of ideas 2) SMA	→	Required: selection of "the most suitable" method of product idea generation

Methods	Types	Task examples	Cmt.
Creative methods	Universal methods		2
Customized application of Algorithm of Inventive Problem Solving (AIPS)	Method for an "absolutely perfect product"	A step-by-step procedure for product description is suggested: An absolutely perfect product that satisfies a particular need instantly and is cost-free, i.e. functions perfectly. A perfect product. The essence of the product. Actual product. Product of the future (perspectives) [229].	2

Evaluation and selection of new product ideas

Given		Required
Given: 1) new product ideas; 2) ideas for SMAs; 3) consumer behavior model; 4) similar cases with correct decisions	→	Required: 1) determination of the demand parameters (quantity, pattern of change of demand) depending on the price and characteristics of a product) 2) evaluation of general appeal of each idea (from dichotomous to quantitative estimate)

Methods	Types	Task examples	Cmt.
Expert evaluation	Universal method is offered for this task in [66]		2
	Method of scenarios	Development of a new product sales development scenario [93], [183]	2
Analogy	Extrapolation based on similar cases	Extrapolation of historical data on similar products in similar markets, they can be the company's own or the competitors' products. Similarity of the products is determined by experts [66]	2
Pattern matching		The calculation of the parameters' value is determined in the same way as in similar cases [294], [292]	2
Quantitative impact analysis	Setting up equilibrium between market efficiency and market share	Market efficiency is the ability of a particular product to satisfy a particular need. It depends on the marketing mix. Market equilibrium means that the market share is proportionate to the market efficiency [190]	2
Analytic calculations		The market potential is calculated using a formula which depends on the number of consumption units, the index of their capacity, the elasticity of demand and other factors [138]	2
Neural network	Forecasting	Building a forecasting system on the basis of neural networks according to the historic data [139], [106]. Models are built separately for each type of lifecycle, which is determined according to the product's characteristics by the above-described neural network.	2
Regression analysis		Building the dependence for a general assessment of an idea on its parameters - according to statistical data for a particular type of product	1
Analytical methods	Engel curves	The dependence of the expenditure of a particular product on the income. The type of dependency is determined by the type of product [35]. Possibility to find an optimal price.	1

	Research on price elasticity	Demand forecasting on the basis of demand during the reference period, prices and profit during the reference and forecast period, elasticity coefficients of the price and profit, inflation coefficient, forecast changes in the market share [35]. Demand forecasting with the use of elasticity coefficients of various factors (nested and crossed) [35]	3
Descriptive marketing research	Surveys	Identification of the demand on the basis of the survey	1
		Panel studies in the real test market [48]	2
Causal research	Experiments	Virtual sales, surveys [270], [110]	2
Numerical calculations	Normative method	Evaluation is based on the available data on: standards test, repeat purchases, purchasing cycles, and other categories [46].	
Numerical methods	Analysis of the quality of goods and services	In order to determine the engineering quality standards index, relative[15] indices, measured during testing, are weighted according to their significance determined by the survey results [21], [96]	2
	Evaluation of the conditional and unconditional indices of consumer utility of innovations	The evaluation of benefits is measured by the consumers' willingness to pay for them. The conditional and unconditional indices of the utility to the consumers of the innovations are determined [309]	2
Matrix method	"Quality-Resource intensity" matrix	Products are classified according to quality and labor intensity. It is suggested that low quality and low labor-intensive products are improved, the sales of the high-quality low-price products are extended, the labor-intensity of the high-quality expensive ones are lowered, and a transition to new models in the case of expensive low-quality products [74]	2
Qualitative methods of decision-	Analytic hierarchy process	A multi-criteria task of selecting a product alternative taking into consideration the resource capacities of a company [140]	2

[15] In relation to the available analogous product

making	Closed procedures	Alternatives (unique, without analogues) are evaluated on the basis of qualitative, partly expert estimates (deconstructed in a manner that suits the human capacity). Systems of alternative ordering are based on the estimates. The greater the volume of the evaluation data, the more complete the ordering will be [64]. This differs from the analytic hierarchy process used for smaller amounts of work and incomplete ordering of the alternatives.	2
Multicriterion choice	Universal methods		2
Numerical methods	Subjective utility function	Each project is granted a certain economic index, e.g. effect. The relationship between the decision-maker and the effect is non-linear and subjective. The function of the Utility (Effect) is built to take this fact into consideration. [293]	2
Decision making under uncertainty [10]	Optimistic, pessimistic and the most probable alternatives	An idea evaluation model is available. Some values are determined by experts and presented as 3 values. Accordingly, three versions of the calculations are performed, and the selection task has three criteria according to: pessimistic, expected, and optimistic estimate [137], [142], [161]. It is also possible to take a weighted average value for the three options as the result. Usually, the weights for the optimistic and pessimistic estimate are considered to equal 1, and the most probable one – 4 [68]. 3. Transition to a task including fuzzy quantities. The Function Probability (Value) has a partial triangular form	2
	Fuzzy quantities	Fuzzy quantities are often used in the evaluation [142], [230]. In the general case function the Probability (Value) has a trapezoidal form.	2
	Fuzzy logic	An idea is evaluated according to the general characteristics, risk, industry practices, and other external factors. A model implies an evaluation of the suggested idea from its complete acceptance to rejection [24], [29].	2
Risk analysis	Decision making under risk	Several uncontrollable outcomes are possible as a result of the decision making. It is necessary to find the one that is optimal in a particular sense [72], [244]	2

Forecast of the development of relationships with business partners

Given: 1) information about the current and forecasted state of the internal and external environments 2) a new product idea	→	Required: 1) determination of the quantity of indices (for partners: volume of orders, loyalty, etc.; for competitors: probability of new product appearance, change in prices, etc.) and qualitative description of measures for each scenario

Methods	Types	Task examples	Cmt.
Expert conclusion	Universal method		2
Risk analysis	Decision making under risk	There is an abundance of action alternatives and possible states of the external environment. There are estimates for each alternative in each state of the environment. Various criteria for selection of the best alternative are proposed (minimax, maximax, Hurwitz's criterion, Savage criterion, Bayes' principle, Bernoulli's principle (utility function) [169], [150]	2
	Decision tree	It is required that a decision be made on the range of goods taking into consideration several possible consumer reactions. Some outcomes may require additional measures [95]	4
Expert systems		Expert experience is formalized	5
Numerical methods	Demand forecast by time series	Information is available on demand. Data smoothing and extrapolations are performed. [78]	1
Dynamic simulation	Qualitative analysis Qualitative solution	A model of the interdependence between the variables describing a particular situation is available. The model links quantities with the rate of their change. It is required that the qualitative characteristics of a solution (stability, variability) are determined and that a qualitative forecast be built on the processes	4
Dynamic programming [18], [78]		There is an abundance of options for transition from one situation to another. It is required that the best way be found from the initial state to the final state	4

Development of the research on a product

Given: description of a new product idea	→	Required: development of a technical task for the research on a product

Performed on the basis of experience

Development of a technological research task

Given: description of a new product idea; 2) description of a company (resources)	→	Required: development of a technical task for the technological research on a product
Performed on the basis of experience		

Identification of methods for concept generation

Given: 1) a set of concept generation methods; 2) a new product idea	→	Required: selection of "the most suitable" method for generation of a product concept

Expert conclusion

Generation of concept alternatives

Given: a new product idea	→	Required: development of alternatives for the product concept

Universal creative methods are applied

Identification of the models of the novelty acceptance by the consumers and evaluation of the concept according the consumers and customers

Given: 1) Product concept 2) a set of standard acceptance models for the novelty 3) analogous cases	→	Required: 1) Identification of models of the consumers' and customers' acceptance of the novelty; 2) Evaluation of the product' levels of necessity, memorability, and the appeal of the concept.

Methods	Types	Task examples	Cmt.
Cognitive maps		Are created by a researcher in order to understand the basic laws of consumer behavior and to build a qualitative model	6
Expert conclusion	Universal method		2
Expert systems		Expert experience is formalized	5
Research of customer and consumer psychology	Conjoint analysis	A set of interrelated parameters for a new product is made available. The survey helps to determine the preferences and quantity of the popular models and their parameters [305], [45]	2
	Perception maps	Non-attributes. - the number of variables, analyzed by consumers while selecting: -their name; -the relative position of the analogous products is determined on the basis of the similarity of the complex products with many of the parameters being perceived by the consumers [171], [206].	2

	Kano method	Customer requirements are divided into basic, desirable and having an influence [280]. There are also more complex modifications. A free web site for conducting research using this method can found at: http://www.kanosurvey.com/	
Numerical calculations		The degree of satisfaction is determined as a weighted sum of satisfactions of several particular parameters weighted by the significance of each particular parameter [252], [250]	2

Identification of the method of concept positioning

Given: 1) a new product concept 2) standard methods of positioning	→	Required: 1) determination of the positioning parameters 2) a method of concept positioning

Methods	Types	Task examples	Cmt.
Expert conclusion	Universal method		2
Expert system		Expert experience formalization	5
Neural networks		The following information is available for a broad group of consumers: information on the value of the factors significant for selection (price, product characteristics); the beliefs and psychological characteristics of the consumers; the marketing influence on consumers, the consumer behavior. The neural network learns to predict behavior on the basis of a set of other (input) factors. The neural network's methods facilitate identification of the complex relations between demand factors, forecasting consumers behavior in the context of changes in marketing policy, identification of more significant factors and optimal positioning, the advertising strategies as well as identification the consumer segment, which is the most perspective for a particular product [238], [32], [106]	2
Multidimensional scaling		Perception of similar products is determined on the basis of surveys, along with a set of important characteristics and their preferable values [206], [45], [30]	2
Matrix methods	"Price-quality" matrix	Positioning of a product depending on its quality and price [287]	2

	"Design level – Technology level" matrix	Positioning depending on design and technology. Product types: generics, kitsch, advanced technology, and breakthrough products [160]	2
Creative methods	Universal methods		2

Identification of the elements of the concept marketing mix and the objectives of each component

Given: 1) concept of a new product 2) positioning principle 3) consumers behavior model	→	Required: identification of elements of the concept marketing mix and the objectives of each component

Methods	Types	Task examples	Cmt.
Expert conclusion	Universal method		2
Creative methods	Universal methods		2
Informal methods			5

Development of the technical parameters of a product

Given: 1) description of the idea and concept of the new product; 2) description of the company's resources	→	Required: determination of the detailed technical parameters of the product

Performed on the basis of experience

Development of a technical task for a product

Given: detailed technical parameters of the product	→	Required: development of a technical task for the design and development work on the product

Performed on the basis of experience

Development of a technical task for technology

Given: 1) detailed technical parameters of the product; 2) results of the design and development work	→	Required: development of a technical task for the design and development work on the production process

Performed on the basis of experience

Concept evaluation in the context of test marketing on model and controlled markets

Given: 1) product concept; 2) consumers' behavior model[16]; 3)results of laboratory experiments; 4) sales number on the controlled market	→	Required: determination of the concept parameters: parameters of transition from lack of information to awareness, trial purchases, repeat purchases.

Methods	Types	Task examples	Cmt.
Analytical methods	The LITMUS model	An advertising influence test is performed in laboratory conditions as regards the possibility to buy a particular product at a discount. Consumers are subject to a survey. As a result the following can be predicted: the transitions from lack of information to awareness, trial purchases, repeat purchases, preferences for the product over analogous ones. Consumer fascination with the product, its distribution, the company brand, and any distortions caused by the laboratory conditions[17] should also be taken into account [46].	2
	Discovery model	The development of the LITMUS model This takes into consideration new forms of awareness building, such as: the Internet, "word of mouth", and the forgetting effect. The interaction of the following main factors of awareness is examined: advertising, promotion, sampling, and distribution (incl. representation on the shelves) [46].	2
Analytical methods	Bases model	A new product is presented to customers as a concept, after which they are asked about purchasing probability and the probability of repeat purchasing. Expected market share, distribution indices, ratings of goods and companies are also taken into consideration [46]	
	Simulator ESP model	This is based on the sales on the controlled market; it includes schemes of repeat purchases (options for time allocation between the purchases). Sales over the first year are predicted as well as further tendencies [46]	2

[16] All models work with both model and controlled test marketing. Controlled test marketing allows the model parameters to be specified on the basis of accumulated real sales experience.

[17] In 90% of sales forecast cases the error of the sales forecast of the new product was less than 15%.

Simulation modeling		The probabilities of the purchasing of a product that belongs to a particular category or type, and repeat purchases are determined on the basis of the characteristics of a segment either by statistics or experts. Then the process of initial and repeat purchases is simulated taking into consideration past events and consumption rates [94], [93]	2
Simulation of control systems with feedback		Reception of the quantitative dynamics after the decision implementation [79].	

Determination of the product variety according to the results of the test marketing on controlled and real markets[18]

Given: 1) a new product concept 2) Results of the test marketing on the controlled market 3) results of the test marketing on the real market	→	Required: determination of product variety

Methods	Types	Task examples	Cmt
Expert conclusion	Universal method		2
Creative methods	Universal methods		1
Analytic calculations		The condition for the practical application of the method is the availability and differentially of the functions of demand and costs as well as the uniqueness of the general costs extremum. The essence is in equating the partial derivatives of these functions to zero [303]	2
Standards		Development of the parameter series of a product in compliance with the standards [295], [100], [173]	2
Numerical calculations	Histograms	A distribution function for the desired values of the parameters for the planned applications is built. On this basis, a determination of the series of parameters is possible [228], [299]	2

18 A certain change of product characteristics and types packaging are possible; this is caused by the specification needs and peculiarities of the processes of sales and distribution.

Analysis of the assortment as a whole or by product line, and an analysis of each product

Given: the parameters of the assortment as a whole, by product lines, and by each product, obtained with the use of measurements, expert evaluations, and consumer surveys.	→	Required: that a decision be made for each product line whether to extend or not extend the assortment, to narrow or not to narrow the assortment, to change or not to change the assortment

<table>
<tr><th>Methods</th><th>Types</th><th colspan="2">Task examples</th><th>Cmt.</th></tr>
<tr><td rowspan="3">Numerical calculations to determine the strategic flexibility of the assortment</td><td>Share of the three leading products</td><td>To determine the dependency of the leading products on the sales volume of each product [12] [108]</td><td rowspan="2">A strong dependency on a small number of products is identified. This may be disadvantageous for the company</td><td>2</td></tr>
<tr><td>The decile sales ratio</td><td>To determine an imbalance in sales by product type [257]</td><td>2</td></tr>
<tr><td>ABC/XYZ assortment analysis</td><td colspan="2">Making a decision about working with a product on the basis of the sales volume or profitability of a particular product over several periods[19] [40], [286]</td><td>2</td></tr>
<tr><td rowspan="2">Numerical calculations</td><td>On the basis of expert evaluations</td><td colspan="2">Product item appeal is evaluated by an expert [242]</td><td>2</td></tr>
<tr><td>Forecast of the future sales volume of a product line and a product</td><td colspan="2">Recommendations on the application of various leveling and extrapolation methods are offered [13], [18]</td><td>1</td></tr>
<tr><td rowspan="3">Matrix methods</td><td>BCG-matrix</td><td colspan="2">Analysis of the growth rate and market share [135], [123]</td><td>2</td></tr>
<tr><td>McKinsey matrix</td><td colspan="2">Analysis of the comparative market appeal and competitiveness [135], [123]</td><td>2</td></tr>
<tr><td>Three-dimensional BCG-matrix</td><td colspan="2">Physical indicators weighted by significance and determined by surveys. Matrix size: 3x3x3 [140]</td><td>2</td></tr>
</table>

19 Possible solutions: to strengthen the production and distribution control, to use the least costly methods of the production and distribution control, to take out of production.

	Modified BCG-matrix (Rybal-chenko meth-od)	Data available on the sales volume of each product for several periods. A matrix is built, where X data is the product share in the company's sales volume; Y data is the rate of increase in the product sales. The Y point of the division is the average rate of in-crease of all the products; the X point of the division is a share median. The size of the circle representing the products reflects ei-ther the impact of a particular product on the company's profit, or the marginal profit from the sales volume of the product [240]	2
Examination of opera-tions, optimi-zation meth-ods	Simplex-method	There is a system of limitations: -market limitations (market potential, mini-mal set of sales volume); - producing capacity; -resources; -prices (demand depends on the price). The optimal output of each product item [284] is determined by the criterion of the maximum marginal profit.	2
Cluster anal-ysis	Examination of the number of product vari-ants and the harmony of their mer-chandising, sales, and usage	A semantic differential survey determines the distance between products. A cluster analysis dendrogram allows the determina-tion of the products that are perceived as similar [45]	2
Reasoning by analogy		Decisions about assortment are made by analogy. In order to form an assortment for a new shop a similar shop type in a similar environment is found and the assortment is made similar to this already existing shop. [28]	2
Classification trees	Search for associative rules	The development of the rules for basket formation - according to the list of products in each basket [146], [186]	2

A posteriori segmentation and pre-selection of the segments

Given: results of consumer satisfac-tion survey, customer complaints, suggestions, and information from sellers about the demand, and rec-ords concerning warranty repair	→	Required: identification of prospective segments of consumers, whose needs can be satisfied

Methods	Types	Task examples	Cmt.

Cluster analysis	Survey on satisfaction with the existing product	Conducting clusterization on the basis of the surveys on consumer satisfaction with the existing products, the selection of “prospective” segments [155], [260]	4
	Segmentation by attitude, on the basis of the surveys	Identification of segments for positioning, selecting consumers with different attitudes [143]	2
	Consumer portrait	Learning product perception through the different segmentation based on the surveys on the significance of the product parameters and on the perception of different types and brands of products [143], [269]	2
Neural networks	Kohonen self-organizing maps	Clusters are formed on the basis of the available customer parameters [176], [272]	2
Decision trees		Scoring systems: a decision on a client’s reliability when a loan is issued according to an application form [38], [300]	4

Profiling of the selected segments

Given: 1) preliminary selected segments 2) results of the survey on consumers that belong to a particular segment	→	Required: determination of each segment’s characteristics, and ideas useful for any development and modification concepts

<table>
<tr><th>Methods</th><th>Types</th><th colspan="2">Task examples</th><th>Cmt.</th></tr>
<tr><td>Expert evaluation</td><td>Universal method</td><td colspan="2" rowspan="2">To determine ideas useful for development and modification concepts, segment parameters (demographic, socio-economic, psychological parameters)</td><td>2</td></tr>
<tr><td>Descriptive marketing research</td><td>Surveys</td><td>2</td></tr>
<tr><td>Discriminatory analysis</td><td></td><td>A linear combination of features is identified. They are used to determine segment affiliations as well as the significance of each characteristic for affiliation determination [179], [277]</td><td rowspan="3">Consumers that belong (and do not belong) to a particular segment are described by a set of parameters. The dependence of the consumer’s behavior on the segment parameters is determined</td><td>2</td></tr>
<tr><td>Decision trees</td><td></td><td>A set of segment features is determined [38], [300]</td><td>6</td></tr>
<tr><td>Testing of the statistical hypothesis</td><td></td><td>Statistical significance of the features for segment differentiation is determined [50], [179], [277]</td><td>2</td></tr>
</table>

Inductive reasoning	Building of a classifier	Deriving the general rules of consumer behavior based on concrete examples [281], [133]	2
	Search for associative rules	It is necessary to determine the rules for the formation of the product basket (e.g., when milk and butter are purchased, sour cream is not bought) [146], [186]	2
Deductive reasoning		Selection of the segment features, starting from the division of all consumers according to each of their characteristics; if successful – the continuation of division into smaller groups [281], [133]	4

Selection of target segments

Given: the characteristics of the selected segments	→	Required: evaluation of the characteristics and making a decision about further actions (estimate: from dichotomous to quantitative)

Methods	Types	Task examples	Cmt.
Expert evaluation	Universal method	Significant factors, such as segment size, growth perspectives, etc., are evaluated [177], [217]	2
Expert systems		Formalization of expert experience in segment selection	6
Neural networks		Building a system for new segment selection on the basis of correctly and incorrectly selected ones	6
Multi criteria choice	Universal methods	Size of a segment, its potential, profitability, availability, competitive situation, working efficiency, and mission compliance are evaluated [112]	2

Development of modification idea alternatives

Given: profiles of target segments	→	Required: development of modification ideas for alternatives to a product

Methods	Types	Task examples	Cmt.
Creative methods	Universal creative methods		1
Analytical and numerical hill-climbing technique	Model of coefficient selection for the significance of the features that influence sales, according to the correla-	Data is available on the sales volume of each product. There is a list of the features that are important to consumers and their significance for each product. This is required to determine the significance of the features of the consumers' choice [33]	2

	tion of their weighted mass with sales volume		

Development of modification concept for each idea alternative

Given		Required
Given: 1) profiles of the target segments 2) new product ideas	→	Required: development of the concepts of product modification alternatives

Methods	Types	Task examples	Cmt.
Creative methods	Universal methods		2
Expert systems		Formalization of expert experience	2

Forecasts concerning relationships with business partners' and competitors' reaction to each alternative modification or elimination

Given		Required
Given: 1) data on the current and predicted state of the external and internal environment 2) new product ideas	→	Required: 1) determination of the values of the indices and a description of the options for a situation development in a qualitative manner 2) offering measures for each option

Methods	Types	Task examples	Cmt.
Expert conclusion	Universal methods		2
Risk analysis	Similar to risk analysis in the context of idea evaluation		6

Determination of the marketing indices for the monitoring of each SMA and the method of their analysis

Given		Required
Given: 1) aims and strategies in each SMA 2) current company activities	→	Required: determination of the derivation of the actual state from the planned state

Methods	Types	Task examples	Cmt
Using the features that are taken into consideration during the preliminary analysis of the available SMA, and the development of a new SMA			2
Expert conclusion	Universal methods		2
Instructions and standard solutions	Based on experience		3

Evaluation of the consequences of an operational decision for partners, competitors, and consumers [20]

Given: knowledge about partners, competitors, and consumers	→	Required: evaluation of the consequences of an operational decision

Methods	Types	Task examples	Cmt.
Expert conclusion	Universal method		2

Universal methods applicable to various tasks

Methods	Types	Task examples	Cmt.
Multicriteria selection tasks under the circumstances of complete certainty (selection of SMA, new or modified product idea, product concept or product for elimination)	Convolution Alphabetical ordering, Pareto principle, Uniform optimality, Ideal point method, etc.	Solution alternatives are available. Each is described by a set of criteria values Required: Selection of the best solution; Ranking the solutions according to preferability. The selection procedure allows the goals of the decision maker to be considered [140]	2
Decision-making in risk conditions??	Making risk decisions[21] based on various criteria: minimax, maximax; Gurvitz, Savage, Laplace, Bayes	There are alternate solutions available, each of them can result in a set of possible uncontrolled outcomes evaluated by probability and result. Selecting the best alternative is required [140]	2
	Making a risk decision using Bernoulli criterion	There are alternate solutions available, each of them can result in a set of possible uncontrolled outcomes evaluated by probability, results, and the subjective utility function of the outcome. Selecting the best alternative is required [140]	2
Estimation of un-	Via entropy	Evaluation: the measure of uncertainty of a situa-	2

[20] In this case we mean highly operational decisions rather than strategical ones. Thus, the methods of strategic analysis are not applicable. Nevertheless, some operational decisions may have broad consequences.

[21] Under circumstances of risk, we understand a situation when a decision may lead to a final number of outcomes, and the outcome is not controlled by a decision-maker.

certainty[22]		tion and accordingly the determination of the potential deviations of the possible utility from those expected [140]	
	According to a pessimistic, optimistic and most likely estimate	There are pessimistic, optimistic, and most likely estimates for the uncertain quantities. Calculation of the three alternate solutions is performed, and the task is reduced to three criteria	2
	With the help of fuzzy quantities	Each quantity is represented as fuzzy (mostly – trapezoidal form). Fuzzy arithmetic is intended for the calculations and comparison of alternatives. [62]	2
	With the help of fuzzy logic	Fuzzy logic quantities are evaluated in a contiguous range from 0 (impossible) to 1 (certain). Fuzzy logic operations are used in order to obtain a final logical evaluation [62]	2
Numerical calculations to evaluate the competitiveness of an SMA, a new product, or a product under modification	Indices	Complex evaluation of a new alternative compared to the initial one. Resultant index shows: $k<0.9$ – competitiveness of a new product is lower than that of the initial product; $0.9<k<1.1$ – same level; $k>1.1$ – the new alternative is more competitive than the old one. Scoring is also possible [77]	2
Testing of statistical hypotheses during analysis external environment and consumers	Hypothesis of a single mean Goodness of the hypothesis fit Hypothesis of statistical independence of features And many others	There is statistical data about the elements of the research. A set of hypotheses and hypothesis testing methods are available. A necessary hypothesis is selected, as a result of testing it is accepted or rejected [60], [167], [253]. Examples of hypotheses for product management tasks: Is there a dependence of the size of a household appliance that is bought on the size of a family? Is it correct that there are 2 big and 3 economic packages bought for every small package? Are there size preferences for the packages bought? Can one consider that the percentage of consumers that prefer larger packages is higher than 50%? Can one believe that the expert opin-	1

[22] Under the term "uncertainty" we understand a situation when evaluation of an alternative is defined as located in contiguous range of values.

		ions are consistent?	
Network planning: operations research, non-optimization methods	Standard network diagram for conducting research [127], [140], [15] Network diagrams of multi-stage operation	Determination of the minimal duration of all activities. Determination of the ways to reduce the duration of the range of work necessary. Determination of which type of work can be performed simultaneously. Checking how the duration of each item of work varies, and whether the organization of the work changes	1
Multivariate regression analysis	Identification of the indices significant for building the external environment models, and the models of consumer behavior	There is a range of research elements. They are characterized by a set of the known values of the features. Moreover, each element is characterized by a certain known value of a "determining" variable (e.g. an SMA is characterized by its appeal, the new product – by profitability, segmentation – and by its potential). How many features and which of them are required in order to determine an output (outcome) variable with a given accuracy? How influential the features are towards the value of an output variable? [86], [56], [45]	2
Discriminatory analysis		There is a set of research elements that are characterized by a set of features and belong to a particular class (e.g., "promising" and "unpromising") How to determine a class of new research elements according to a linear combination of features? What variables are the most important for this division? [179], [277]	2
Factor analysis	Method of principal components	There is a set of research elements that are characterized by a set of features. How many factors determine the differences between the research elements and what features constitute these factors? What features are the most important for differentiation between the research elements? [105], [121], [158]	2
Classification trees: determination of parameters significant for classification of objects	QUEST CART CHAID	How to distinguish groups of research elements that have a different value for a dependent variable, using the values of the independent variables? [164], [261] ,[285], [296]	6

Creative methods applied to idea and concept generation for new products or products under modification Algorithm of Inventive Problems Solving		Solution of complex creative tasks in the area of development of new products with a high level of novelty [6], [124], [153]	1
Theory of inventive problem solving	Method of separation (a power supply unit is separated from a device) Beforehand cushioning (plastic support ring in a car tire that allows temporary use of a wheel if its tire is punctured), etc. (up to 100 techniques)	Solving technical contradictions [93], [184]	1
Brainstorming	Collective discussion by experts	Identification of solution alternatives for complex creative tasks [188], [220]	1
Corrective action team	Collective discussion by a permanent team of experts	Identification of solution alternatives for complex creative tasks [7], [219]	1
Morphological analysis [288], [278]	Morphological box	Identification of the principles for new product development in situations where multiple solution alternatives are available	1
	Method of “negation and construction”	Creation of a brand new product	1
	Method of systematic area coverage	Directing a researcher towards a discovery [182]	1
Methods of creative activities	De Bono’s hats, W. Disney method, bisociation method, etc.	To systematize the process of invention [103], [223]	1
Obtaining expert judgments and their evaluation	Determination of the coefficient of concordance	Testing the consistency of the opinions of two experts using a ranked estimation	2

	Determination of the coefficient of concordance and a general ranking estimate based on the surveying of several experts	Testing the consistency of the opinions of several experts using a ranked estimation	2
	Delphi method	Obtaining quantitative estimates	2
Systematized knowledge representation	Object-centric model	Systemization of the knowledge concerning the subject field [57], [73]	1
	Semantic networks		
	Production models		

The results of the current chapter allow a significant orientation in the great variety of methods applied to product management.

3.2.1 Means used for product lifecycle management

It is worth mentioning that the term marketing tools is a rather blurred concept in the literature. Marketing per se is often considered a tool for the achievement of company goals. The elements of the marketing mix (price, product, promotion) are also often considered a tool. A questionnaire used in marketing research is called a data-gathering tool.

One can agree with all these approaches, however, understanding the term in such a broad manner is not practical in the context of a specific piece of research.

In the current research, a more narrow (regarding both functions and object of management) definition of the term is used. The term product lifecycle management tools are understood as the technical means and the software that provides this activity.

These technical means can be classified according to the group of tasks they support. The first group includes the means of controlling the marketing activity. In generally, however, they are universal project management facilities and means of data processing, with the aim of accounting and controlling the type of activity under review.

Another group of tools consists of the means of economic analyses and calculations, from general purpose (Excel) to specialized programs for economic analyses and forecasts.

The third group of tools is represented by marketing tools per se. They provide information on the performance of the product management activity, according to the researched stages, tasks, and tendencies presented previously.

Finally, the fourth (the most diverse) group consists of the means of conducting the research: the technical means for observation (multi-purpose video cameras, magnetic resonance apparatus, polygraph, etc.); the means of surveying (from telecommunication means to databases that have contact information about respondents and their answers; data processing software , from organization of telephoning to respondents to complex methods for the analysis of the collected data); the means for the graphic representation of the results.

In the previous chapter, there were a number of difficulties identified in the last two groups, which explain why the current research will be devoted to these particular groups of tools.

According to its purpose, all the software that belongs to the identified group can be divided into the following: the means of data processing and analysis; decision-making; simulation; and knowledge information processing (accumulation, storing and output).

Finally, according to the method of data processing this software can be divided into the following types [209]:

1 Information systems. These are based on database management systems and represent a database per se and operational tools: input, processing, and output means. The main feature of these systems is elaborated on in rather structured reports that are oriented towards a constant monitoring of a situation. Additionally, monitoring systems of this type can be used for storing different marketing information.

2 Information retrieval system. This provides a fast means of searching for information (knowledge), primarily on the Internet and in the normative databases.

3 “Classic” decision making support systems. The general understanding of the term “a decision making support system” is rather broad and ambiguous. It includes various tools from a simple What-if analysis to artificial intelligence techniques. For the purposes of the research, it is appropriate to accept the definition stated in [45], according to which a decision making support system is a triad of: the information system;

the system of models and algorithms for data processing; and the dialogue system. Its purpose is to provide a means of testing the various hypotheses created by marketing analysts.

4 Online analytical processing (OLAP) systems. These systems can be considered as a further development of the classic concept of a decision support system. Data is organized into data warehouses that have a broader functionality than traditional databases. Data stored in these warehouses is represented as hyper cubes, which allow the researcher analyze more easily, for example, the difference in marketing indices according to the products, regions, periods, distribution channels, etc. These systems are characterized by a rather complex concept and require highly qualified users.

5 Data mining. It is the most sophisticated research tool. By searching vast data volumes a computer can identify hidden, less evident data patterns. For example, by analyzing receipts from hypermarkets, such systems can determine products that are bought together, which allows the development of new product modifications, e.g. grocery sets. Intellectual data analysis includes a number of special methods from automated regression analysis to evolutionary algorithms and genetic programming. [209].

6 Artificial intelligence systems. Separation of these systems in the current research is determined by their broader universality in comparison with the Data Mining techniques. In particular, they can be used for the selection of a product management method relevant to a particular situation. Their specialty is that they realize the data and knowledge processing algorithms [195]. In some cases, the data processing algorithm can also undergo changes. Such systems are generally used for decision making, particularly when the data is incomplete. Neural networks and expert systems belong to this group. One can also note a currently developing class of hybrid systems that combine features of the two above-mentioned classes.

Thus, product lifecycle management tools are rather diverse. In order to select the correct marketing tools, it is prudent to use an artificial intelligence system. This is a system of method selection for product management that can combine the individual product management methods with a joint methodology.

3.3 Recommendations on the application of the methods for task solution in the area of computerized product lifecycle management

In this paragraph, examples are examined of the application of the most significant methods for product management tasks that, as mentioned in the previous paragraph, require more detailed consideration. These tasks are marked with number 4 in the tables above.

Determination of the features significant for success in different SMAs with the use of classification trees

The relevance of this task is determined by the fact that the important factor can depend on the time, on the company (its experience, leadership at the market, resources), and on the state of the external environment (e.g., government regulation of industry can have both a positive and negative effect).

The stages of task solving are as follows:

For each available SMA (not necessarily the one where the company is already working) a set of characterizing parameters is determined. An approximate list has been summarized for the current paper from [12], and is presented in Table 3–1.

Parameter	Values
Qualitative indicators	Denotation
Predominant type of clients	1 – ultimate consumers; 2 – production; 3 – public institutions; 4 – persons of free professions
Demand lifecycle stage	1 – “bleeding edge”; 2 – ascent; 3 – decay; 4 – maturity 5 – decline
Technology lifecycle stage	1 – “bleeding edge”; 2 – ascent; 3 – decay; 4 – maturity; 5 – decline
Type of technology	1 – stable; 2 – productive; 3 – unstable; 4 – combination of productive and unstable

Growth indicators (Score)	State (from 0 – bad to 5 – excellent)	Variation (from minus 5 – degeneration to +5 – improvement)
The level of the corresponding sector of economic activity		
The number of consumers that belong to the sector as a part of the population		
Market geography		
Degree of product obsolescence		
Degree of product renewal		
Degree of technological upgrading		
The level of demand saturation		
Social acceptability of the goods (service)		
State regulation of costs		
State regulation of growth		
Adverse impact on growth/profitability		
Favorable impact on growth/profitability		
Other factors significant for the SMA		
Profitability indicators (scores)	**State (from 0 – bad to 5 – excellent)**	**Variation (from minus 5 – degeneration to +5 – improvement)**
Profitability fluctuations		
Sales volume fluctuations		
Price fluctuations		
Demand cyclicism		
The level of demand with respect to facilities		
Characterization of market organization (level of concentration)		
Stability of market organization		
Renewal of assortment		
Duration of lifecycles		
Duration of new product development period		
Expenses on R&D		
Costs required for access to the market (market exit)		
Aggressiveness of leading competitors		
Competition of foreign companies		
Competition on the resource market		
Intensity of advertising		
After-sale service		
Degree of consumer satisfaction		
State regulation of competition		
State regulation of production of goods (services)		
Consumer pressure		

Table 3–1 SMA parameters

When applying this method to a certain task, some parameters that do not relate to the analyzed SMA can be removed from the list, at the same time new parameters can be included.

After this modification, the significance of each selected parameter is determined.

[12] suggests examining various factor combinations, selecting a weight coefficient for each factor in order to determine its significance on the basis of personal experience or preferences.

Modern methods of Data Mining allow patterns to be identified more precisely in an available set of data. The grade of appeal is determined for each available SMA (a posteriori is enough) on a scale from 0 (not appealing) to 1 (appealing). This precise method will be described later on in the research.

Tabulated data is processed by a program that creates/ builds classification trees. Due to the high dimensionality of the task, a simplified example of an SMA for a certain company is presented. The estimation of the SMA parameters is shown in Table 3–2.

Name of SMA	Predominant type of clients	Degree of product obsolescence	Degree of product renewal	Change of demand saturation level	Demand cyclicism	Successfulness of the work on the SMA a posteriori
SMA 1	1	3	3	3	2	0
SMA 2	1	2	4	2	2	0
SMA 3	1	0	1	0	0	1
SMA 4	3	4	2	-1	3	0
SMA 5	3	4	3	-1	3	0
SMA 6	1	1	4	0	2	0
SMA 7	2	1	1	0	3	1
SMA 8	1	2	5	2	2	0

Table 3–2 Estimation of SMA parameters

The first five variables are independent, while the last one is dependent.

This data is processed by a Data Mining program applying a method using classification trees. In the example, an SPSS Answer Tree program was used.

The tree built by the program is presented in Figure 3–1.

The upper node ("leaf" of a tree) summarizes all the research elements. The bar chart shows that in most of the cases success was not attained (variable Success is examined and measured on the x-axis: 0-faliure, 1-success; the number of cases is placed on the y-axis). The first branch shows that the main parameter differentiating between a successful and unsuccessful SMA is the level of product renewal (Renew). When this is high, none of the SMAs are successful (the right branch), when it is low, the share of successful SMAs is significant and branching can continue. The following main feature of SMAs with a low level of renewal is the fluctuations in demand (variable DemSat). Success is possible only if the fluctuations are small. The following rule is articulated: success is possible in an SMA with a low renewal level and a low level of fluctuations. The important parameters are the level of product renewal and the fluctuations in demand.

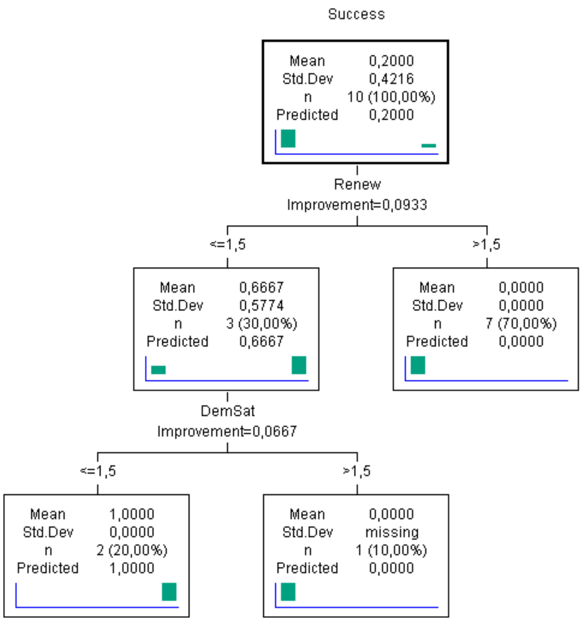

Figure 3–1 Decision tree for the identification of the significant parameters of an SMA

3.3.1 Discussion

There is often the possibility of obtaining false dependencies among the 10 cases, therefore the number of research elements should be no less than 50. This is not a difficult task, as it is stated in [12] that the number of SMAs for some companies reaches 30...50. It is also possible to examine the work done in other companies on SMAs.

The method also requires adjustments and a detailed manual for the application of the method is described in [158], [206], [19].

The software used allowed us to select an SMA for the work /task??, that provided information about the improvement of the indices of the company's activities if the unsuccessful SMAs were removed.

3.3.2 Identification of promising SMAs with the help of neural networks

In general, an artificial neural network represents a system of interconnected units (neurons). Each neuron receives several inputs and produces one output.

The outputs offer values for the independent variables describing a particular situation in numerical terms. Qualitative parameters should be converted into scores or discrete values 0-no, 1-yes. The predictive values of dependent variables are formed as an output. Each neuron transforms an input into an output in two phases. In the easiest case on the first stage, there is a weighted sum of inputs (each input is preliminarily weighed), and on the second stage a threshold function is applied. The threshold is adjusted separately for each neuron.

In order to work correctly, a network requires a learning process, during which the structures and weights of the inputs and thresholds are adjusted; this occurs according to an available set of situations: the values of all the input variables and the corresponding set of output variables.

The principles of the operation of artificial neural networks, their types, and features are widely described in literature [32], [229], [19], [302].

The purpose of the neural networks application in this particular case is the prediction of potential, new SMAs on the basis of the input set of values of the SMA's parameters. The network's potential is a dependent variable, while the set of parameters is represented by independent variables.

Supervised learning is the most popular method due to its simplicity. In this case, the learning takes place on the basis of a set of available SMAs with known sets of values of their independent variables, together with the available correct solutions for the dependent variables (whether a SMA is promising or not). The work on such systems takes place in three stages. In the first stage, the structure of the network is determined. In the second stage, network learning takes place (automatic adjustment of the parameters). The third stage is the application of the network: the parameters of the new SMA are input, and the network accordingly produces the value of a dependent variable.

Statistica 7 offers rather powerful tools for the creation of neural networks that allow the features of the method to be illustrated.

In order to represent the application of the method, input data from previous examples have been used.

The network structure can be set manually or automatically.

Option 1. The network structure is set by a human, as presented in Figure 3–2. The number of inputs is equal to the number of independent variables and is set as 5. One output is provided, because there is only one dependent variable. Moreover, a system can have up to three layers; the number of layers and the number of processing elements per layer can be set by the user. As a first approximation, one layer is set with the number of neurons equal to the number of inputs[23].

After the training, the duration of which is 10 000 epochs[24], the program automatically calculates the connection weights and threshold values of each neuron. The results show that all available changes have been correctly classified (Table 3–3).

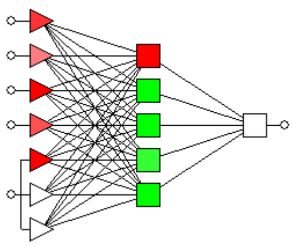

Figure 3–2 Neural networks for identifying promising SMAs

As a result of the learning, a nonlinear response surface for 5 variables has been effectively created. As long as the whole surface is difficult to build,

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[23] As the number of interim layers grows, the flexibility of learning increases, but so does its duration. When learning does not provide any result, the number of levels and neurons is increased.

[24] An epoch is a one-time presentation of a complete set of cases available to the network. Usually, the process convergence is slow, thus the number of required epochs is vast. Each calculation takes about 5 minutes.

we will provide a particular case according to the variable level of the renewal Renew and level of demand saturation DemSat (Figure 3–3).

Prediction (2) (Spreadsheet1)		
	Success	Success.2
1	0	0
2	0	0
3	1	1
4	0	0
5	0	0
6	0	0
7	1	1
8	0	0
9	0	0
10	0	0

Table 3–3 Comparison of the correct (on the left) results and those predicted by the network (on the right)

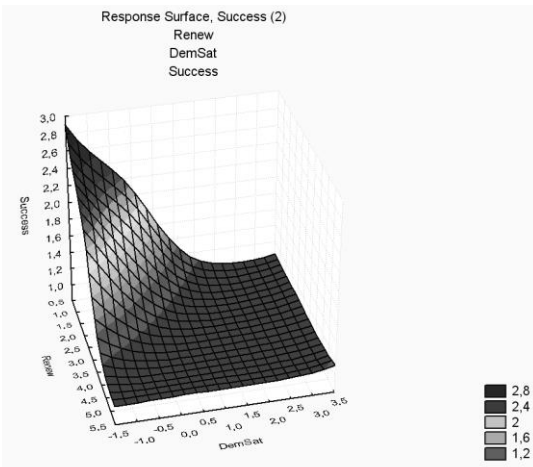

Figure 3–3 The response surface of a neural network after the learning process has been completed

Classification of a new SMA is performed on the surface: a 2-d point on the horizontal surface corresponds to the new SMA and is determined by the values of the above-mentioned parameters, while the result is determined according to the response surface. The values for the success of the dependent variable in the SMA are equal or higher than 1, and this corresponds to a successful SMA. It is evident that success is achievable when the values of the Renew and DemSat variables are low. One should note that the user does not receive the response surface in an explicit form. The user merely inputs a set of values of a new SMA into a computer and obtains an answer from the neural network about the appeal of the researched SMA.

Analogously, a response surface can be built for other variables, such as GetOld and Renew (Figure 3–4). In this case. there is also zero prediction error. A prediction for the results' value for the three variables Renew, GetOld, and DemSat can be obtained with the use of this method.

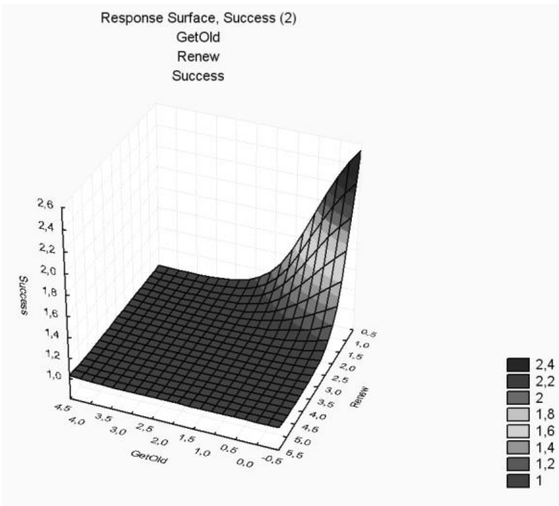

Figure 3–4 The response surface for the variables GetOld and Renew

Option 2. Automatic generation of the neural network structure.

Statistica 7 allows the automatization of the process of building a neural network with the help of the Intelligent Problem Solver mode. Network parameters (the number of inputs and outputs) are set automatically, after which, a generation of a vast number of networks is performed (up to several thousand), they differ in the number of layers and the number of neurons on each of them. Genetic algorithms are used to accelerate the search process in order to find a perfectly predicting network that allows the simulation of the changes in the structure "generations" and keeps successful solutions for the next "generation". This method usually generates several models. Each new program launch leads to different results, because a random factor is implemented in the process.

Some of the automatically produced models are represented in Figure 3–5, a, b, c.

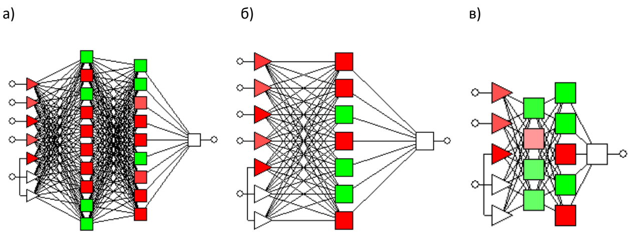

Figure 3–5 Models produced automatically

The last version of the response surface for an appealing SMA value is presented in Figure 3–6. An SMA is considered appealing if the value of the response surface is higher than 0.5. The more complicated shape of the surface is determined by the excessive number of network nodes.

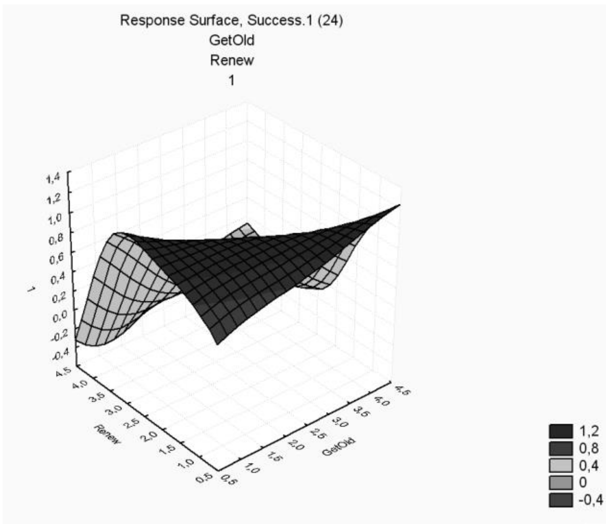

Figure 3–6 Response of the model in Figure 3–5 for the value 1 (attractive SMA)

3.3.3 Discussion

The main difference between this method and the others is that network building does not require any additional knowledge about the research object and the relationships between the variables. Only a training set containing the correct results is required. This is a significant advantage when dealing with high dimensional tasks and complex selection rules.

The example demonstrates that a small number of measurements produces ambiguous results: various versions of networks that would provide high level of accuracy can be built.

From the theoretical research [229], [19], it is evident that there are a number of problems with the application of neural networks. For example, the main feature of neural networks as well as other learning systems is their adjustability by using a training set. This means that overtraining effects can occur in a system, i.e. the system perfectly classifies training examples, but is confused by new cases. In order to eliminate these effects one part of the case is used as a training set, and another part as a cross-validation set. However, this procedure requires a greater number of cases.

In comparison with the method of classification trees, the current method requires, as a rule, more time due to the great number of adjustments that can only be made manually by experiment. Among these are:

- The learning speed. A lower speed, as a rule, improves convergence, but prolongs the duration of the learning process;
- The structure of a network. Selection of the structure is a difficult issue. The above-described genetic algorithm also has a number of adjustments, such as mutation level and strictness of selection.
- The possibility of the randomization of parameters when the learning process reaches "the dead point".

Most of the parameters (but not all of them) are set automatically in the newer versions.

In comparison with the earlier versions of the neural network building programs, the modern ones are notable for their high speed of operation and improved convergence. This is determined by the application of a number of special adjustment techniques. For example, network adjustment is performed not on the basis of separate examples, but on their sets.

Modern neural networks have become a convenient way of data analysis, and they are comprehendible to everyone, not only professional analysts [221].

3.3.4 Evaluation of the predictability of the external environment

It has already been mentioned in Chapter 1 that a great role in product management is played by research into the external environment. According to the results demonstrated in [5], [297], [159] chaotic motions are possible in economic systems. A chaotic motion is a non-periodical motion extremely sensitive to the smallest changes of the initial conditions and parameters, thus, it is almost impossible to predict by long-term forecasting or be controlled. Chaotic modes appear in the systems that do not include any random factors.

According to the modern notions, economic processes often have chaotic features. Among these processes, the authors of the above-mentioned scientific works indicate the dynamics of stock prices and rates of exchange. There is an example of such a mode in the dynamics of production and sales of similar products in a company in a duopolistic market [148]. In general, all of the above-mentioned processes can affect the marketing activity of a company.

Identification of chaotic motion allows us to avoid the dangers in unpredictable situations. Due to its aperiodicity, chaotic motion is often confused with stochastic motion.

There are a number of methods that allow us to check whether the motion is chaotic, among the simplest are [9], [156]:

Analysis of the motion direction from each point of the system's state space (i.e., the area of change of its parameters). Chaotic motion is characterized by the fact that the direction vectors in a small area of the space are directed towards same direction. This pattern is absent in stochastic motion.

Test for direction similarity can be performed in the following way:

1 Several neighboring points are selected. As a practical experience of application of this method and as the following example shows, it is appropriate to select a number of these point from the range from 30 to N/(5×k), where N is the number of available points of measurement, k – the dimensionality of the state space of the system. If N/(5×k) < 30, then the level of the validity check is over the insufficient number of the measured points.

- The direction from each point to another one is measured. This direction can be called the angle of the φ_i vector. It is determined as the angle between the vector's direction and a certain initial direction, for example, the direction of one of the axes of the state space.
- As a measure of direction similarity, a range of variations of the measured angles can be used. It is considered sufficient if the differ-

ence between any of the two angles φ_i and φ_j does not exceed 180o, i.e. that the vectors are not directed in the opposite directions. If the directions are similar, one can suppose that the motion is chaotic.

2 Evaluation of the uniformity of the filling of the state space. When the motion is chaotic, in contrast to stochastic motion, the uniformity of filling does not grow along with the number of observation periods. In order to evaluate the uniformity of the filling of the state space, we suggest applying a chi square criterion, according to the following method:

- All the state space of a system is divided into a number of areas (we suggest the following initial option: to divide each axis into 10 segments, then the total number of the areas equals 10k)[25].
- The number of measurements in each area is measured. It should not be less than 5 (this is recommended in the literature on the application of chi square criterion). If this condition is not met, the number of areas should be reduced. It is not recommended to divide the parameters range into less than 5 segments. Thus, the lower limit of the number of areas equals 5k.
- The usual chi square criterion is applied in order to compare the empirical and theoretical distribution. As long as the equitability is examined, the number of measurements in each area, which equals the total number of measurements divided by the number of areas, is considered a theoretical distribution. If the hypothesis as regards the concurrence of the empirical distribution is rejected, the motion is considered chaotic.

In order to illustrate the methods of identification of chaotic motion, it is convenient to use the duopoly model, widely known in literature and described, e.g., in [148]. There are two companies in the market that produce similar product. Each of the companies follows the same rule: the product launch in the following period (e.g., month) depends on the number of products launched in the previous months by the company-competitor. The dependence is as follows:

[25] Due to the fact that the dimensionality of the state space of the analyzed system rarely exceeds 3, the number of areas will be acceptable for computerized processing.

$$Y_i = \begin{cases} X_{i-1} \times 2, & \text{if } 0 < X_{i-1} < \dfrac{M}{2} \\ 2 \times M - 2(X_{i-1}), & \text{if } \dfrac{M}{2} < X_{i-1} < M \end{cases}$$

where Y_i – is the planned launch by the company during the current period (thousands units, KU); X_{i-1} – th products launched by another company in the previous period (KU); M – the market capacity (KU).

The standard process that takes place in the market in this case is described in Figure 3–7. The dots correspond to the market conditions at a particular period and are connected with straight lines. One can note the vague unevenness of the filling. A random walk with the same number of measurements (about 1000) offers a more consistent picture. Moving the direction of the trajectory from each dot is illustrated in Figure 3–8. One can see that in the small areas (e.g., in the top right corner) these directions are analogous.

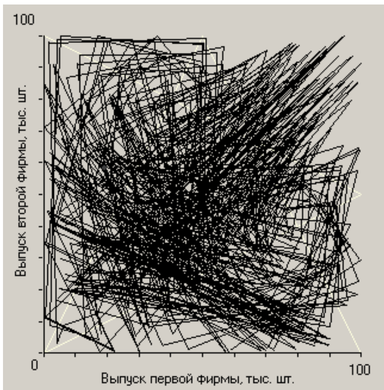

Figure 3–7 Example of chaotic motion

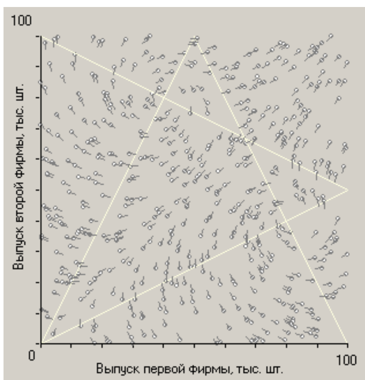

Figure 3–8 Identification of chaotic motion

3.3.5 Discussion

Chaotic behavior is rather abundant in nature (weather), physics (motion of liquid and gas flows), and technology (flutter, wobbling). However, in most cases, economic systems demonstrate a combination of stochastic and chaotic motion; chaotic motion appears only under particular combinations of the values of the system parameters. The methods for identification of chaotic behavior can be useful for an analysis of the behavior of economic and mathematical models of the external environment, but not for real situations. There are certain attempts to use randomness when operating with foreign exchange and share markets [40].

3.3.6 The building of a cognitive model for an understanding of the basic laws of the external environment

A cognitive model [157], [222], [241] is built during the initial introduction into a particular system or a complex object. As an example, we have taken an SMA of the production of fiction literature.

The research starts with the identification of the variables describing the external environment. A set of variables that characterize the external environment can be taken from analytical reviews about economic conditions, from interviews with experts on these areas, or be based on one's own experience. The example under consideration is based on a rather full set of variables from [185], some non-significant variables and the ones that are stable at the current stage, have been excluded. The controlled variables that characterize the existing strategy are:

- the intensity of the advertisement;
- the price level;
- the level of development of the new products.

All variables are marked as rectangles in Figure 3–9.

A model of cause-effect relationships between the variables is built. Each relationship is indicated with an arrow pointing from the causal variable to the effect-variable. For example, it is known that raising the level of competition in a particular industry affects staple (paper) prices. In addition to this, the relationships determined by the company's strategies are also introduced. These are marked with thick arrows. It is suggested in the example that the intensity of the advertisement will depend on the level of demand saturation, the price level – on the level of demand saturation, as well as the aggressiveness of the leading competitors, and the new products output – in addition to the level of obsolescence of the available products.

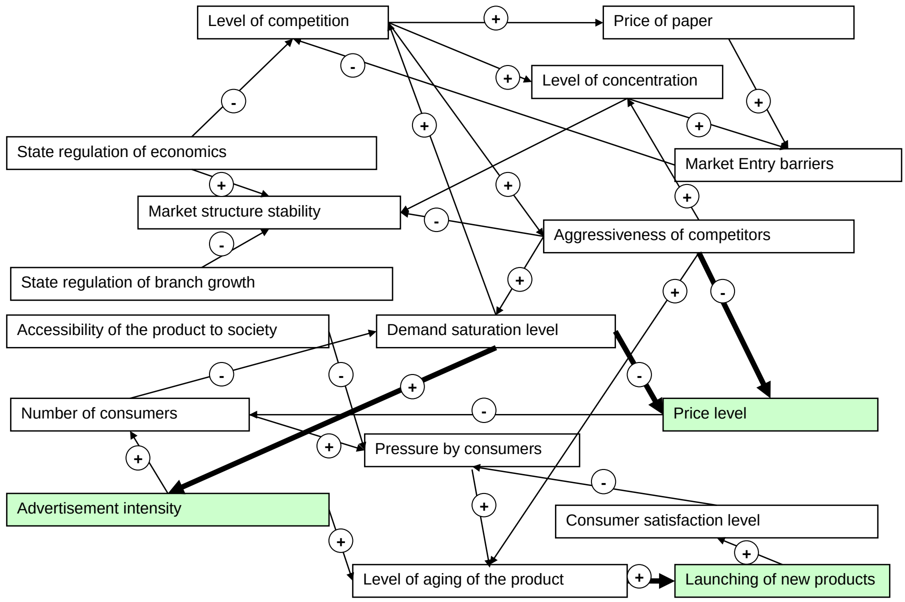

Figure 3–9 A cognitive map of an SMA for the production of fiction books

Each relationship is marked. If an increase in a causal variable causes an increase in the effect-variable and vice versa, the relationship is positive. On the other hand, if an increase in a causal variable causes a decrease in the effect-variable and vice versa, the relationship is negative. The result is illustrated in Figure 3–9.

In order to forecast values for the exogenous variable (State regulation of competition and the industry growth; public acceptance of a product) separate cognitive maps can be generated.

Analysis of feedback loops allows an evaluation of the development of a situation as a whole, with the use of a selected strategy. A loop with a positive feedback (with an even or zero number of negative relationships) is unstable, while a loop with a negative feedback (the number of negative relationships is odd) is stable or can have an oscillatory nature. Oscillation was typical for transitional economies when there was no experience in company marketing management, and the reaction to variations in the input variables had an excessive character. Nowadays, an admission can be made based on the observation that in most of the cases oscillation does not occur or it rapidly decays.

The picture demonstrates that most of the loops have negative feedback; therefore, the selected strategy is correct.

In-depth analysis can be performed on the loops that pass through the level of the competition variable. This is determined by the fact that these loops differ in the positive and negative nature of the feedback. Even though the cognitive map for these loops does not solve the problem, it allows the determining of the factors significance for the further analysis.

The evaluation of the selected strategy, on the basis of the cognitive map, is that the strategy provides a stable company operation on the market.

3.3.7 The systematization of knowledge concerning SMAs

In order to systemize the knowledge about a certain object domain, a number of the methods examined in [122] can be applied. In the current research, it is convenient to address one of the simplest methods – semantic networks [234], [43].

Semantic networks can be applied for the systematization of knowledge about SMAs. An example of a semantic network generated for this purpose is presented in Figure 3–10.

3.3.8 Discussion

Semantic networks are an informal means of knowledge representation and they are mainly created as an option by an expert. The level of generality of the notions represented by the nodes increases towards the upper part of the picture. The available knowledge is saved in certain nodes. Knowledge saving is performed at the highest possible level. For example, the knowledge about technology in general (data on a list of parameters for technology description, knowledge about the role of technology on company activities, etc.) is located at a higher level than knowledge about particular technologies (data archiving and saving). General knowledge describing any SMA is saved on a high level in the node “SMA”. The same rules apply to users: knowledge about users in general is located at a higher level than knowledge about particular types of users.

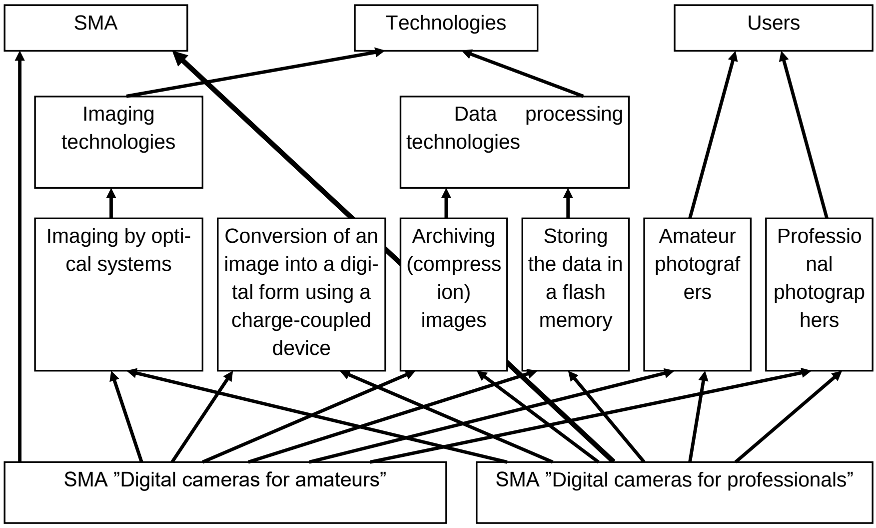

Figure 3–10 Example of a semantic network fragment

The search for the required knowledge about an SMA is conducted from the bottom up from a particular SMA, e.g. “digital cameras for amateurs”. The search is facilitated by the fact that the only examined fragment of the network is the one that is located on the higher level and is attainable from the lower node via connections. This helps to easily find the required information and work directly with it.

A small fragment of an SMA has been represented in the picture, while the full knowledge structure can be rather complicated.

3.3.9 Forecasting the development of relationships with clients with the use of decision trees

The example is based on [165].

A company produces a certain product (e.g., electric lawn mowers). A decision maker (e.g., a vice-president for manufacturing) has an opinion that the hand mower market is currently broadening. The company needs to make a decision on whether the company should start manufacturing hand mowers and if it does, should it continue to manufacture electric ones. Manufacturing of both types of lawn mowers requires an increase in manufacturing capacity. Before the decision is made, the decision maker should collect information about the expected profit for all the alternatives and their probability. This information is represented in the form of a decision tree (Figure 3–11) [182].

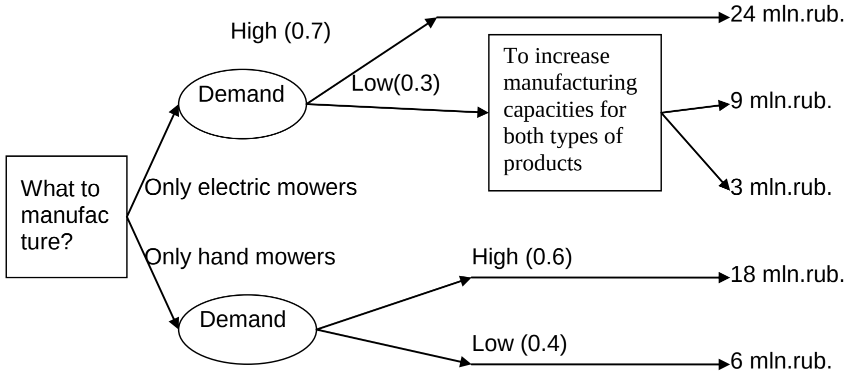

Figure 3–11 A decision tree for a marketing situation

Decisions are depicted as squares and the uncontrolled reaction of the external environment as ovals. It is evident from the tree that some of the decisions may require additional decisions. In order to make a decision, the company should evaluate the consequences of each alternative; these are represented at the terminal branches. Moreover, it is necessary to assess the probability of each outcome of each uncontrolled event (in the brackets), in most cases this is a subjective assessment made by the decision maker.

Subsequently, the general effect made by each decision is evaluated. For example, the second decision is in favor of increasing the manufacturing capacity. Thus, if the demand for electric mowers is low the result is 9 mln rub.

The result of the first decision – to manufacture only electric mowers – is evaluated as an average of the expected result 0.7×24+0.3×9 = 19.5 mln rub. In the same manner, the result of the decision to continue manufacturing only one type – hand lawn mowers is 0.6×6+0.4×2=4.4 mln rub. Thus, the decision about manufacturing of electric mowers is preferable.

3.3.10 Discussion

A decision tree, as noted in [45], allows all possible scenarios to be evaluated. However, it is usually highly dimensional even for simple situations.

Apart from the weighted average result, application of other criteria for evaluation of the alternatives is possible. For example, the size of the guaranteed result of each decision can be determined.

3.3.11 Qualitative analysis of a dynamic system

This example is based on the task from [45] in which the purchase of cars is examined. The product parameters i.e. the visual attractiveness (appeal) and technical characteristics. The consumer parameter i.e. the satisfaction with the characteristics. The company parameter i.e. the new car development time.

The engineering time affects the product parameters. If it is short, it does not provide a high level of satisfaction, but offers a high level of appeal. A longer engineering time does not allow a consideration of the changing market requirements, which means that the appeal level will not be high, but the technical characteristics that provide satisfaction will be improved.

The attractiveness affects the process of purchasing, while satisfaction affects repeated purchases.

Figure 3–12 is a flow diagram which reflects the dynamics of the consumers-owners of Model 1. It is assumed that they buy Model 1, because they have been unsatisfied with the previous purchases of Models 2 and 3. If the customers are satisfied with Model 1, they will buy its new modification. If they are attracted by other models, they will buy them. In the model (Figure 3–12), the wavy lines represent the origins and run-offs. The level of the owners of Model 1 is represented by a rectangle. The material flows (in this case – the consumers who have kept or have changed their opinion) are represented by solid lines. The data communications managing the “valves” are represented by dotted lines.

A model can be completed by including the levels of the owners of Models 2 and 3, the source of new auto enthusiasts, and the loss of people who do not use a car anymore. At the same time, the general discussion can be based on the model already built.

It is evident that the number of repeat purchases of Model 1 depends on the satisfaction with the previous model, and the transition to another model – on the level of appeal of the other models. This means that the external appeal of a particular model provides rapidly rising sales. In order to attract customers to a certain model, its new modifications should be developed with speed. However, in order for customers to remain loyal to a particular model, their satisfaction should be obtained, i.e. new models should be well crafted, which in turn requires more engineering time. The general conclusions of the analysis of the model are as follows: fast development of new models results in short-lived growth, followed by a low level of repeat purchasing and a reduction in the number of owners of this model; while detailed elaboration results in a possible sales recession due to customers' transition to other, more appealing models, followed by stabilization based on the high level of repeat purchases.

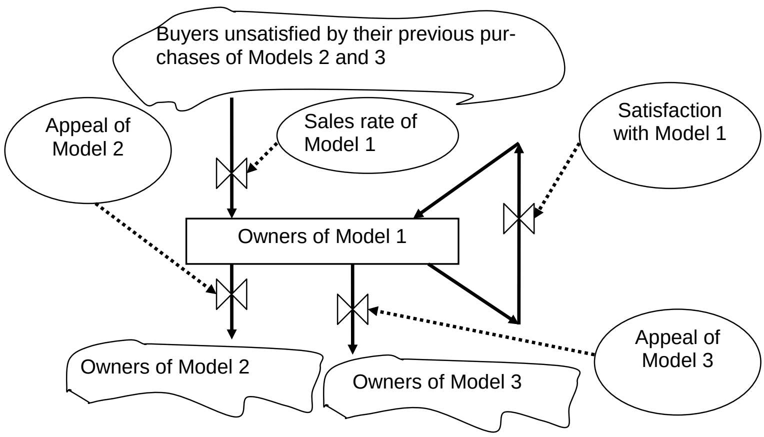

Figure 3–12 Flow of the car buyers

3.3.12 Discussion

A flow diagram has a number of common features with a cognitive map, which has been noted in [62], therefore, some conclusions can be made on a qualitative level without the application of differential equations.

In order to apply differential equations, one should determine the parameters of the researched object with high level of precision. Complex interrelations between elements and applied admissions lower the precision of the forecast.

The method under consideration can be successfully applied to forecasting such processes as the development of an industry or a country's economy, as well as demographic processes, etc. They examine large-scale phenomena: variables (population, number of producers, number of FMCG consumers) and can be considered continuous with a high level of precision.

Nowadays, this method is not widely used due to complexity of obtaining precise initial data and the high complexity of the interrelationships between variables in real economic systems. Moreover, the method does not consider the qualitative changes in the initial system that take place during its operation, and therefore it is not applicable for long-range forecasting.

3.3.13 Qualitative solution for a dynamic model

The current paragraph will be devoted to the description of the process of development of a dynamic model of a duopolistic market reaction to the release of a new product with a low level of uniqueness. The product can be, e.g., a certain brand of cell phones, released in several modifications (different colors or designs).

The current paragraph also illustrates the application of a succession of models of different natures in order to obtain the correct quantitative forecast. The results obtained in the paragraph have been published in [197].

Task description

There is a certain market in which two companies offering analogous products operate. The consumers and end users are particular individuals. It is supposed that the process of product modification is accompanied by advertising support, through which new features become known to consumers, and the more innovations that occur, the more intensive the advertising becomes and the more people learn about them and become interested.

The task is to simulate time changes in sales volume. The aim of the simulation is to find a method of cost distribution for the output of the product modifications.

Cognitive model

Firstly, in order to comprehend the peculiarities of a particular task, a cognitive map of the researched system is developed. Making a cognitive model starts with the selection of the significant variables:

- The number of people who are not interested in any products (1 or 2);
- The expenses incurred for development in Company 1; Company 2;

- The number of consumers who are interested in the product of Company 1; the products of Company 2 (in future referred to as Product 1 and Product 2 respectively), but do not own any of them;
- The number of consumers buying Product 1; Product 2;
- The number of Products 1; Products 2 owned by the population;
- The intensity of information exchange from the people who own a Product to the ones who do not know about it;
- The number of discussions between the consumers who own a product and the ones who do not know about Product 1; Product 2.

Secondly, the relationships between the variables are determined. The form of a cognitive map is presented in Figure 3–13.

- The number of consumers interested in Product 1 depends on the expenses on development of Company 1[26]. The same rule applies to Company 2 (relationships 1 and 1' in Figure 3–13) [27];
- The more unconcerned people there are, the faster the growth of the number of people interested in a product[28] (relationships 2 and 2');

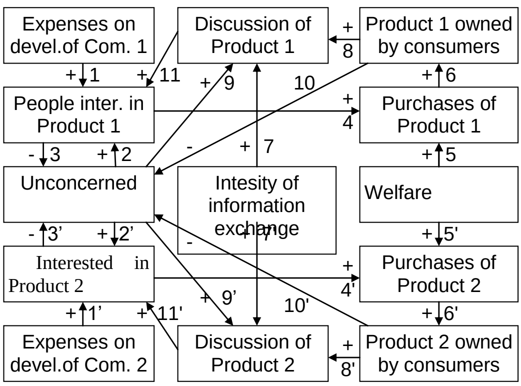

Figure 3–13 Cognitive map of processes in a duopolistic market

[26] An admission is made about a uniform dependence of product popularity on the amount of expense involved in its development. In a broad sense, this can include the development of marketing efforts, advertisement in particular.

[27] Relationships are not usually marked in a cognitive map, here it is done only for the purpose of making comments.

[28] If everybody is already interested in the product, the number of those interested does not increase.

- A group of consumers interested in a product is supplemented by the unconcerned consumers. Thus, the faster the number of the consumers interested in a product increases, the faster the number of unconcerned consumers decreases (relationships 3 and 3');
- The more people are interested in a product, the greater its sales volume (relationships 4 and 4');
- Sales volume is directly dependent on the welfare of the population (relationships 5 and 5');
- The greater the number of purchases, the more products consumers own (relationships 6 and 6');
- The intensity of the information exchange directly influences the number of discussions on a product (relationships 7 and 7');
- The number of discussions also depends on the number of "storytellers"- consumers who own a product (relationships 8 and 8') and on the number of "listeners" – the unconcerned consumers (relationships 9 and 9'),
- As long as in the assumed system of variables the number of unconcerned people equals the population minus the number of people who own a product, the relationship 10 and 10' can be introduced;
- The discussions result in increasing the number of people who are interested in a product (relationships 11 and 11').

The behavior of the system under consideration is examined on the basis of a cognitive map. It is assumed that rumor intensity/information exchange and welfare are constants. As a preliminary, the development expenses of each company are also assumed as constants.

At the start, the number of interested consumers increases swiftly , due to the great number of people who are not aware of the product. At the end, the growth slows down, because everybody has become interested.

Discussions about the products are weak at first due to the limited number of consumers. At the end they are also weak, because there are almost no unconcerned consumers left.

The fastest growth of the number of interested consumers occurs when the discussions about the product are numerous, i.e. in the middle of the process.

The number of purchases is high when the number of interested consumers is high, i.e., also in the middle of the process.

Each of the numerous feedback loops could have been examined, however, as has already been demonstrated the processes are intensive in the beginning, then the variables change rapidly, and in the end their change slows down again while the feedback loops intensify these events. Thus, direct evidence is provided tas regards the traditional bell-shaped product lifecycle curve. After having understood the general principles of this model's operation, one can solve the current task. If the development expenses increase, the number of interested consumers also increases, which leads to an increase in the number of purchases. Thus, product sales have a high and rapid "splash". One should note that the sales are higher for the company that offers more intensive development.

The general conclusion is as follows: if a company assigns more means to development, the sales of its products are high, and rapid. If small investments are made in development, there will not be a big "splash" and another company will sell more items.

Distribution of the costs of development with the help of the model under consideration is rather difficult due to its purely qualitative nature. However, the model built does allow a determination of the type of process and the relationships between the variables of the model.

Flow-oriented model

The prerequisite for the application of this type of models is the fact that the flow (e.g., the number of purchases) and the level (e.g., the number of products bought by consumers) of the variables have been identified in the cognitive model. On the basis of the numeration of the variables, a reservoir model can be built. Detailed descriptions of this type of simulation can be found in [34], [84] and other publications. The model is presented in Figure 3–14.

Initially, when comparing Figure 3–13 and Figure 3–14, one should notice that the latter is easier to comprehend. Unfortunately, this advantage is not visible in complex systems, when a reservoir simulation model consists of a vast number of knots-levels, knots-control variables connected with two types of relationships[29].

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[29] An example of a city model can be found at: http://www.mista.ru/gorod/ index. htm.

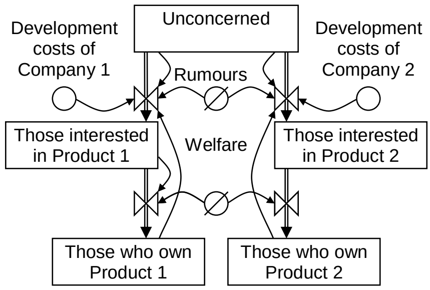


Figure 3–14 Reservoir model with flow interconnections

Models in Figure 3–14 differ from the general models through the absence of sources and runoffs. According to the initial admissions, the population is a constant and that is why the model does not have an inflow and outflow of population. Another acknowledgment is that the product does not go out of service, which makes the runoff for the consumers who have lost their product unnecessary.

This model presents the following features rather well:

Material flows from one level –“reservoir” to another, is marked with double arrows (in this case, this means the transition of people from the category of unconcerned to the category of those interested in a product, but not owning one, and then – to the category of those who own the product); the meaning of the variables, e.g., of the variable ‘interested’, is evident;

Dirigible linkage are marked with single arcuate arrows indicating which variables the flow speed depends on; unfortunately, this type of dependence is not determined in the notation, however, Figure 3–14 is a convenient step to the building of differential equations.

A conclusion can be made on the basis of the picture that if the flow of the customers interested in Product 1 is not increased, potential consumers can be missed as they will transfer into the category of those interested in Product 2 and will be “lost” for Company 1.

The picture addresses the issue of which variables this process depends on (on the number of those who own a product on the intensity of rumors, on the development costs). The conclusion is the importance of the management of development costs.

Additional conclusions can be made if additional notes on the sign of the dirigible linkage are made (Figure 3–15).

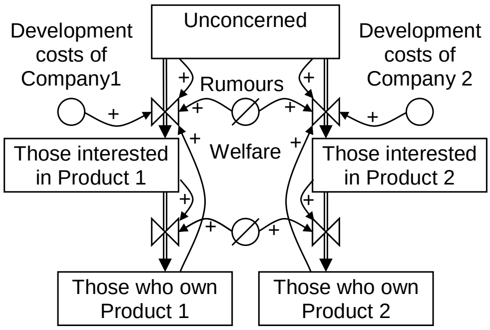


Figure 3–15 Reservoir model with flow interconnections in a modified notation

In order to increase the speed of expansion of the consumers interested in a product, a company should increase development costs.

As the number of consumers who own the product grows, the speed of expansion of the interested consumers also increases (with the help of rumors). However, due to the decreasing number of unconcerned people, this speed is reduced with time.

Thus, the suggested consideration of the sign of the dirigible linkage helps to keep the advantages of the cognitive model, combining them with a visualization of the flow-oriented model.

Model in the form of differential equations

Differential equations describing the task can easily be based on Figure 3–14 and Figure 3–15. However, the functional dependences that have only been presented as the presence of a dirigible linkage should be specified.

In order to build the equations, it is convenient to introduce the following notations : H – the number of people unconcerned about a product; $З_1$ – the number of people interested in product 1; $З_2$ – the number of people interested in product 2; $И_1$ – the number of people who own Product 1; $И_2$ – the number of people who own Product 2; $Р_1$ – the coefficient of the novelties' action of Company 1: the share of people not concerned about the product, who became interested in Product 1 per time unit[30]; $Р_2$ – the coefficient of the novelties' action of Company 2: the share of people not concerned

[30] This process is highly affected by the advertising effectiveness, but in the context of the example, it is considered a time-constant equal for both companies.

about the product, who became interested in Product 2 per time unit; С – the coefficient of rumor spreading: the number of discussions per couple, one of which owns the product, while the other is unconcerned about it, per time unit; Б – the welfare coefficient – the percentage of people who have bought the product among the people interested in it, per time unit.

A derivative is marked as “ ' ”.

The equations describing the system are in the form:

$$Н'=-(Н\times И_1\times С+Н\times Р_1)-(Н\times И_2\times С+Н\times Р_2);$$
$$З_1'=Н\times И_1\times С+Н\times Р_1-З_1\times Б;$$
$$З2'=Н\times И_2\times С+Н\times Р_2-З_2\times Б;$$
$$И_1'=З_1\times Б;$$
$$И_2'=З_2\times Б.$$

They are based on Figure 3–15. The first equation represents the rate at which the number of unconcerned people decreases. As long as the decrease takes place in two flows, there are two components marked with brackets. The negative sign before them indicates that the number of unconcerned peoples is decreasing (the flows “run out” from the unconcerned “reservoir”). Figure 3–15, also demonstrates what the decrease rate depends on. The first addend in the brackets is the role of rumors: the greater the numbers of unconcerned people and people who own a product of a particular type, and the more intense the rumor spreading, the higher the decrease rate. The second addend in the brackets reflects the role of advertising in this process: the higher the advertising costs and the greater the number of unconcerned people, the more people will know about a particular product from the advertisement of the novelty.

The addends in the second brackets are analogous with regard to Company 2.

The second and third equations describe the change rate of the number of people interested in Products 1 and 2. This number increases as the number of unconcerned people decreases. That is why the first two addends in the second and third equations correspond to the content of the brackets in the first one. The last addend in the second and third equations reflects the decrease in the number of people who are interested in the product but do not own it as the number of people who have bought the product increases. This is the reason why it is preceded by a negative sign. The decrease rate of the number of people who are interested in a product (technically, it is a purchase rate) equals the number of people interested in the product multiplied by the welfare coefficient.

The fourth and fifth equations demonstrate an increased rate in the number of people who own the products of Companies 1 and 2. It is evident from the picture, that the increase occurs by means of a decrease in the number of people who are interested in a product but do not own it. This is the reason why the left side of the equations correspond to the last addends of the second and third equations, but has the opposite sign.

Thus, the flow-oriented model can be used as a basis for a system of differential equations describing the system.

In order to solve the developed system, the initial conditions should be articulated. According to the initial statement, in the beginning, nobody is interested in the products; this is why the number of unconcerned people equals the population size, and the initial values of the variables $З_1$, $З_2$, $И_1$, $И_2$ equal zero. It is convenient to solve such equations by applying percentages rather than numbers. This is applicable due to the recognition that the population is a constant. Thus, the initial conditions are of the form:

$$H(0)= 100(\%);$$
$$З_1=0;$$
$$З_2=0;$$
$$И_1=0;$$
$$И_2=0.$$

If the solution is not performed with the use of special tools, such as Excel, then it is required to input it manually, as a differential equation applying the determination of the derivative:

$$X' \underset{df}{=} \lim_{\Delta t \to 0} \frac{x(t+\Delta t)-x(t)}{\Delta t}.$$

In this case, one should turn from derivatives to finite differences:

$$(Н(t+\Delta t)-Н(t))/\Delta t=-(Н(t)\times И_1(t)\times С+Н(t)\times Р_1)-(Н(t)\times И_2(t)\times С+Н(t)\times Р_2);$$

$$(З_1(t+\Delta t)-З_1(t))/\Delta t=Н(t)\times И_1(t)\times С+Н(t)\times Р_1-З_1(t)\times Б;$$

$$(З_2(t+\Delta t)-З_2(t))/\Delta t=Н(t)\times И_2(t)\times С+Н(t)\times Р_2-З_2(t)\times Б;$$

$$(И_1(t+\Delta t)-И_1(t))/\Delta t=З_1(t)\times Б;$$

$$(И_2(t+\Delta t)-И_2(t))/\Delta t=З_2(t)\times Б.$$

The iterative formulae for the recalculation of the values of all the variables can be determined by multiplying by Δt and transferring the value of the variables at a particular t moment onto the right hand side of each equation:

$$Н(t+\Delta t)=Н(t)-(Н(t)\times И_1(t)\times С+Н(t)\times Р_1+Н(t)\times И_2(t)\times С+Н(t)\times Р_2)\times\Delta t;$$

$$З_1(t+\Delta t)=З_1(t)+(Н(t)\times И_1(t)\times С+Н(t)\times Р_1-З_1(t)\times Б)\times\Delta t;$$

$$З_2(t+\Delta t)=З_2(t)+(Н(t)\times И_2(t)\times С+Н(t)\times Р_2-З_2(t)\times Б)\times\Delta t;$$

$$И_1(t+\Delta t)=И_1(t)+З_1(t)\times Б\times\Delta t;$$

$$И_2(t+\Delta t)=И_2(t)+З_2(t)\times Б\times\Delta t.$$

Figure 3–16 demonstrates type of transient processes[31] for the variables $З_1$, $З_2$, $И_1$, $И_2$ under the above-mentioned initial conditions and $\Delta t=0.01$ unit of time. A time unit is assumed to be one month. The coefficients are: $С=0.5$; $Р_1=0.6$; $Р_2=0.4$; $Б=0.5$.

It is evident from Figure 3–16 that the number of people who own a product produced by a particular company increases slowly in the beginning, then its growth accelerates and slows down again by the end of the process. By the 1000th step of the simulation (by the end of the tenth month) the number of people who own a product barely changes, which means that the sales have almost stopped. The number of people who are interested in the product but do not own it, reaches its highest value around the end of the first month, and gradually decreases, because the growth of this number slows down (many people are already interested in the product). In addition, the transition of people to the category of those who have already bought the

[31] It is created in Excel by means of the above-mentioned formulae.

product reduces the number of people who are interested in the product, but do not own it.

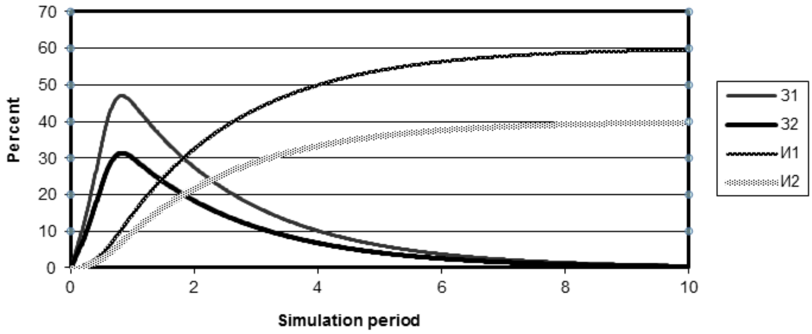


Figure 3–16 Transient processes in the simulated system

The fact that the sales volume of each product is proportionate to the number of people interested in the product can be applied in order to assess the sales volume according to the schedule, this follows from the initial differential equations describing the simulated system.

Simulation time in this case is selected empirically. In a case where the transient processes (changes of variables with time) are not yet completed, the simulation continues.

Simulation step Δt needs to be adjusted in a case where its duration is comparable to the duration of the transient processes. The minimal value of the step should be about 10…20 times less than the fastest of the transient processes. In the current case, the duration of the transient processes is 10 months, which is why the minimal possible value of Δt is 0.5 of a month. The applied value $\Delta t=0.01$ allows a safety margin of simulation precision. However, the Δt quantity has another limit. If its value is large, there is a possibility for the variables to exceed their notional limits. For example, when the simulation step has a significant duration, the number of people interested in both the products can exceed the number of the unconcerned people, which, in turn, will lead to a negative number of unconcerned people in the next stage. As a result, the types of transient processes will differ from reality, which usually results in increasing oscillation. Thus, one should start with small values for Δt. In cases where the physical resources of a computer are insufficient, e.g., in the task under consideration the transient processes start at the 1000th step, then one can decrease Δt until the above-mentioned error occurs. For the task under consideration, an increasing oscillation already occurs at

Δt=0.05, and the number of unconcerned people reaches (-8·1035) soon after the 200th step.

The same problem occurs in discrete-time models.

Differential equation models provide more information about the system under consideration than the flow-orientated models. For example, it is evident that the company that has a higher value for the coefficient of the development impact (which is reached by increasing the advertising costs), achieves a higher level of promotion of its product, i.e. its sales volume exceeds the sales number of the competitor. It is also evident that the number of people interested in the product produced by this company reaches its highest point (and the peak of sales accordingly) earlier than its competitor and this point is also higher. In contrast to the qualitative assessment provided by the flow-orientated models, the differential equation model allows quantitative assessment with the application of various values of the model coefficients.

It is also easy to evaluate cost allocation according to periods. In order to do this, one should introduce some time variables instead of the constant coefficients P_1 and P_2. The time variables are the essence of the management decision. A decision-maker can, for example, compare two options:

- large-scale advertising at the outset aimed at the fast attraction and attention of potential buyers to the company's product;
- lowering of the advertising impact at the sales peak in order to achieve a higher level of sales evenness.

These options are tested in the model. The model assesses whether the unevenness in the sales extends beyond the limits that have been set, and whether the captured market share corresponds to the company objectives. In a case where both options are applicable, the most suitable one (e.g. the least expensive) is selected.

Asymptotic convergence can be considered as one of the disadvantages of this type of model. For example, at the end of the 10th period, the value of H equals 2×10-223. This is difficult to interpret as a percentage of the population even for a megalopolis, because this value corresponds to a population smaller than 1 person. Meanwhile, this effect becomes evident when the values of the variables are rather small, however, it is barely noticeable during the transient processes under consideration.

Thus, the application of the model to differential equations and process simulation in the system under consideration permits the reception a considerable amount of valuable information and evaluates the solution options in a quantitative way.

Discrete-time models

These types of models are often referred to as models where the time delay is examined in [227].

Providing the building process for this model differs from the previous one, it is convenient to describe it as a cognitive model rather than as a development of a continuous model.

The initial task data, verbal description, and discussion of the admissions are summarized in Table 3–4. In addition to the notations introduced in the previous paragraph, additional ones have been added: $У_1$ – the number of people who have learnt about the product of Company 1 over a period of time; $У_2$ – the number of people who have learnt about the product of Company 2 over a period of time; $К_1$ – the number of people who have bought the product of Company 1 over a period of time; $К_2$ – the number of people who have bought the product of Company 2 over a period of time.

The set of equations describing the simulated situation is as follows:

$$К_1=З_1×Б;$$
$$К_2=З_2×Б;$$
$$У_1=Н×Р_1+Н×И_1×С;$$
$$У_2=Н×Р_2+Н×И_2×С;$$
$$З_1=З_1-К_1+У_1;$$
$$З_2=З_2-К_2+У_2;$$
$$И_1=И_1+К_1;$$
$$И_2=И_2+К_2.$$
$$Н=Н-К_1-К_2+У_1+У_2.$$

This set of equations has much in common with the form of differential equations.

The initial conditions correspond to the task in the form of differential equations. The following initial conditions should be added:

$$К_1(0)=0;$$
$$К_2(0)=0;$$
$$У_1(0)=0;$$
$$У_2(0)=0.$$

The formulated model requires some correction of formulae and the introduction of additional restrictions. The need for these is not evident. Their absence, as a rule, is not visible during the simulation of continuous systems with a small pitch distance, but as the distance increases considerable distortions may occur. The above-mentioned corrections should be also applied at the end of the simulation process, however, it should rather be anticipated at the beginning.

<table>
<tr><th>Initial data</th><th>Discussion on admissions</th></tr>
<tr><td>Two companies producing similar goods (e.g., TVs) enter the consumer's market of a city. Nobody knows about this product and have never purchased it before</td><td>It is a rather serious admission, because even if the product has not been sold in the city before, it could have been bought and brought to the city by people from other places. Development of mass communications makes this assumption problematic. Thus, the assumption about complete unawareness makes the task purely theoretical. Such s model can be close to reality only in cases of the introduction of new products.</td></tr>
<tr><td>The product has an unlimited period of validity, does not go out of service, and is not resold. Thus, a consumer purchases the product once and uses it for a nearly indefinite period of time</td><td>In reality, even goods with very long period of validity (cars, refrigerators, etc.) can be resold, or a need for one more product may occur (a refrigerator for a summer cottage). Thus, due to this assumption, the example is a matter of purely academic interest.</td></tr>
<tr><td>One can learn about the product from the advertisement. The advertisement impact coefficients P1 and P2 are defined as the percentage of those unaware about the product – who then learn about Products1 and 2 respectively over the same period of time</td><td rowspan="2">Only two channels of data acquisition are addressed here. They are often the most important, but additional examination of other channels is also required.</td></tr>
<tr><td>One can learn about the product by word-of-mouth These are transferred from those who own a product to those who are not aware of it. The spreading of rumors is characterized by the coefficient of the word-of-mouth intensity C – the number of product discussions over a period of time between two people, one of whom has the product and one who is unaware of it.</td></tr>
<tr><td>No seasonality</td><td>This admission requires verification.</td></tr>
</table>

After learning about one product, a consumer is no longer interested in another similar product and does not learn about it.	This can be correct, because usually the product that has been learned about first, is that bought with a higher probability. At the same time this admission requires additional verification.
Each consumer purchases one unit	This admission is not so important, because one unit can be easily replaced by an average number of purchased units.
The process is simulated by periods. The duration of a period is one month.	In reality, the process is continuous and should be examined by days, or even by hours. However, simulation by days requires taking into consideration weekends, which will significantly complicate the task.
	The effect of the replacement of the current values by average ones can occur during the simulation of such long periods. For example, in the suggested model the number of those who are aware of the product changes abruptly over the period, though it is a continuous magnitude that is changing on a daily basis. The number of those who have purchased the product depends on the number of those who are aware of the product. In practice, this means that the values of the quantities can pass their logical limits. For example, the number of people who have learned about the product over a period of time can be calculated to be higher than the number of people who are not aware of the product.
A certain share (Б) of those who knew about the product in the previous period purchase it in the current period. Share Б characterizes the welfare of the population.	The admission is rather realistic: after learning about a product one should make up one's mind as th whether to purchase it. However, doubt can be cast upon the constancy of the share during the simulation period.
The number of different categories of consumers (aware, not aware, etc.) is continuous. In other words, the population size can be reflected by a non-integer number.	For a great number of the consumer (over 10 000) errors caused by this assertion are increasingly small in the transient processes and are of no importance for the established regimes.

Table 3–4 Initial data, assertions, and comments on the assertions

- At the end of the simulation, when nearly everybody is aware of the product, the number of people who have learned about it over a particular period can be more than the number of people who are still not aware of it. For example, in a case where 4 per cent of the people are not aware of the product; 3 per cent have learned about product 1, and 4 percent have learned about product 2. For this case, a correction of the formulae for the calculation of the number of people who have learned about the products is introduced: the rest of the consumers learn about the products in proportion to previously calculated numbers. For the current example: 4/7×3=1.71% will learn about product 1, 4.7×4=2.29% – about product 2, which accounts for the remaining 4%.

- After another calculation step the last equation can result in a magnitude lower than 0. In this case, it is replaced with 0.

The above-mentioned corrections are easy to implement into the simulation algorithm. Taking them into account, the formulae for the simulations are as follows:

$$К_1=З_1×Б;$$
$$К_2=З_2×Б;$$
$$У_1=IF(Н<0.001;0; IF ((Н×Р_1+Н×И_1×С+Н×Р_2+Н×И_2×С)<Н;(Н×Р_1+Н×И_1×С);(Н×Р_1+Н×И1×С)/(Н×Р_1+Н×И_1×С+Н×Р_2+Н×И_2×С) ×Н);$$
$$У2= IF (Н<0.001;0; IF ((Н×Р_1+Н×И_1×С+Н×Р_2+Н×И_2×С)<Н;(Н×Р_2+Н×И_2×С);(Н×Р_2+Н×И_2×С)/(Н×Р_1+Н×И_1×С+Н×Р_2+Н×И_2×С) ×Н);$$
$$З_1=З_1-К_1+У_1;$$
$$З_2=З_2-К_2+У_2;$$
$$И_1=И_1+К_1;$$
$$И_2=И_2+К_2;$$
$$Н= IF ((Н-К_1-К_2+У_1+У_2)<0;0;(Н-К_1-К_2+У_1+У_2)).$$

The notation analogous to the one used in Excel is applied in this case:

IF (condition, expression 1, expression 2).

The result of the application of this function equals expression 1, if the condition is true, and equals expression 2 otherwise.

Selection of the simulation time is performed in the same manner as in the case of differential equations.

The simulation step equals the selected time unit, i.e. one month. The task solution is performed by a multiple calculating of the above-mentioned formulae. The final diagrams for the initial data, corresponding to the solution by the system of differential equations, are presented in Figure 3–17.

Comparison with the diagrams, obtained as a result of the application of differential equations, which are evidently more precise, demonstrates that the quality of the transient processes has been preserved as well as their duration and final values. Thus, the same conclusions can be made for the model as those in the form of differential equations.

The differences include:

- the maximum values of the number of those who are aware of the product (it is rather easy to count these on the basis of the diagram as all the people became aware of the products over the second period: 60% – about Product 1, and 40% – about Product 2.
- the existence at beginning of the transient processes of a lag, which is demonstrated in Figure 3–17. Firstly, the calculations start not from the t=0 moment of time, but from step (period) 1, which is more habitual. However, one can consider the initial state as step 0. Secondly, period 2 corresponds to the initial state when nobody yet knew about a particular product; this is why nobody bought it after step 1.

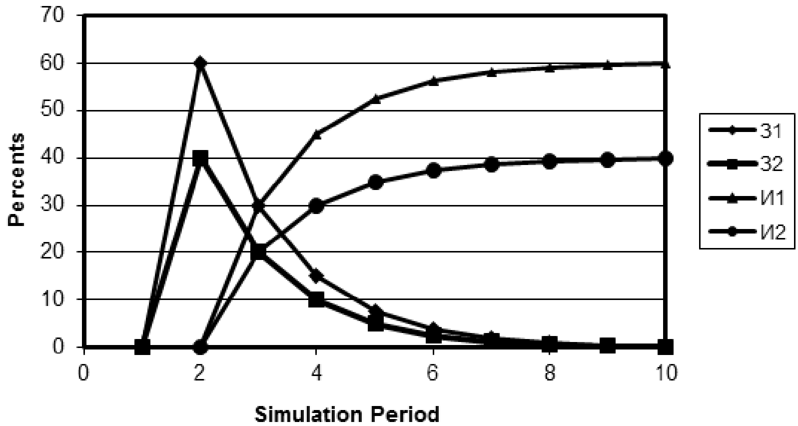


Figure 3–17 The transient processes in a system with a time delay

A discrete-time model allows the building of a diagram of product lifecycles by their sales on the basis of the calculated values of K_1 and K_2. The diagram demonstrates their duration and height and is presented in Figure 3–18.

The model allows an easy planning of the amount of advertising expenses incurred in each period. In order to analyze the various options, one should replace constants P1 and P2 with a set of their values by periods. This is easier than using formulae for a model in the form of differential equations.

Thus, the application of models with a time delay is easier for managers to comprehend, because they see the results and can make plans in a normal sequence of periods. However, the building process for such models is rather more complicated than for models in the form of differential equations, because it requires additional reasoning, assumptions, and formula corrections that are not immediately obvious.

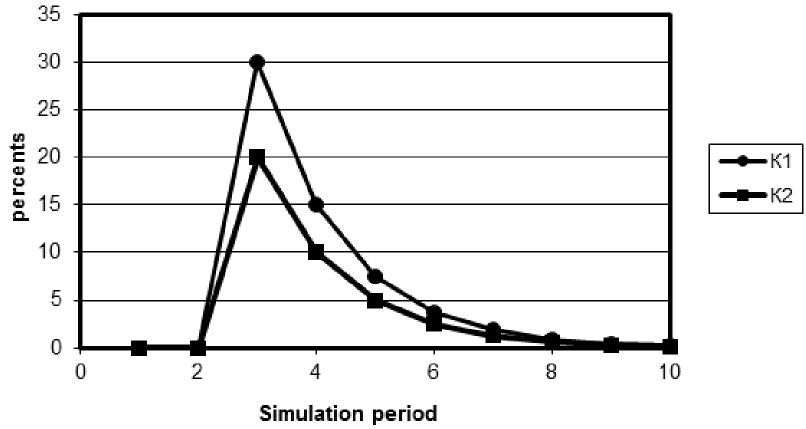


Figure 3–18 Product lifecycles

In conclusion, one should note that the preservation of quality and the high number of quantitative estimates produced by the large values of the simulation step give evidence of the fact that the solution using a differential equation with the help of a computer is not such a time-consuming task. At the same time, the following issues may occur:

The verification of model precision produced by the large step values, is not a simple task for complex models;

The number of mistakes increases when a model becomes more complex, particularly when several models are consolidated[32].

3.3.14 Optimization of market entry by the dynamic programming method

The idea of building of a market entry model is taken from [135].

[32] For the example under consideration, one can build a model of the change in population or welfare and use the outputs of these models as inputs for a duopoly model.

A company issues a number of products and wants to develop a number of markets. The costs incurred by the market entry are determined by a number of factors, among which are:

- the presence on the market of other products;
- the consumers' experience of the use of the products;
- the actions of the competitors that depend on the number of "our" products on this market;
- the influence of neighboring markets: if "our" product is available there, the success probability is higher.

It is supposed that the sequence of the market entry is not optional: firstly, product 1 can be introduced, then product 2, and product 3 after that. This assumption is reasonable for some products, such as Smartphones, where the main product is introduced first, and then the accessories, after which – the spare supply sources can be introduced. It is also supposed that the order of market development is set (according to the order number). These assumptions are introduced in order to simplify the example.

Taking these assumptions into consideration, one can introduce the following denotations for the market state: a_i – the number of product categories in the market, i; – the number of markets

The possible means of market coverage are demonstrated in Figure 3–19. The arrows show the possible transitions from one state to another, the arrow weights show the pre-calculated profit from the coverage of a new market sector (profit from the new market minus the costs of the products development). The measure is given in mln rub.

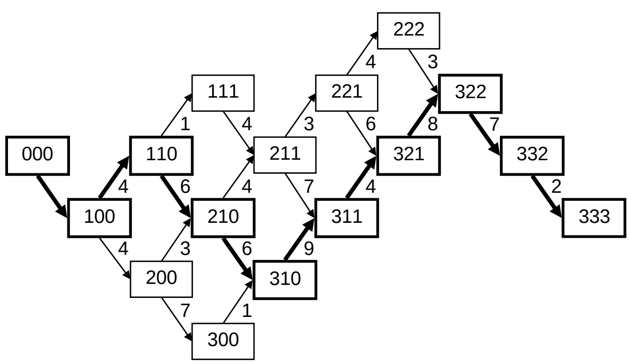


Figure 3–19 Methods of market coverage

In the solution process, the states that allow the final state to be reached in steps 1, 2, 3, 4, etc. are considered in turn. The number of steps required to reach the final state from a particular state is called a rank of this state.

Optimal profit values that can be achieved by moving from each apex to the final state for each state are demonstrated in Table 3–5. It is evident that the general maximum profit after entries into all the markets with all the products is 55.

The main result of the calculations is the optimal way of market penetration. This route for market penetration follows the apices marked in bold in the Table 3–5 and Figure 3–19: 100, 110, 210, 310, 311, 321, 322, 332, 333.

Rank	Apices	Maximum profit from transition to the final state
1	332	2
2	332	9
3	222	12
3	321	17
4	221	max(П(222)+4;П(321)+6)= max(12+3;17+6)=23
4	311	21
5	211	max(П(221)+3;П(311)+7)=max(23+3;21+7)=28
5	310	9+П(311)=30
6	111	4+П(211)=32
6	210	max(П(211)+4;П(310)+6)=max(28+4;30+6)=36
6	300	П(310)+1=31
7	110	max(П(111)+1;П(210)+6)=max(32+1;36+6)=42
7	200	max(П(210)+3;П(300)+7)=max(36+3;31+7)=39
8	100	max(П(110)+4;П(200)+4)=max(42+4;39+4)=46
9	000	П(100)+9=55

Table 3–5 Calculation of Π(i) – profit from the transition to the final state from the i-th apex

Discussion. In order to move to the task of dynamic programming, one should make rather important assumptions. Generally, these assumptions touch upon the final set of states and the sequence of transitions between them. It is supposed that the costs and profit that occur during a transition do not depend either on the previous history, nor the intentions for further business reach.

3.3.15 Evaluation of demand parameters depending on the product features with the help of neural networks

Demand depends on a great number of variables, among them: product and market parameters, parameters of competitive position, development of economy and, finally, parameters of the marketing mix of the company-producer and middlemen.

Qualitative and integral parameters

During the idea analysis stage, it is convenient to evaluate the demand parameters irrespective of the marketing mix. Development of the marketing mix should be performed on the latest stages of product management.

The following demand parameters will be discussed (they are considered dependent variables in the current research).

1 The type of a lifecycle curve. It is suggested to typify these according to [93]. The following numerical designations can be introduced for the types of curves: 1 – long teaching, 2 – no teaching, 3 – splash, 4 – splash with the residual market, 5 – failure, 6 – long cycle, 7 – new wave, 8 – new start, 9 – unsuccessful market introduction , 10 – "two-humped" cycle. This list is not inclusive. A neural network should forecast the value of this variable.

2 Seasonality. It is suggested that three levels be defined: 1 – low (oscillations from 10%), 2 – medium (oscillations from 1 to 25%). 3 – high (oscillations over 25%).

3 Market potential. This can be evaluated quantitatively. In this case, we suggest having three evaluation values: 1 – low potential (lower than an average product from this commodity group has), 2 – average potential (differs from the potential of an average product from this commodity group by no more than 10%), 3 – high potential (a much higher potential than an average product from this commodity group would have).

The list of independent variables is based on the one offered in [76] with some alterations.

Product parameters: novelty level, specific variables and constant expenses, breakeven sales volume, target sales volume, cannibalization share, price demand elasticity, stock of goods, etc.

Consumers' parameters: the percentage of need, the index of active application, the levels of awareness, the idea, the intentions, loyalty, the number of potential buyers, the speed of innovation diffusion, etc.

Market parameters: the brand development index, the category development index, the test purchasing level, he repeat purchasing level, the level and variability of prices, etc.

The Parameters of the industry: the market share, the level of competition, the number of competitors, the level of industry concentration, etc.

Marketing parameters: the average acquisition cost, the advertising rate for a thousand contacts, functions of advertisement feedback, etc.

General economic parameters: the rate of inflation, GDP growth, etc.

A neural network can learn from a number of available training examples with known values for both the dependent and independent variables. A trained network can provide rather correct predictions of the values of dependent variables on the basis of the independent ones. The results can be quantitative (expected sales volume) as well as qualitative (e.g., low, average, or high seasonality).

Discussion. It is noted in [42] that one should treat the results with caution, because qualitatively new factors, currently unknown as regards the forecasting, may occur for new products, therefore, the results should be verified by experts.

Quantitative evaluation

The quantitative parameters obtained as a result of the application of neural network can be the inputs from other neural networks that will determine the quantitative parameters and the dynamics of demand. This approach has been successfully applied by GoalAssist Corporation [238] that has built two sequenced neural networks for the Ward Systems Group: The NeuroShell Classifier, with various product and advertising policy parameters as the input data. With the help of this network, especially designed for classification, the inputs have been classified into 4 classes on the basis of customers' feedback. The same inputs together with the output of the first network have then been set as the input of the second network, the NeuroShell Predictor, which is designed for tasks of quantitative forecasting. The average prediction error was 4%. The building process for the model took approximately 120 hours, however, the pre-processing of the input data also required a particular amount of time.

3.3.16 Concept evaluation with the help of numerical methods

This type of evaluation method is based on the idea suggested in [136]. In this case, the correspondence between a concept and a particular segment that the product was designed for, is evaluated. Calculations are performed using the example of a new automatic washing machine with improved characteristics.

A list of segment parameters, which have been obtained from its profiling results, clearly show a set of the input data stages of family development: a completely nested nest; the family income e.g. average; a family where the members do the housework or there is not enough time for the housework; a high level of innovation.

Expert evaluation of the importance of the Vi parameters of the target segment for a product of this category (automatic washing machines) is performed. For example, the importance of the social role of "doing the housework" is higher than the psychological characteristics "innovator". Characteristics of the selected segment are introduced in the left-hand column of Table 3–6, while evaluations of their importance in segment profiling – in the second column to the left.

	Significance of segment characteristics Vi, i=1,n	Operation speed	High washing quality	Gentle wash	Baby clothing wash	Handy modes (delay start, end of cycle alarm...)	Low price
Implementation of Pj, j=1,m in the product		0.8	0.6	0.4	0.2	1.5	0.4
Family stage "full nest"	5	5	5	5	5	3	3
Average family income	4	3	4	4	5	3	3
Homemaker takes care of the housework	4	5	5	5	3	2	2
Little time for housework	5	5	5	3	3	5	2
Innovators	3	3	3	3	3	3	2

Table 3–6 Evaluation of the product concept

Evaluation of the fulfillment level of the Pj characteristics of the product can also be performed by experts. These evaluations are represented by the upper row of numbers highlighted with color. The names of the significant characteristics are in the upper row of the table. Level 1 corresponds to the best world achievements. The possible values may vary from 0 (not fulfilled) to 1 and above, in cases where a product exceeds the world level.

The importance the W_{ij} of each product's characteristics for each segment's characteristics is evaluated. For example, consumers who do not have enough time for the housework are more interested in speed rather than price.

The calculations are performed.

The level of correspondence between the product and the segment on the basis of the i-th characteristics of the latter is as follows

$$C_i = \frac{\sum_j^m P_j W_{ij}}{\sum_j^m W_{ij}}$$

For the best available product, the level of correspondence equals 1.

The general level of correspondence between the product and the segment is

$$C = \frac{\sum_{i=1}^n v_i \sum_j^m P_j W_{ij}}{\sum_{i=1}^n v_i \sum_j^m W_{ij}}$$

For the example: C_1=0.60; C_2=0.60; C_3=0.61; C_4=0.74; C_5=0.66. This means that the product mostly corresponds to such segment characteristics as consumer's lack of time, and, to a lesser degree, to the stage of a "completely nested nest" in the family lifecycle, and to an average level of family income. The general correspondence is 0.65, which is not a high activity.

3.3.17 Scoring with the help of classification trees

The example is taken from the User Manual for the Answer Tree Program [263]. Thia program includes 323 customer records with correct solutions.

Data: dependent variable Credit result (Credit_R, good/bad), independent variables: age (Age, young/middle/old), availability of a bank card (AMEX, yes/no), salary (Pay_Week, weekly pay/monthly salary), Class, management/professional/clerical/skilled/unskilled).

The result of building a tree with the help of CHAID is demonstrated in Figure 3–20.

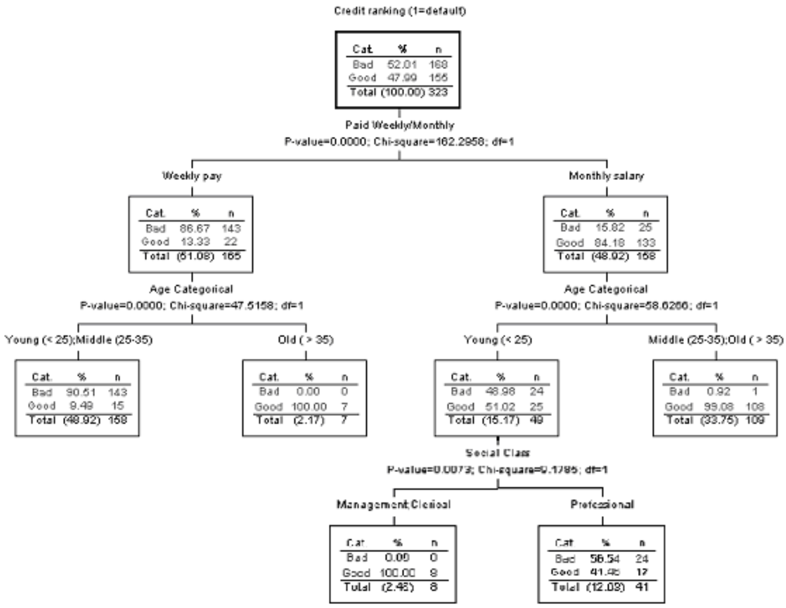


Figure 3–20 Classification tree illustrating scoring

It is evident that 3 segments have been identified that it is advisable to work with. These are: those who receive weekly wages and are older than 35 (7 people, all of them have good results); those who receive a monthly salary and are under 25, the managers and office workers (8 people); those who receive a monthly salary and are 25 and older (108 people among whom only one person had bad results). The level of good results in other segments was about 50%, except in middle-aged group with weekly wages: among the 143 people in this group, only 15 (9%) demonstrated good results.

Thus, a portrait of a client with good results for loan repayment has been created.

Discussion

The method only demonstrates the formal aspect of data and does not provide a causality examination. It is possible that older people with a weekly wage belong to a particular range of occupations, have a particular level of education, and other characteristics that would allow a more precise forecasting of their behavior. However, the rules obtained are:

- The method functions in practice;
- It provides information on the direction for further examination.

Software tools allow more subtle analysis of databases to be conducted. In order to extend the analysis of particular branches, it is necessary to reduce some of them, as well as to obtain a quantitative evaluation of particular terminal nodes and their sets. A set of segments that have good functioning prospects can be selected.

3.3.18 Scoring with the use of neural networks

The same data has been used in the following example, where EasyNN Plus 10.0e has been applied. The data has been transferred into a text file and reduced to 100 examples due to the limitation of the evaluation version of the program.

One hidden level with 10 as the maximum number of neurons has been set as a requirement for the neural network. This decision has been based on practical experience. The overloading of neural networks (setting extra layers of neurons "just in case") complicates the obtaining of good results, because the dimensionality of the search task considerably increases. At the same time, the setting of certain freedoms of choice (mostly this applies to the number of neurons at each level) facilitates the location of a good network.

The program sets the teaching mode automatically. The randomization of parameters, such as the study speed, is widely applied during the learning process.

The network demonstrated in Figure 3–21 has been obtained as a result. The Relative importance of the inputs is evident from Figure 3–22. The result of the classification of the available cases, performed by the network, is demonstrated in Figure 3-23. The process of neural net training is represented by Figure 3–24 a maximum error (it has increased and equals 1), a minimum error (has always equalled almost zero); an average error (dropped almost to zero in the middle of the process which points at the good quality of the network). After this, new cases for classification can be input. Correctly classification is expected, because among 100 available cases only one has been classified incorrectly.

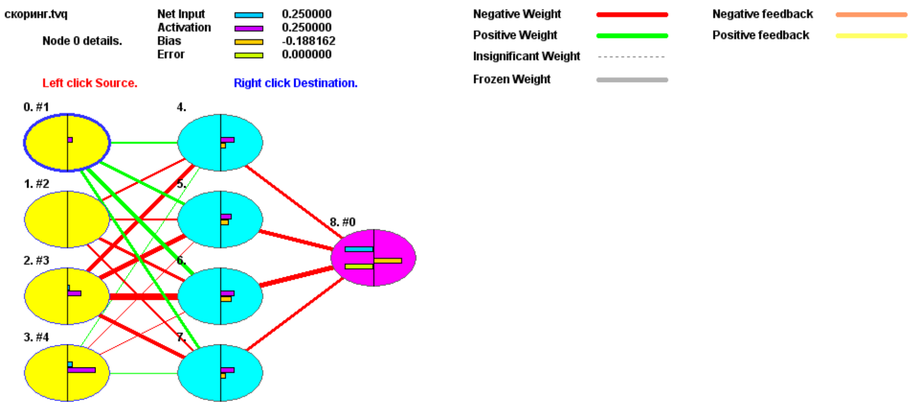
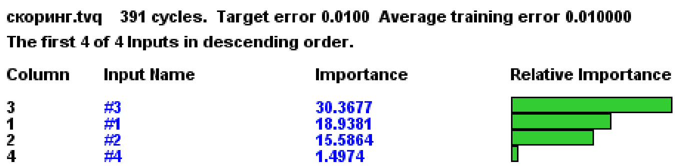


Figure 3–21 Neural network used for scoring



скоринг.tvq 391 cycles. Target error 0.0100 Average training error 0.010000
The first 4 of 4 Inputs in descending order.

Column	Input Name	Importance	Relative Importance
3	#3	30.3677	
1	#1	18.9381	
2	#2	15.5864	
4	#4	1.4974	

Figure 3–22 Results of the working process: relative importance of the inputs

3.3.19 A posteriori segmentation with the use of cluster analysis

This method is designed to search for new product ideas within the existing product line and is based on consumer surveys.

The ask solution consists of the following stages[33].

4 Parameters significant for the consumers are determined by one of the established methods. One method is to ask an open-ended question about the significant parameters. It is also possible to ask consumers about the differences of the existing products in a particular product

[33] Details of the marketing research (selection of respondents, conducting surveys, etc.) are omitted in the current research due to their irrelevance to the research object.

line. Those parameters mentioned most often are selected for further research.

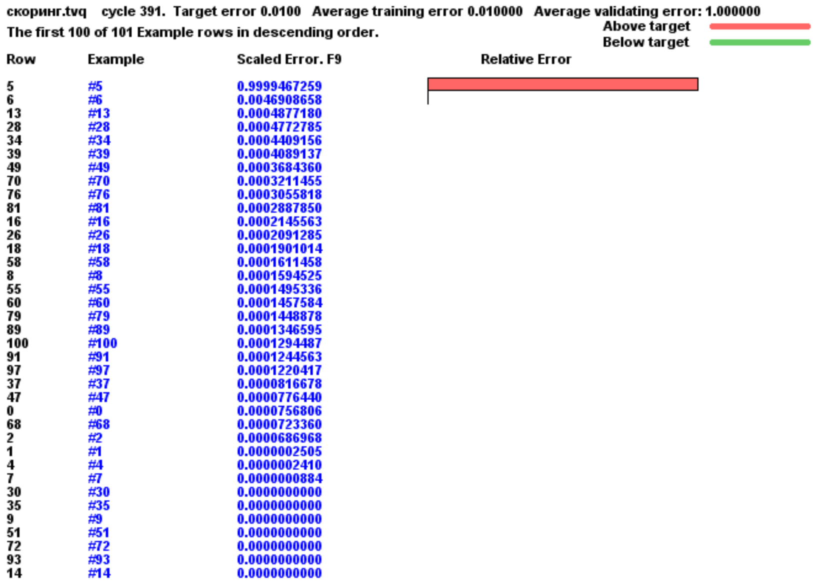


Figure 3-23 Results of the classification of the available cases performed by the network

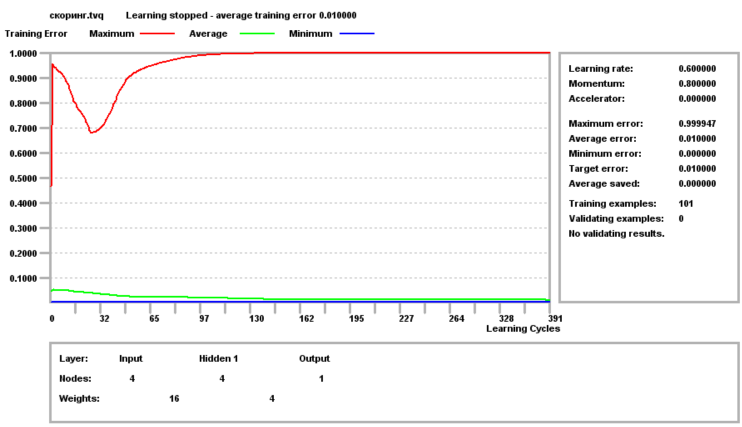


Figure 3–24 Process of neural network training

5 The selected parameters are used for compiling a questionnaire about satisfaction with the existing products. The following questions are asked:

How significant in your opinion is each of the following characteristics? (Evaluate from 1 to 5)

To what extent is each of the characteristics implemented in the best product available?
(Evaluate from 1 to 5)

What characteristic value do you consider is best or how can it be improved[34]? (Open-end question).

As long as this is a pilot study, the number of respondents should be in the range of 30 to 50. The analysis of the survey results follows the scheme:

6 The dissatisfaction of each respondent with each product's characteristics in the product line is calculated.

$$D_{ij} = S_{max} - S_{ij},$$

where D_{ij} is the dissatisfaction of the i-th respondent by the j-th characteristics, S_{max} – the maximum grade of satisfaction (it equals 5 in the suggested example); S_{ij} – the evaluation of the satisfaction of the i-th respondents by the j-th characteristics (in the suggested example it is in the range from 1 to 5).

7 The weighted dissatisfaction is calculated:

$$W_{ij} = D_{ij} \times w_{ij},$$

where W_{ij} is the weighted dissatisfaction of the i-th respondents by the j-th characteristics; w_{ij} – the significance of the j-th characteristics for the i-th respondents (there are answers for the first question in the range from 1 to 5).

An example of the analysis results is demonstrated in Table 3–7.

Respondent	1	2	3	4	5	6	7	8	9	10
Price	1	3	15	0	8	…				
Durability	4	6	8	10	2	…				
Usability	0	16	6	3	3	…				
Exterior	0	5	10	15	20	…				
Power consumption	4	3	2	1	0	…				

Table 3–7 Evaluation of the weighted dissatisfaction of the respondents. Example

[34] If consumers state that they are not satisfied with the size of the product, the final decision will depend on the size of the desirable modifications (larger or smaller ones).

Cluster analysis is performed. This results in the consideration of a sequence of clusters that can potentially become segments. In order to identify close groups of respondents a complete-linkage clustering is performed[35]. It is advised that a Quadratic Euclidean distance be used as a distance unit, because, firstly, all coordinates represent dissatisfaction by features, and secondly, a square is better able to distinguish the groups of the research elements.

The results of the cluster analysis performed by SPSS 11.5 are represented in Figure 3–25.

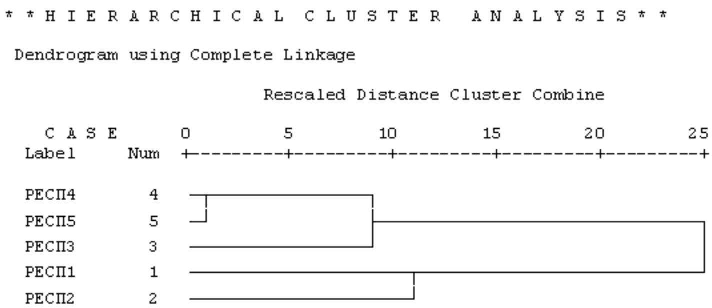


Figure 3–25 Dendrogram of the hierarchical clustering of respondents

If several similar respondents are identified, this raises confidence in a positive market reception. Thais is why the examination of the potential clusters starts with those that form the closest groups. These groups are formed by respondents 4 and 5 in the Figure 3–25. If this cluster is successful, the examination moves on towards the group of three respondents: 4, 5, and 3. A cluster consisting of respondents 1 and 2 is examined in the following stage. The practice of method application in different types of surveys shows that in cases where the linkage takes place on a level higher than the 5th (according to the rescaled distance formed by computer in the upper side of Figure 3–25), the respondents' opinions widely differ. Thus, the clusters that are selected are finally: 4 and 5; 3; 1; 2.

The last clusters consist of one element each.

Cluster selection. In order to develop a new product modification, it is appropriate to select a cluster of respondents who are not satisfied by one or two characteristics and are nearly fully satisfied by the others. Thus, by im-

[35] This method is also known as the farthest neighbor clustering.

proving the unsatisfactory characteristics[36], one can obtain a high level of satisfaction in the segment. During selection, a decrease in dissatisfaction and any remaining dissatisfaction should be noted.

In order to determine the potentiality of clusters the following evaluation units are introduced:

$$O_{1i} = \left(\underset{j=1}{\overset{m}{F_1}} \left(\sum_{n \in \{n_i\}} H_{nj} \right) \right) * \frac{\left(\underset{j=1}{\overset{m}{F_1}} \left(\sum_{n \in \{n_i\}} H_{nj} \right) \right)}{\sum_{n \in \{n_i\}} \sum_{j=1}^{m} H_{nj}} = \frac{\left(\underset{j=1}{\overset{m}{F_1}} \left(\sum_{n \in \{n_i\}} H_{nj} \right) \right)^2}{\sum_{n \in \{n_i\}} \sum_{j=1}^{m} H_{nj}};$$

$$O_{2i} = \frac{\left(\underset{j=1}{\overset{m}{F_1}} \left(\sum_{n \in \{n_i\}} H_{nj} \right) + \underset{j=1}{\overset{m}{F_2}} \left(\sum_{n \in \{n_i\}} H_{nj} \right) \right)^2}{\sum_{n \in \{n_i\}} \sum_{j=1}^{m} H_{nj}}.$$

where O_{1i} is the evaluation of the utility improvement of one characteristic for the i-th segment; O_{2i} is the evaluation of the utility improvement of two characteristics for the i-th segment; n – the current number of a respondent from the i-th segment; $\{n_i\}$ the multitude of respondents from the i-th segment; $j = \overline{1,m}$ is the number of a characteristic; H_{nj} – the weighted dissatisfaction of the n-th respondent by the j-th characteristic; $\underset{j=1}{\overset{m}{F_1}}$ – the function for finding the maximum value of dissatisfaction by characteristics for the n-th respondent[37]; $\underset{j=1}{\overset{m}{F_2}}$ - the function for finding the second largest maximum value of dissatisfaction with the characteristics for the n-th respondent.

Significantly, O_{1i} consists of two multipliers, which is evident from the middle part of the formula. The first multiplier expresses a total decrease of the dissatisfaction after product modification. For example, respondent 3 was

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[36] It is assumed that the characteristic is improved to an ideal rate.

[37] Such notation is introduced for the purposes of the uniformity of indication of F1 and F2, and also because there is a similar function in Excel MAX (<cell block>;<number>). A number that equals 1 corresponds to the maximum, a number that equals 2 corresponds to the second maximum (closest to the maximum).

mostly dissatisfied with the price (15 points). After modification resulted in reducing the price to a "perfect" level, the dissatisfaction is assumed to decrease by 15 points. The second multiplier indicates what part of dissatisfaction can be eliminated after modification. For respondent 3, this equals 15/44=0.37. Thus, a general evaluation of improvement after modification is 0.37×15=5.5. The formula can be rearranged in the form shown on the right-hand side of the formula

In order to evaluate the prospectivity of a segment after the improvement of two parameters, it is assumed that the two parameters with the maximum level of dissatisfaction are transformed into perfect ones. These factors for respondent 3 are the price and the exterior. The general decrease of dissatisfaction will be 15+10=25, dissatisfaction will increase by 25/41=0.61, and the general evaluation of the prospectivity will reach 25×0.61=15.2. If a cluster includes several respondents, then, firstly, the summation of the dissatisfaction of all the cluster elements is performed, and then the following steps are analogues to the previous calculations.

After performing calculations for clusters with one element as well as for the cluster that include respondents 4 and 5, it is evident that performing improvements is more appropriate for the segment that includes respondents 4 and 5.

O_1 and O_2 are the results for each cluster as well as the names of those parameters that are planned to be improved.

Discussion. The current model does not take into consideration the complexity of those parameter modifications that can influence the segment selection. This is why this method is mostly aimed at segment ranking for further consideration rather than for an accurate estimation of the size and prospectivity of a segment. The method allows prospective segments to be identified where the generation of modification ideas is appropriate.

The following step is the generation of modification ideas for the selected segments. This is an intellectually demanding task with multiple solutions. It is possible that the solution for the most prospective segment will not be found due to objective and/or subjective reasons. However, one idea can simultaneously improve several characteristics to a variable degree.

3.4 General layout of the reception of the preferability ranking of the solution methods for tasks in product lifecycle management on the basis of information about situation

On the basis of the performed research, one can define the general layout of interrelationships between the variables when they are converted from situation parameters to the applicability of each solution method as regards the situation under consideration.

1 The applicability of various methods for the solution of different tasks at different stages of product lifecycle management is evident from section 2.3. However, due to the same methods continually appearing in lists for the solution of different tasks, a more precise "focusing" is required, thus the selection should be based on the aim of the solution.

Further dependencies have been identified on the basis of the examples provided in the current research as well as in the literature, this list is provided in sections 3.2,3.3.

2 The aim of the solution is defined by the stage of the decision-making process and by its class: decision-generation, decision-classification or decision-selection.

3 The class of the decision is determined by the availability of alternate solutions for the analyzed situation, and by the availability of off-the-shelf solutions for the class of situations.

4 The method selection is affected by the possibility of managing the values of the variables of a particular situation.

5 The method of selection is affected by the method of determining the values of the variables.

6 In turn, the method of determining the values of the variables is affected by the stage of product management.

The method selection is influenced by the prevailing type of parameters and by the applied method per se. An example of method selection for analysis of data collected as a result of marketing research can be found in [45].

7 The type of prevailing situation parameters determine the type of situation model, this issue is also addressed in [45].

8 The method selection is affected by the logical variables: whether the decision has one-step or multi-steps; the availability of several optimality criteria; the availability of uncontrolled events with several outcomes.

9 The method of selection is also influenced by fuzzy-logical variables: the availability of off-the-shelf solutions for various situations; the availability of a large number of experts; whether the task is high-repeatable; the possibility to manage the values of the variables.

10 The task defines the stage, the possibility of managing the values of the variables, the purpose of the decision, the method of parameter determination, and their type.

11 Finally, the model type is defined by the following facts: whether the decision is one-step or multi-step, the availability of one or several optimality criteria, the availability of uncontrolled events with several outcomes, the availability of off-the-shelf solutions for various situations, the number of experts, the grade of repeatability of the task, the required precision for the presentation of the values of the parameters.

12 The final stage is the application of the evaluations O1 of the applicability of the methods of decision making concerning the organizational aspects, e.g., orientation towards a one-time solution for unique situations (in companies with a stable assortment) or towards highly-repeatable solutions for cases when the assortment is often modified.

As a result, the complete layout of the data conversion is formed (Figure 3–26).

The suggested scheme has the following features:

1 There is a multi-step process for the conversion of the initial data into results, which is typical for expert systems that are repeatedly implemented in the IF-THEN rules.

2 Conversions have different types: logical value →probability line; fuzzy-logical value → probability line; probability line → probability line; probability line → fuzzy-logical value; probability line → evaluation.

3 The unification of the intermediate results with the available initial assumptions is performed during the conversion process.

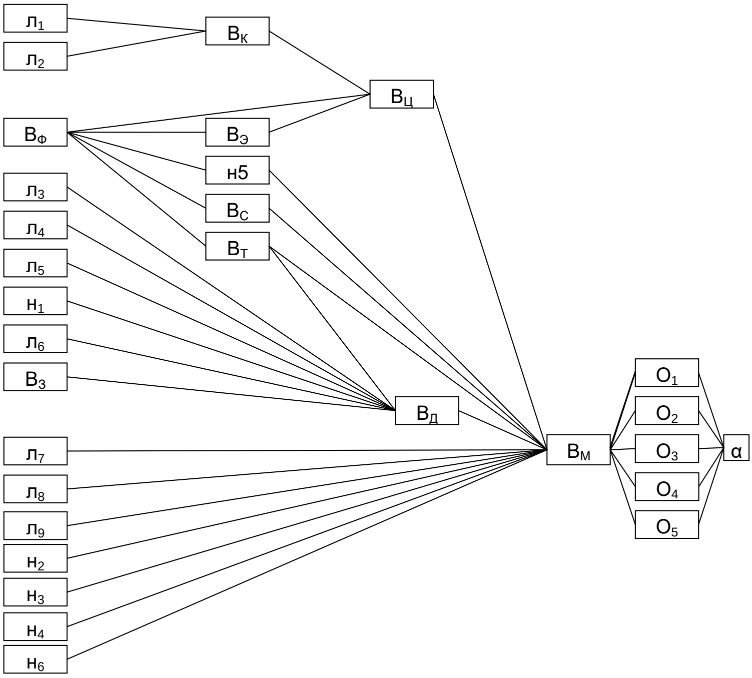

Figure 3–26 The scheme of the conversion in order to obtain a solution

4 The evaluation of the general preferability is based on partial estimates; therefore, it is suggested that the weighted average values are determined according to the preferences of a decision maker.

5 The decision maker has the opportunity to input the available data at each stage of the solution.

It is important to note that the lists of tasks, the methods of their solution, the set of evaluation situation parameters and the methods are open. The current research takes into consideration rather full sets of the above-mentioned objects on the basis of which the applicability of the suggested approach has been demonstrated. The approach is formed in such a manner that each of the lists can be modified or extended. Thus, the suggested decisions take into consideration the development of the theory and practice of the product management.

3.4.1 Conclusion

1. The complex of methods and models for implementing the solution of the tasks for all the product lifecycle management stages, is systematized by tasks and characteristics of the available situations. This considerably simplifies the selection of a solution method, and the solution as regards the scope of the tasks. The general structure of the tasks, methods and models is open to new elements.

2. A system of methods and models for product lifecycle management has been developed. It includes the selection of strategic management areas and prospective market segments with the use of neural networks; the evaluation of the prospectivity of the market segment obtained as the result of a cluster analysis of consumers' satisfaction with product innovations; a forecast on the speed of market penetration with the use of a reservoir model completed by cognitive map elements; the evaluation of the sale's dynamics with the help of the knowledge of the process of market detalization. This broadens the possibilities of product lifecycle management by intellectual methods applicable in cases of incomplete knowledge about a particular situation and the absence of a quantitative model.

3. A general structure has been obtained for the conversion of different types of data (probability lines, logical and fuzzy-logical variables) into degrees of preferential application for each method of the product management as regards the situation under consideration. This allows results to be obtained in cases of incomplete and fuzzy knowledge about a particular situation, as well as taking into consideration the personal preferences of the decision maker.

4 DEVELOPMENT OF EXPERT DECISION SUPPORT SYSTEM FOR EFFECTIVE PRODUCT LIFECYCLE MANAGEMENT

The central uniting element of the offered intellectual interactive methodology is the decision support system for the selection of a method for making marketing decisions on the basis of the situation parameters; the system is developed as a fuzzy matrix expert system. The main elements of the expert system, as is well known, are those facts that describe the value of the parameters, the rules that set the facts' modification techniques, the output mechanism providing the operability of the system, and the auxiliary tools that improve the accessibility of the system.

The fact base includes parameters that describe a particular situation in the form of probability lines, and the logical and fuzzy-logical magnitudes. This list has been developed in section 2.4, and the transformation method – in section 3.4. An example of a file that contains the facts about a situation can be found in the Appendix.

4.1 Rules of fact transformation in the expert system

In this paragraph, we will provide details of the transformation that has been reflected in formula (1) in Chapter 1.

These transformations implement the relationships between the facts. After a separate description is performed for each transformation, they can be combined into a unified expert system.

Determination of the class of the decision-making task:

$$<\text{л}_1, \text{л}_2> \rightarrow \text{В}_\text{К}$$

This relationship helps to identify the class to which a decision-making task belongs.

This relationship can exemplify the essence of fuzzy-matrix conversions in the suggested expert system. The conversion is graphically presented in Figure 4–1.

1 Initial state:

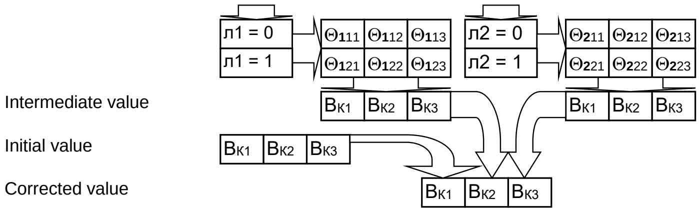

Figure 4–1 Graphic representation of one-step of conversion

- Values of logical variables л1 (availability of alternate decisions) and л2 (availability of solutions for standard situations). These are input variables, and their possible values of 0 (no), 1 (yes), "?" (unknown) are set before the start of the solution process;
- Value of a probability line for fuzzy-logical variables of the problem class. B_K= {$в_{k1}$, $в_{k2}$, $в_{k3}$}. These are the possibilities of the fact that the task belongs to decision-selection, decision-classification or decision-generation. The possible values either belong to the range from 0 to 1 or marked with "?". They are described as an Initial Value in the picture.

2 Value of $л_1$ converts into the first intermediate value BK (left-hand side of the picture) with the help of a transformation matrix Θ_1. This matrix has two rows for the number of values of л1 and three rows for the number of BK elements. It is known that if there are alternatives available, the decision belongs to the class of decision-selection, otherwise, it belongs to any other class. That is why the matrix is in the following form:

$$\boldsymbol{\Theta}_1 = \begin{bmatrix} 0\,0\,1 \\ 1\,1\,0 \end{bmatrix}$$

If $л_1$=0 (no alternatives available), then the first row of the matrix is applied and the result will be 0 0 1. The class of the problem is surely one of decision-generation. In a case where $л_1$=1 (there are available alternatives), the second row of the matrix is applied with the result of 1 1 0. The decision can be either one of decision-generation, or decision-classification.

This type of conversion is performed by the following formula:

$$B_{Kq} = \begin{cases} \Theta_{q1}, & \text{if } л_q = 0 \\ \Theta_{q2}, & \text{if } л_q = 1 \\ NULL, & \text{if } л_q = Null \end{cases} \quad (2)$$

where B_{Kq} is the result of the q-th matrix operation, the q-th estimation of B_K; $л_q$ is the input variable for the q-th conversion; Θ_q is the matrix of the q-th conversion with Θ_{q1}, Θ_{q2} being its first and second rows accordingly, NULL is the indefinite row of the result.

3 There is a fusion of the initial value of BK and the intermediate value obtained in step 2.

The operation of fusion of the preliminary results requires further development according to the following requirements:

- the results of the elementary operations should be considered as well as the initial opinion of the decision-maker;
- the operation should be applicable to all kinds of evaluations, both logical and fuzzy-logical;
- the result of the operation should belong to a range from 0 to 1;
- the possibility of consistent work should be available: there is an initial evaluation of opportunities in the beginning, which becomes more precise with every obtained result.

The following fuzzy-logical operations are available [180].

4 Fuzzy logical AND and OR operations. The main requirement is that they work as an AND and an OR for non-fuzzy logic. Usually, for an AND operation over fuzzy values one applies the minimum probabilities of two variables, and their maximum for an OR operation. However, this conversion leads to the fact that the result probability becomes either too low or too high. In order to obtain an evaluation of applicability of a particular method, a vast number of evaluations can be used. In this case, the result of an AND operation can be that neither of the model types will have a high level of applicability. On the other hand an OR operation can result in the fact that almost all the model types will have high level of applicability.

5 Conversions that provide an intermediate result, e.g., averaging. This can result in all the values having an average applicability level.

6 If one considers the applicability as probability, which is done rather often, a formula for the probability occurring of at least one of the events can be applied:

$$B_{12}=1-(1-B_1)\times(1-B_2),$$

where B_{12} is the resulting applicability, B_1, B_2 are the applicability of result 1 and result 2 accordingly.

All the methods have been experimentally verified with the help of a beta version of the expert system that has been addressed in section 4.3. It has become evident that methods 2 and 3 provide an excessive number of values of an output variable with applicability value 1. Thus, the fuzzy-logical AND operation, defined as the minimum of the two fusing evaluations of applicability, has been applied:

$$B_{12} = \begin{cases} \min(B_1; B_2), & \text{if } (B_1 \neq \text{NULL}) \& (B_2 \neq \text{NULL}) \\ B_1, & \text{if } (B_1 \neq \text{NULL}) \& (B_2 = \text{NULL}) \\ B_2, & \text{if } (B_1 = \text{NULL}) \& (B_2 \neq \text{NULL}) \\ \text{NULL}, & \text{if } (B_1 = \text{NULL}) \& (B_2 = \text{NULL}) \end{cases} \quad (3).$$

7 Value л2 is converted into the second intermediate value of BK (the right side of Figure 4–1). It is known that in cases where the solutions for standard tasks are available, one can talk about a decision-classification, if they are not available, then it is either decision-generation or decision-selection. Thus, matrix Θ2 is as follows:

$$\Theta_2 = \begin{bmatrix} 101 \\ 010 \end{bmatrix}.$$

Conversion is performed by formula (3).

8 Value of BK is again adjusted by formula (3).

As a result, one obtains the probability values of various classes of decision-making tasks, specified according to the available information.

4.1.1 Determination of the stage of decision-making process by a product lifecycle management task

$$< B_{\Phi} > \rightarrow B_{Э}.$$

Example. If an analysis of the external environment is performed, comprehension of the situation is likely required.

In the current case, the matrix-probability row of the accomplishment of the product management task BΦ is set as an input of the conversion operation (see Figure 4–1). It is transposed into a column. The dimensionality of the conversion matrix Θ_3 is as follows: the number of rows equals the number of possible product management tasks; the number of columns corresponds to the number of stages of the problem solution process.

The purpose of the row of the conversion matrix Θ as a row input variable: the probability of an output variable having a definite value under the condition that the probability of the input feature corresponding to this row equals one.

The following initial values for the conversion matrix Θ_3 are suggested (Table 4–1).

The values of the matrix elements determine to what extent a particular marketing task is described in a row, and corresponds to the stages of decision-making process addressed in the columns. 1 – complete correspondence; 0.9 – often corresponds; 0.8 corresponds rather often; 0.5 – corresponds in nearly 50% of cases; 0.3 – corresponds rather rarely, 0.1 – corresponds very rarely, 0 does not correspond.

The considerable number of values in the first column (situation comprehension) are typical for the beginning of a particular stage; for example, in order to determine the significant parameters of an SMA or customers' behavioral model. For tasks that require particular initial data e.g., evaluation and selection of ideas, a situational comprehension has already been accomplished.

Numeral values for the table have been defined by experts on the basis of the review of decision-making methods, provided in Chapter 2. The following observations have been taken into consideration.

Stage \ Task	To comprehend a situation	To build a model of the situation	To generate alternatives	To obtain evaluation of the alternatives and select one	To calculate a solution	To classify the situation	To make a decision
Determination of the parameters of the available SMAs' significance for the decision making	1	0.5	0.5	0.5	0	0.5	1
Determination of the indices of the internal environment for analysis	1	0.8	0.1	0.1	0	0.1	1
Evaluation of the marketing estimates of a company	0.5	0.3	0	0	1	0.8	0.3
Evaluation of available SMAs' appeal	0.3	0.1	0	1	0	0.8	0.3
Development or adjustment of the product strategy	0.3	0.1	0.8	0.8	0.5	0.8	1
Generation of new SMA alternatives	1	0	1	0	0	0.8	0.3
Evaluation of new SMA alternatives	0.3	0.5	0	1	0	0.8	0.3
Determination of the consumers' behavior models for the SMA	1	1	0.3	0.3	0.8	0.8	0.5
A priori segmentation	0.5	0.5	0.8	0.8	0	0	0.5
Evaluation of the segment appeal and the selection of a target segment	0.5	0	0	1	0	0.8	0.8
Determination of the idea generation methods	0	0	0.3	1	0	0.5	0
Generation of alternatives for new product ideas	0	0	1	0	0	0	0
Forecast on the development of relationships with partners	0.8	0.3	0.8	0.8	0.3	0.5	0.3
Evaluation and selection of new product ideas	0	0	0	1	1	0.3	0
Development of research on a product	0	0	0.3	0.3	0.5	0	0.3
Development of a technological research task	0	0	0.3	0.3	0.5	0	0.3
Identification of methods for concept generation	0	0	0.3	1	0	0.5	0
Generation of concept alternatives	0	0	1	0	0	0	0
Identification of buyers' and consumers' persistence models as regards their view of the novelty and concept evaluation	0.5	1	0.3	0.3	0.9	0.5	0.3
Identification of the method of concept positioning	0	0	0.8	0.8	0	0.5	0
Identification of the marketing mix elements and their concepts and purposes	0.5	0.3	0.9	0.9	0	0.3	0.9
Development of product's technical parameters	0	0	0.1	0.1	0.9	0	0
Development of a technical task for a product	0	0	0.3	0.3	0.5	0	0.3
Development of a technical task for the technology	0	0	0.3	0.3	0.5	0	0.3
Scheduling of TM as an experiment	0	0	0.5	0.5	0.8	0.1	0.1
Concept evaluation according to the TM on model and controlled markets	0	0	0	0	1	0.5	0.1
Determination of a list of product varieties according to the TM results in controlled and real markets	0.3	0.1	1	0.5	0	0	0.1
Analysis of product assortment as a whole, according to product lines and analysis of each product	0.8	0.5	0	0	1	0.8	0.1
A posteriori segmentation and segment pre-selection	1	0.8	0	0	0	0.8	0.3
Profiling of the selected segments	1	1	0	0	0	0.5	0
Selection of target segments	0	0	0	1	0	0	1
Development of modification idea alternatives	0.3	0	1	0	0	0	0.3
Development of modification concepts for each idea alternative	0	0	1	0	0	0.3	0.3
Forecast o relationships with partners and competitors and their reaction to each modification alternative	1	0.8	0	0	0.5	0.8	0.3
Evaluation and selection of modification alternatives	0	0	0	1	0	0.5	0.8
Forecast on relationships with partners and competitors and their reaction to each elimination alternative	1	0.8	0	0	0.5	0.8	0.3
Evaluation and selection of elimination alternatives	0	0	0	1	0	0.5	0.8
Determination of marketing indices for monitoring each SMA and the method of their analysis	1	0.8	0.5	0.5	0	0.5	0.5
Evaluation of the operational decision consequences for partners, competitors, and consumers	0.1	0.1	0	0	0.5	0.5	0.5

Table 4–1 Initial values of the conversion matrix Θ_3 (task-stage)

The second column (model building) nearly always has a smaller number of values than column 1. This is explained by the fact that the comprehension process does not necessarily reach the model-building stage.

The third and the forth columns, reflecting the stage of decision-selection, indicate the level of applicability of the decision-selection for each task.

The fifth column determines the applicability of the decision-generation to the tasks.

The multitude of large values in the column of situation classification is explained by the popularity of decision-classification methods, such as neural networks and classification trees.

The values in the last column (Decision comprehension) are meaningful for those tasks that require important decisions. It is implied that the decision-maker should be able to comprehend the decision justification.

The system allows for an absence of the evaluation values of the matrix elements. In this case, this element is denoted as "?".

Conversion probability row →probability row is analogous to the previous case, although it has an additional output probability row B'q that consists of a number of output elements:

$$B'_{qt} = \begin{cases} 1-\prod\limits_{p}\left(1-\begin{cases} B_{qp} * \Theta_{qpt}, & \text{if} \quad B_{qp} \neq Null \\ 0, & \text{if} \quad B_{qp} = Null \end{cases}\right), & \text{if} \quad \underset{\mathrm{p}}{\exists} B_{qp} \neq Null \\ Null \ , & \text{if} \quad \underset{\mathrm{p}}{\forall} B_{qp} = Null \end{cases} \quad (4)$$

where B'_{qt} is the t-th element of the output row of the q-th conversion; B_{qp} is the p_{th} element of the input row of the q_{th} conversion; Θ_{qpt} is the t-th element of the p-th row of conversion matrix Θ_q. Rows of conversion matrix Θ_q correspond to the values of the input variable, and the columns – to the values of the output one. For example, if the probabilities of the product management tasks are inputs, and the method is an output, then the number of rows and columns equals N_Φ and N_M respectively.

The probabilities obtained as a result of this conversion are combined with a priori probabilities of the stage of the marketing task solution with the help of formula (3).

4.1.2 Determination of the precision of the initial data evaluation for a product management task

Initial data can have a different level of precision depending on the stage of decision-making. The precision of the analysis of the external environment can be lower than the precision of the new product parameters, because it is not always possible to collect precise information about the external environment. Moreover, the external environment is constantly changing:

$$< B_{\Phi} > \rightarrow H_5 \;.$$

In this case, the conversion matrix has only one column (Table 4–2).

The most significant ideas that are based on the evaluations are as follows.

High precision is not required for all tasks; that is why its entry level is on average – 0.5.

Higher precision is required at the stage of making important decisions, such as the determination of a list of product variety; determination of new product parameters as well as the selection of target segments and modification / elimination alternatives.

External environment data is usually less precise than information about the internal environment and consumers.

Idea and concept generation require less precise data than that of their evaluation and decision-making.

Operational decisions are usually based on highly precise data.

Tasks associated with forecasts usually do not require a high precision of data, because a particular situation is often influenced by a number of factors that are hard to consider.

In this case, one can talk about the row → fuzzy-logical values conversion. This type of conversion should fulfill the following requirements:

The result should take into consideration all composing probabilities for each row.

If at least one row has a unitary probability, the result is a unitary probability.

If there are nonzero probabilities in two or more rows, the result should be no less than the maximum probability among the available ones.

Task	Precision 0…1
Determination of the parameters of the available SMAs that are significant for decision making	0.5
Determination of the indices of the internal environment for analysis	0.8
Evaluation of the marketing estimates of a company	0.8
Evaluation of the available SMA's appeal	0.5
Development or adjustment of the product strategy	0.8
Generation of new SMA alternatives	0.5
Evaluation of new SMA alternatives	0.8
Determination of consumer behavior models for the SMA	0.5
A priori segmentation	0.5
Evaluation of the segment appeal and the selection of a target segment	0.9
Determination of methods for idea generation	0.3
Generation of alternatives for new product ideas	0.3
Forecast on the development of relationships with partners	0.8
Evaluation and selection of new product ideas	0.9
Development of research on a product	0.8
Development of a technological research task	0.5
Identification of methods for concept generation	0.8
Generation of concept alternatives	0.8
Identification of buyers' and consumers' persistence models concerning their novelty and concept evaluation	0.5
Identification of the method of concept positioning	0.8
Identification of the marketing mix elements and their concepts and purposes	0.8
Development of the product's technical parameters	0.9
Development of a technical task for a product	0.9
Development of a technical task for the technology	0.9
Scheduling of TM as an experiment	0.5
Concept evaluation according to the TM in model and controlled markets	0.8
Determination of a list of product varieties according to the TM results in controlled and real markets	0.9
Analysis of product assortment as a whole, according to product lines and the analysis of each product	0.9
A posteriori segmentation and segment pre-selection	0.9
Profiling of the selected segments	0.8
Selection of target segments	0.9
Development of alternatives for modification ideas	0.5
Development of modification concepts for each idea alternative	0.5
Forecast on relationships with partners and competitors and their reaction to each modification alternative	0.8
Evaluation and selection of modification alternatives	0.9
Forecast on relationships with partners and competitors and their reaction to each elimination alternative	0.8
Evaluation and selection of elimination alternatives	0.9
Determination of marketing indices for monitoring each SMA and the method of analysis	0.5
Evaluation of the consequences of the operational decisions for partners, competitors, and consumers	0.75

Table 4–2 Initial values of conversion matrix Θ_4 (task – precision of initial data)

Probability cannot exceed 1.

The following conversion fulfills all the requirements.

$$H_q = \begin{cases} 1 - \prod_p \left(1 - \begin{cases} B_{qp} * \Theta_{qp1}, & \text{if } B_{qp} \neq Null \\ 0, & \text{if } B_{qp} = Null \end{cases} \right), & \text{if } \exists_p B_{qp} \neq Null \\ Null\ , & \text{if } \forall_p B_{qp} = Null \end{cases} \quad (5),$$

where H_q is evaluation of the output fuzzy logical variable of the q-th conversion; B_{qp} is evaluation of the p-th option for the value of the input variable for the q-th conversion; Θ_{qp1} is the p-th element of the only column of matrix Θ_q.

4.1.3 Determination of the predominating type of initial data for a product management task

Different types of initial data can be required depending on a product management task. For example, it is more likely that exploratory research will require qualitative data, while descriptive research will require qualitative data:

$$< B_{\Phi} > \rightarrow B_T.$$

Initial values for conversion matrix Θ_5 are presented in Table 4–3.

It is evident from the table that the role of the quantitative parameters increases along with the growth of the concreteness of the task. If the task is the selection of an SMA, analysis of the external environment or forecasting, then qualitative evaluations are mostly applied; while when one is dealing with the technical parameters of a product or selection of a target segment, then role of the quantitative parameters are more applicable. Scoring is applied to experts and consumers surveys.

There are several zero values in the fuzzy parameters column due to the fact that they are only applied in particular cases.

Conversions are performed by formula (4).

4.1.4 Determination of a data collection method for a product management task

Different data collection methods can be applied depending on the product management task:

$$< B_{\Phi} > \rightarrow B_C.$$

Task \ Type of initial data	Quantitative continuous	Quantitative discrete	Fuzzy	Multi-valued	Scoring	Comparative	Qualitative
Determination of the parameters of the available SMAs that are significant for decision making	1	0.5	0.5	0.5	0	0.5	1
Determination of the indices of the internal environment for analysis	1	0.8	0.1	0.1	0	0.1	1
Evaluation of the marketing estimates of a company	0.5	0.3	0	0	1	0.8	0.3
Evaluation of the available SMAs' attractiveness	0.3	0.1	0	1	0	0.8	0.3
Development or adjustment of the product strategy	0.3	0.1	0.8	0.8	0.5	0.8	1
Generation of new SMA alternatives	1	0	1	0	0	0.8	0.3
Evaluation of new SMA alternatives	0.3	0.5	0	1	0	0.8	0.3
Determination of consumers' behavior models for the SMA	1	1	0.3	0.3	0.8	0.8	0.5
A priori segmentation	0.5	0.5	0.8	0.8	0	0	0.5
Evaluation of the segment attractiveness and the selection of the target segment	0.5	0	0	1	0	0.8	0.8
Determination of idea generation methods	0	0	0.3	1	0	0.5	0
Generation of new product idea alternatives	0	0	1	0	0	0	0
Forecast on the development of relationships with partners	0.8	0.3	0.8	0.8	0.3	0.5	0.3
Evaluation and selection of new product ideas	0	0	0	1	1	0.3	0
Development of the research on a product	0	0	0.3	0.3	0.5	0	0.3
Development of a technological research task	0	0	0.3	0.3	0.5	0	0.3
Identification of methods for concept generation	0	0	0.3	1	0	0.5	0
Generation of concept alternatives	0	0	1	0	0	0	0
Identification of the models of the novelty acceptance by the consumers	0.5	1	0.3	0.3	0.9	0.5	0.3
Identification of a method for concept positioning	0	0	0.8	0.8	0	0.5	0
Identification of the marketing mix elements and their concepts and purposes	0.5	0.3	0.9	0.9	0	0.3	0.9
Development of the product's technical parameters	0	0	0.1	0.1	0.9	0	0
Development of a technical task for the product	0	0	0.3	0.3	0.5	0	0.3
Development of a technical task for the technology	0	0	0.3	0.3	0.5	0	0.3
Scheduling of the TM as an experiment	0	0	0.5	0.5	0.8	0.1	0.1
Concept evaluation according to the TM on/in model and controlled markets	0	0	0	0	1	0.5	0.1
Determination of a list of product varieties according to the TM results on/in controlled and real markets	0.3	0.1	1	0.5	0	0	0.1
Analysis of product assortment as a whole, according to the product lines and analysis of each product	0.8	0.5	0	0	1	0.8	0.1
A posteriori segmentation and segment pre-selection	1	0.8	0	0	0	0.8	0.3
Profiling of the selected segments	1	1	0	0	0	0.5	0
Selection of target segments	0	0	0	1	0	0	1
Development of alternatives for the modification ideas	0.3	0	1	0	0	0	0.3
Development of modification concepts for each idea alternative	0	0	1	0	0	0.3	0.3
Forecast on the relationships with partners and competitors and their reaction to each modification alternative	1	0.8	0	0	0.5	0.8	0.3
Evaluation and selection of modification alternatives	0	0	0	1	0	0.5	0.8
Forecast on the relationships with partners and competitors and their reaction to each elimination alternative	1	0.8	0	0	0.5	0.8	0.3
Evaluation and selection of elimination alternatives	0	0	0	1	0	0.5	0.8
Determination of marketing indices for the monitoring of each SMA and the method of their analysis	1	0.8	0.5	0.5	0	0.5	0.5
Evaluation of the consequences of operational decisions for partners, competitors, and consumers	0.1	0.1	0	0	0.5	0.5	0.5

Table 4–3 Initial values of the conversion matrix Θ_5 (task – type of initial data)

The values of matrix Θ_6 are provided in Table 4–4. Formula (4) is applied.

Method of obtaining the parameters \ Product management task	Secondary data	Measurement	By analytical or numeral model	By imitational model	Standards	Expert evaluations
Determination of the parameters of the available SMAs that are significant for decision making	0.8	0	0.1	0.2	0	0.9
Determination of the indices of the internal environment for analysis	1	0.4	0	0	0	0.3
Evaluation of the marketing estimates of a company	0.5	0.9	0.3	0.1	0	0.7
Evaluation of the appeal of the available SMAs	0.5	0	0	0	0	1
Development or adjustment of product strategy	0.2	0.1	0.1	0.5	0	0.9
Generation of new SMA alternatives	0.2	0.1	0.1	0.5	0	0.9
Evaluation of new SMA alternatives	0.5	0.3	0	0	0	0.5
Determination of consumer behavior models for SMAs	0.5	0.3	0.3	0	0	0.5
A priori segmentation	1	0.5	0	0	0	1
Evaluation of segment appeal and selection of a target segment	0.5	0.8	0	0	0	0.5
Determination of the idea generation methods	0.1	0	0	0	0.3[38]	0.9
Generation of alternatives for new product ideas	0	0	0	0	0	1
Forecast on the development of relationships with partners	0.1	0	0.5	0.1	0	0.9
Evaluation and selection of new product ideas	0	0	0	1[39]	0	0.9
Development of research on a product	0	0.9	0	0	0.5	0.5
Development of a technological research task	0	0.9	0	0	0.5	0.5
Identification of methods for concept generation	0	0	0	0	0.3[37]	1
Generation of concept alternatives	0.3	0	0	0	0.3[37]	1
Identification of the models of the novelty acceptance by the consumers	0	1	0.1	0.3	0.3	0.8
Identification of the concept positioning method	0	0	0	0	0.5	1
Identification of the marketing mix elements and their concepts and purposes	0	0	0	0	0.5	0.9
Development of the product technical parameters	0.5	1	0.5	0.5	0.5	0.1
Development of the technical task for the product	0	0	1	0	0.9	0.1
Development of a technical task for the technology	0	0	1	0	0.9	0.1
Scheduling of the TM as an experiment	0	0	0	0	1	0
Concept evaluation according to the TM in the model and controlled markets	0	1	0.8	0	0.5	0.5
Determination of a list of product varieties according to the the TM results in the controlled and real markets	0	1	0.9	0	0.3	0.5
Analysis of the product assortment as a whole, according to	1	0.3	1	0	0.5[40]	0.1

[38] TRIZ/TIPS is meant in this case.

[39] Cases where the product is a queueing system or a service provided by this system are taken into consideration.

[40] An example of a standard for this case is the Pareto principle (20/80).

the product lines and the analysis of each product						
A posteriori segmentation and segment pre-selection	0	1	0	0	0	0.1
Profiling of the selected segments	0.5	1	0	0	0	0.1
Selection of target segments	0	0	1	0	0	0.1
Development of alternative modification ideas	0.3	1	0	0	0	0.3
Development of modification concepts for each idea alternative	0.5	1	0	0	0	0.3
Forecast of the relationships with partners and competitors and their reaction to each modification alternative	0	0	1	0.5	0	0.5
Evaluation and selection of the modification alternatives	0	1	0	1[38]	0	0.9
Forecast of the relationships with partners and competitors, and their reaction to each elimination alternative	0	0	1	0.5	0	0.5
Evaluation and selection of elimination alternatives	0	1	0	1[38]	0	0.9
Determination of the marketing indices for monitoring of each SMA and the method for their analysis	0.9	0	0.1	0	0	0.9
Evaluation of the consequences of operational decisions for partners, competitors, and consumers	0.3	1	0.5	0	0	0.5

Table 4–4 Initial values of the conversion matrix Θ_6 (task – method of initial data obtaining)

The role of the expert evaluations is significant in the cases where a particular decision is associated with the external environment, forecasting, and creative tasks. The tasks with precise qualitative evaluations often require measurements, which are mostly understood as being from a survey in the area under consideration.

4.1.5 Determination of the model type

Model selection depends on a number of parameters:

$$< В_{Т}, В_{З}, л_{3}, л_{4}, л_{5}, л_{6}, н_{1} > \rightarrow В_{Д}.$$

Dependencies of the model type on multi-valued variables are demonstrated in Table 4–5, while the dependencies on logical and fuzzy-logical variables – in Table 4–6.

4.1.6 Determination of a decision purpose

The purpose of a particular decision is suggested as being determined according to the class of decision-making tasks, according to the task, and according to the stage of the decision-making process.

Type of parameters, type of dependencies \ Model type	Analytical	Numerical	Dynamical (differential or residual equations)	Math. Programming (linear, integer, convex)	Queueing system simulation	Markov chains	Interrelations of psychological attributes	Network diagram	Non-optimizational operational research	Decision tree	Knowledge representation (semantic or object-oriented network)	Statements, IT-THEN rules, IT-THEN managing rules	Cognitive	Qualitative (including.verbal description)	Gaming	Dynamic programming	Cybernetic	Morphologic	Cellular automatons	Absent
Depending on predominating type of parameters																				
Quantitative Continuous	1	0.5	1	0.8	0.8	0.1	1	1	1	0.3	1	0.5	0	0	0.3	0.1	1	0.1	0	0.1[41]
Quantitative discrete.	0.1	1	0	0.3	0.3	0	0	0.1	0.1	0	1	0.9	0	0	0.8	0.1	0	0	1	0.1[40]
Fuzzy	0.3	0.5	0	0	0	0	0	0.1	0	0.1	1	0.5	0	0	0.1	0	0	0	0	0.3[40]
Scoring	0	1	0	0	0	0	0	0	0	0.1	1	0.5	0	0	0	0	0	0	0	0.5[40]
Comparative	0	0	0	0	0	0	0	0	0	0.1	1	0.5	1	0.3	0	0	0	0	0.1	0.5[40]
Qualitative	0	0	0	0	0	0	0	0	0	0	1	0.5	1	1	0	0	0	1	0	0.5[40]
Depending on the predominating type of dependencies																				
General mathematical	1	0.3	0	0.5	1	1	0	0	0.5	0	0	0	0	0	0	0	0	0	0.3	0
Value and its rate of changing	0.3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Linear	0.3	0	0	1	0.1	0	1	0	0.5	0	0	0	0	0	0	0	0	0	0	0
Cause-and-effect	0	0	0	0	0	0	1	0	0	1	1	1	1	1	0	0	0	0.3	0.3	0
Stochastic	0.5	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
Tabular (numeral)	0	1	0.1	0.3	0.1	0	0	1	0.9	0	0.5	0.5	0	0	1	1	0	0.3	0	0
Algorithmic	0	0	0.1	0	1	0	0	0	0.9	0	0	0	0	1	1	0	0.5	0	1	0
Unpredictable	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Undefined	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	1

Table 4–5 Conversion matrices Θ_7, Θ_8: $< B_3, B_T > \rightarrow B_Д$

[41] Data in this column has been obtained on the basis of statistics gathered by the author and is subjective to a certain extent

Logical values of the input variables	Analytical	Numerical	Dynamical (differential or residual equations)	Math. programming (linear, integer, convex)	Queueing system simulation	Markov chains	Interrelations of psychological attributes	Network diagram	Non-optimizational operational research	Decision tree	Knowledge representation (semantic or object-oriented network)	Statements, IF-THEN rules, IF-THEN managing rules	Cognitive	Qualitative (incl. verbal description)	Gaming	Dynamic programming	Cybernetic	Morphologic	Cellular automatons	Absent
↓ Discreteness of the sampling instant of the parameters and control																				
0	1	0.5	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	0	1
1	0.75	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1
↓ Discreteness of the values of the control actions																				
0	1	0.5	1	1	0	1	1	0	1	0	1	0	1	1	0	0	1	0	1	1
1	0.5	1	0	0	1	0	0	1	1	1	1	1	0	1	1	1	0	1	0	1
↓ Availability of homogeneous requests																				
0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	0	0	0	1[42]	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
↓ Need for process examination																				
0	1	1	0	1	0	0	1	0	1	1	1	1	0	1	0	0	0	1	0	1
1	0	0	1	0	1	1	0	1	1	0	0	0	1	1	1	1	1	0	1	1
↓ Difficulty of homogeneous requests processing																				
0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0.5	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4–6 Conversion matrices Θ_9, Θ_{10}, Θ_{11}, Θ_{12}, Θ_{13}, $< л_3, л_4, л_5, л_6, л_7, н_1 > \rightarrow В_Д$

$$< В_К, В_Ф, В_Э > \rightarrow В_Ц.$$

The values of conversion matrices are described in Table 4–7, and with comments added in – Table 4–8.

The values of the conversion matrices (in order of appearance in the formula) are addressed in Table 4–9 and Table 4–10.

[42] For example, in a classic transportation problem, etc.

Objective / Solution class, Product management task, Stage of decision making process	To learn value of variables	To learn relations between variables	To build model of a situation	To build a system of knowledge formalization	To gather data about past decisions and their accuracy	To develop alternatives	To obtain quantitative evaluations of consequences of a decision	To obtain qualitative evaluations of consequences of a decision	To determine predictability of system behavior	To obtain quantitative evaluation of a system after decision implementation	To obtain qualitative evaluation of a system after decision implementation	To obtain probability of occurrence of events	To obtain fuzzy evaluations of alternatives	To select the best decision	To select admissible solutions	To completely rank the available alternatives	To partly rank the available alternatives	To determine admissibility of an available alternative	To generate the best solution	To generate an admissible solution	To determine class of an available situation foe decision-making	To build a classifier of new situations by solutions	To build an automatic control system	To find a multi-step solution	To eliminate current problems	To reflect solution process in natural language
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Solution class – objective																										
Choice	0.5	0.5	0.5	0.3	0.3	1	1	1	0.5	0.5	0.5	0.5	0.5	1	1	1	1	1	0	0	0	0	0	1	0.5	0.3
Classification	1	0	0	0.3	1	0	0	0	0.1	0	0	0.3	0.3	0	0	0	0	0	0	0	1	1	0.5	0.1	1	0.5
Generation	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0.5	0.8	1
Product management task – objective																										
Determination of the parameters of the available strategic business areas, and their significance for decision making	0	0	0.5	0.1	0	0.5	0	0	0.1	0	0	0	0.5	0.8	0.8	0.8	0.3	0.1	0.8	0.5	0	0	0	0	0	0.5
Determination of the indices of the internal environment for analysis	0	0	0.5	0.1	0	0.5	0	0	0	0	0	0	0.5	0.8	0.8	0.8	0.3	0.1	0	0	0	0	0	0	0	0
Evaluation of the marketing estimates of a company	1	0.8	0.5	0	0	0	0	0	0	0	0	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Evaluation of the attractiveness of the available strategic business areas	1	1	0.8	0.1	0.8	0	0.5	0.3	0.1	0	0	0.3	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.3
Development or adjustment of the product strategy	0	0.1	0.1	0.1	0.8	0.8	1	0.8	0	0.3	0.3	0.5	0.1	0.5	0.5	0.5	0.1	0.3	0.8	0.1	0.1	0	0	0	0	1
Generation of alternatives for new strategic business areas	0	0.1	0.1	0.1	0.3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evaluation of the alternatives for the new strategic business areas	1	0.9	0.9	0.3	0.1	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.5
Determination of consumers' behavior models for the strategic business area	0.9	1	1	0.3	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A priori segmentation	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evaluation of the attractiveness of the segment and the selection of a target segment	1	0.8	0.8	0.1	0.5	0	1	0.5	0	0	0	0	0.8	0.8	0.8	0.9	0.5	0.5	0	0	0	0	0	0	0	0.9
Determination of idea generation methods	0	0.1	0	0	0.1	1	0	0.3	0	0	0	0	0	0.1	0.9	0.3	0.1	0.1	0	0	0	0	0	0	0	0
Generation of alternatives for the new product ideas	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0
Forecast of the development of relationships with partners	1	1	1	0.1	0.5	0	0	0	0.3	0.5	0.8	0.9	0.9	0	0	0	0	0	0.9	0.9	0.1	0	0	0	0	0.3
Evaluation and selection of new product ideas	1	0.8	0.8	0	0	0	1	0.9	0	0	0	0.5	0.5	0.9	0.8	0.9	0.3	0.1	0	0	0.3	0	0	0	0	0.5
Planning the research on the product	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Table 4–7 Conversion matrices Θ_{14}, Θ_{15}, Θ_{16}:$B_К$, $B_Ф$,$B_Э$ → $B_Ц$

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Planning the technological research task	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Identification of the methods for concept generation	0	0.1	0	0.1	0.1	1	0	0.3	0	0	0	0	0	0.5	0.9	0.3	0.1	0.1	0	0	0	0	0	0	0	0
Generation of concept alternatives	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0
Identification of the models of the novelty acceptance by buyers and consumers and concept evaluation according to them	1	1	1	0.1	0	0	1	0.8	0	0.8	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Identification of the method for concept positioning						0.5	1	0.8	0	0.5	0.3	0.1	0.3	0.9	0.5	0.3	0.1	0	0	0	0	0	0	0	0	0
Identification of the marketing mix elements and their concepts and purposes	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0.9	0	0	0	1	0	1
Development of the technical parameters of the product	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0
Development of the technical task for the product	0	0	0	0	0	0	0	0	0	0	0	1	0.3	0.5	0.8	0.1	0	0	0	0	0	0	0	0	0	0
Development of the technical task for the technology	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0.8	0.1	0	0	1	0	0	0	0	0	0	0
Scheduling of test marketing as an experiment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Concept evaluation according to test marketing on model and controlled markets	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.3
Determination of list of product varieties according to the test marketing results on controlled and real markets	1	0	0	0	0.1	0	1	0.5	0	0.5	0.1	0.8	0.8	0	0.9	0.9	0.1	0.1	0.5	0	0.1	0	0	0	0	0
Analysis of product assortment as a whole, according to product lines and analysis of each product	1	0.3	0	0	0	0	0	0	0	0	0	0.3	0.3	0.8	0.5	0.9	0.3	0	0.5	0.5	0.9	0	0	0	1	0.5
A posteriori segmentation and segment pre-selection	1	0.1	0.3	0	0.3	0	1	0	0	0	0	0	0	0.5	0	1	0	0	0	0	1	0.5	0	0	0	1
Profiling of the selected segments	0.5	1	0.8	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Selection of target segments	1	0	0	0	0.8	0	1	0.5	0	0	0	0.3	0.3	0.5	0.3	1	0.3	0.3	0	0	0.5	0.5	0	0	0	0.8
Development of alternatives of modification ideas	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Development of modification concepts for each idea alternative	0	0	0	0	0	1	0	0	0	0	0.5	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0
Forecast on relations with partners' and competitors' and their reaction for each modification alternative	1	1	1	0.1	0.5	0	0	0	0.3	0.5	0.8	0.9	0.9	0	0	0	0	0	0.9	0.9	0.1	0	0	0	0.5	0
Evaluation and selection of modification alternatives	1	0.3	0.3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Forecast on relations with partners' and competitors' and their reaction for each elimination alternative	1	1	1	0.1	0.5	0	0	0	0.3	0.5	0.8	0.9	0.9	0	0	0	0	0	0.9	0.9	0.1	0	0	0	0.5	0
Evaluation and selection of elimination alternatives	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Determination of marketing indices for monitoring of each SMA and method of their analysis	0	0	0.5	0.1	0	0.9	0	0	0.1	0	0	0	0.5	0.8	0.8	0.8	0.3	0.1	0.8	0.5	0.8	0.3	0	0	0	0
Evaluation of the consequences of operational decisions for partners, competitors and consumers	1	0	0	0	0.8	0	1	0.9	0	0.1	0.1	0.1	0.1	0	0	0	0	0	0	0	0.8	0.8	0.5	0	0	0.8
Stage of decision making process - objective																										
To comprehend a situation	0	1	0	0	0	0	0	0	0.1	0	0	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0.9
To build a model of the situation	0	0	1	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9
To generate alternatives	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9
To obtain evaluation of alternatives and to select the best one	1	0	0.3	0	0	0	1	0.9	0.1	0.8	0.5	0.5	0.5	0.9	0.9	0.9	0.9	0.9	0	0	0	0	0	0.5	0	0.5
To calculate a solution	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0.5	0.5	0	0.5
To classify a situation	0	0	0	0	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.9	0	0	1	0.5
To comprehend a decision	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 4–7 Conversion matrices Θ14, Θ15, Θ16:BК, BФ,BЭ → BЦ (Continued)

Task	Comments on values of a Task → Purpose matrix
Identification of SMA parameters for decision-making	Usually, the list of parameters is known from operational experience with similar SMAs; they should be ranked by significance. Sometimes the alternatives have to be invented, evaluated, and selected. In some cases the external environment can be unpredictable
Identification of the indices in the internal environment for decision-making	This is performed in a similar manner, but the unpredictability level is lower, thus, the generation of lists of parameters is not applicable, in contrast to the evaluation and selection
Evaluation of the company marketing estimates	The values of the parameters are determined. Additionally, the relationships between the variables are examined. In some cases, a situation model is built. Operations with probabilities and fuzzy magnitudes are performed. Reflection in ordinary language is important in cases where the role of the decision-maker in the final decision-making is significant.
Evaluation of the existing SMA appeal	Usually, this means obtaining the values of the variables and the interrelational force between them. Forecasting is often applied in order to evaluate the consequences of a particular decision. Evaluation on the basis of similar cases is often applied. Fuzzy magnitudes and probabilities can be used
Development or adjustment of product strategy	Application of the following methods by analogy is possible: generation of alternatives with pre-evaluation and pre-selection, sometimes a particular task is solved by calculations
Generation of new SMA alternatives	Generation is performed on the basis of past experience
Evaluation of new SMA alternatives	This is the obtaining of the evaluations of the parameters, their interrelationships, and sometimes – building a model of a particular situation. Fuzzy magnitudes and probabilities are applicable
Determination of consumers behavior model for an SMA	A model of the interrelationships between the variables is emphasized. Quantitative evaluations are often required.
A priori segmentation	Creative task
Evaluation of the segment's appeal and the selection of a target segment	Obtaining the parameters, the strength of the interaction between them, and a forecast on the consequences of a decision. Often there is a particular degree of fuzziness, or probability which requires evaluation. The role of ranking is significant
Identification of methods for idea generation	The general method for the solution of creative tasks is the invention of alternatives, followed by a selection of the best ones. The role of ranking increases due to the fact that the decision is made by a mental process and, therefore, it is a fuzzy one as a rule. Moreover , additional actions can be performed (their values are 0.25 and 1)
Generation of alternatives for new product ideas	Creative processes and sometimes calculations
Forecast on the development of relationships with partners	It is necessary to learn the values of variables, evaluate the consequences of particular decisions, and select the best decisions. A model is often already available, interrelationships between the variables are determined; they are only specified at this stage. It is difficult to formalize this task, therefore, the role of expert evaluations is increased
Evaluation and selection of new product ideas	Quantitative evaluations are preferable, but due to the high complexity of the task, the role of qualitative evaluations and ranking is also significant for the final decision. Solution-classification can sometimes be applied
Development of the research on a product	Marketing specialists take part in the scheduling of periods and stages. Time periods can be edited

Development of a technological research task	during the process of the operation
Identification of methods for concept generation	This is analogous to idea generation, but the role of qualitative evaluations is higher due to the more formalized character of the stage
Generation of concept alternatives	This generally corresponds to idea generation
Identification of the models of the novelty acceptance by the consumers	The main purpose is to obtain qualitative evaluations. Their role is significant due to complexity of the task. Fuzzy magnitudes and probabilities are applicable.
Identification of the method of concept positioning	Selection of the best solution is desirable on the basis of quantitative evaluations, but due to the complexity of the task, qualitative evaluations, fuzzy magnitudes, probabilities, and decision ranking are applicable
Identification of concept marketing mix elements and their purposes	Usually, this is a means of solution-generation. A decision is often made on the basis of calculations. Usually, the implementation of a marketing schedule goes through several stages. Sometimes the model of consumer behavior is detailed.
Development of the product's technical parameters	The alternatives are already available, but they need to be specified and the best one should be selected. Parameters can be obtained by calculations
Development of a technical task for a product	This stage is mostly devoted to scheduling of periods and stages.
Development of a technical task for technology	This combines the features of the two previous stages.
Scheduling of a TM as an experiment	The plans for experiments are well-developed, the most applicable one should be selected for the current situation
Concept evaluation according to TM on the model and controlled markets	Standard models are available. A suitable one should be selected and its parameters specified based on the measurements (surveys)
Determination of a list of product varieties according to the TM results on/in the controlled and real markets	Preferably, this is a quantitative task. Inaccurate values are possible (qualitative evaluations, fuzziness, probabilities). Several types are selected; therefore, the role of ranking and the determination of acceptability is significant. Calculation methods and recommendations on standard series are applicable
Analysis of the product assortment as a whole according to the product lines and an analysis of each product	Preferably, this is a quantitative task. It is often performed in order to eliminate problems. Significant roles belong to the decision-maker and the ranking. Solutions are standard (to extend, to narrow), thus a decision-classification is applicable.
A posteriori segmentation and segment preselection	Quantitative evaluations are preferable, but the role of the decision maker is significant, so is the role of the ranking. A classifier based on neural networks or decision trees is applicable, because the tasks may need to be repeated rather often and require the collection of data about past decisions. It is important to reason the segmentation in everyday language.
Profiling of the selected segments	The most important task is to learn the relationships between the variables that characterize a particular segment. It is important to obtain a description in everyday language.
Selection of target segments	Ideally, this task requires quantitative evaluations, but due to the number of segments and the complexity of the task, the main role belongs to the ranking. Task automatization can be performed with the help of classifiers based on neural networks and classification trees.

Development of modification ideas alternatives	Creative methods or methods of calculation
Development of modification concepts for each idea alternative	Creative task with qualitative evaluations
Forecast on relationship with partners and competitors, and their reaction to each modification alternative	Analogous to the forecast in the previous case
Evaluation and selection of modification alternatives	Quantitative task. Values of the variables are known rather precisely. Specification of the situation model can be required.
Forecast on relationships with partners and competitors and their reaction to each elimination alternative	Analogous to the forecasts in the previous case
Evaluation and selection of elimination alternatives	Analogous to the modification, but all models are known and all relationships are determined.
Determination of the marketing indices for monitoring of each SMA and the method of their analysis	Analogous to examination of a new SMA. Expert evaluations and standard solutions are available.
Evaluation of consequences of the operational decisions for partners, competitors, and consumers	Quantitative task. Often all parameters are known with a high level of precision. One can examine the issue of building an advisory automated system on the basis of classifiers.
Stage	Comments on the values of the Stage-Purpose matrix
To learn the values	It is most important to determine the relationships between the variables. In some cases risks, fuzziness, and predictability are examined
To build a model of the situation	The main element is a model, as knowledge formalization is effective
To generate alternatives	The main task is to generate alternatives and explain the decision
To obtain evaluation of the alternatives and to select the best one	It is required to learn the values of the variables, evaluate the consequences of a particular decision, and sometimes to consider incomplete data. Qualitative evaluations are performed more often than quantitative. Multi-step solutions are often evaluated. The difference in the results is explained by the fact that the decision-maker makes the final decision. The role of explanations at this stage is insignificant.
To calculate a solution	This is the solution-generation; therefore, the purposes of this type of solution are achieved. Sometimes an administration system can be built or calculations of multi-step solutions can be performed.
To classify a situation	Everything that is required for building and operating a classifier is considered. However, the decision can also be obtained from experts, without the classifier
To comprehend a decision	Explanation of the Auxiliary knowledge representation is required

Table 4–8 Comments on Table 4–7.

4.1.7 Determination of a solution method on the basis of initial and intermediate data

Method determination is performed with the help of the connection:

$$< \text{В}_{\text{Ц}}, \text{В}_{\text{С}}, \text{В}_{\text{Т}}, \text{В}_{\text{Д}}, \text{л}_7, \text{л}_8, \text{л}_9, \text{н}_2, \text{н}_3, \text{н}_4, \text{н}_5 > \rightarrow \text{В}_{\text{М}}.$$

Method / Objective Method of determining of parameters Type of parameters Model type	OLAP	Uncertainty analysis	Risk analysis	Analytical calculations, models, methods	Classification trees	Decision trees	Dynamic simulation	Dynamic programming	Discriminant analysis	Chaos identification	Monte Carlo simulation	Operational research, nonoptimizational methods	Operational research, optimizational methods	Causality research	Examination of psychological characteristics	Descriptive research	Exploratory research	Cluster analysis	Cellular simulation	Cognitive analysis	Creative activity	Matrix methods	Multi-criteria selection	Morphological analysis	Neural networks	Nonformalizable methods	Repeating solutions	Knowledge representation	Decision making, qualitative methods	Testing of stochastic hypotheses	Deductive reasoning	Inductive reasoning	Traductive reasoning	Regression analysis	Administration systems with feedback	Pattern matching	Standards, instructions and standard decisions	Game theory	TRIZ/TIPS	Factor analysis	Numerical calculations	Expert conclusion and expert evaluations	Expert systems
Objective																																											
To learn value of variables	0.5	0.1	0.1	0.3	0	0	0	0	0	0	0.3	0	0	0	0.3	1	0	0	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0.1	0.3	0	0	0	0.3	0.3	0.1
To learn relations between variables	0.9	0	0	0	0.9	0.1	0	0	0.8	0.1	0	0	0	0.5	0.3	1	0.8	0.1	0.3	1	0		0	0.1	0	0.1	0.5	0.3	0.3	0.8	0.1	0.3	0	0.9	0	0.1	0.3	0.3	0	0.9	0	0.5	0
To build model of a situation	0	0	0	0	0.5	0.3	0.5	0.1	0.9	0.1	0.9	0.5	0	0.3	0.5	0.5	0	0.3	0.5	0.8	0	0.1	0	0.5	0	0	0	0.5	0	0.5	0	0	0.5	0.9	0.5	0	0.3	0.5	0	0.8	0	0	0
To build a system of knowledge formalization	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
To gather data about past decisions and their accuracy	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0.5	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0
To develop alternatives	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.5	0	0.8	0	0.3	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0.5	0
To obtain quantitative evaluations of consequences of a decision	0	0.5	0.5	0.8	0	0.5	0.8	0.8	0	0	0.9	0.9	0.8	0	0.3	0	0	0	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0.1	0.3	0	0.5	0	0	0.8	0.5	0.5
To obtain qualitative evaluations of consequences of a decision	0	0	0	0	0.9	0	0.5	0	0.9	0	0.5	0.5	0.3	0.9	0.5	0	0	0	0.5	0.8	0	0.8	0	0.1	0.5	0.5	0	0	0.8	0	0.5	0.3	0.5	0	0	0.5	0	0	0.8	0	0	0.5	0.8
To determine predictability of system behavior	0	0.1	0.1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
To obtain quantitative evaluation of a system after decision implementation	0	0	0	0	0	0	1	0	0	0	0.8	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0.3	0
To obtain qualitative evaluation of a system after decision implementation	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0.5	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
To obtain probability of occurrence of events	0	0	1	0.5	0	0.8	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
To obtain fuzzy evaluations of alternatives	0	1	0	0.1	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5
To select the best decision	0	0.5	0.5	0.5	0.5	0.8	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.8	0.8	0	0.5	0	0	0	0	0	0	0.5	0	0.8	0	0	0.5	0.8	0.8
To select admissible solutions	0	0.5	0.5	0.5	0.1	0.5	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.8	0.3	0	0.9	0.8	0	0.8	0	0	0	0	0	0	0.5	0.5	0.5	0	0	0.5	0.8	0.9
To completely rank the available alternatives	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0.5	0.3	0
To partly rank the available alternatives	0	0.5	0.5	0.5	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.8	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0.5	0.3	0
To determine admissibility of an available alternative	0	0.5	0.5	0.5	0	0	0	0	0.8	0	0.5	0.8	0.5	0	0	0	0	0	0	0.5	0	0	0.5	0	0.9	0.5	0.5	0	0.5	0	0.5	0	0.5	0	0	0	0.5	0.5	0	0	0.5	0.8	0.5
To generate the best solution	0	0.8	0.8	0.9	0.8	0.8	0.5	0.9	0	0	0	0	0.9	0	0	0	0	0	0	0	0.5	0	0	0	0	0.5	0.5	0	0.5	0	0	0	0	0	0.9	0	0.3	0	0	0	0.9	0.5	0.8
To generate an admissible solution	0	0.8	0.8	0.5	0.5	0.5	0.5	0.3	0	0	0	0.5	0.5	0.3	0	0	0	0	0.3	0.3	0.8	0	0	0.3	0	0.8	0.9	0	0.9	0	0.3	0	0.3	0	0.1	0	0.5	0	0	0	0.8	0.8	0.9

Table 4–9 Conversion matrices Вц, Вс,Вд → Вм

To determine class of an available situation foe decision-making	0	0	0	0	0.9	0.3	0	0	0	0	0	0	0	0	0	0	0	0.8	0.3	0.5	0	0.8	0.1	0.3	0.9	0.5	0.5	0	0.3	0	0.3	0	0.3	0	0	0.5	0.5	0	0	0.3	0.5	0.8	0.8
To build a classifier of new situations by solutions	0	0	0	0	1	0.8	0	0	0.9	0.3	0	0	0	0	0	0	0	0.3	0	0.8	0	0	0	0	1	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.9
To build an automatic control system	0	0	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0	0.5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
To find a multi-step solution	0	0	0	0	0	0.8	0	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.1	0
To eliminate current problems	0	0	0	0	0	0.3	0	0	0.1	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0.5	0.5	0	0.5	0.5	0.8	0	0.1	0	0	0	0	0	0.9	0	1	0	0	0	0.5	0.5	0.8
To reflect solution process in natural language	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.5	0	0	0	0	0	0	0.5	0	0.1	0	0.1	0.1	0	0.5	0.5	0.5	0	0	0	0.1	0	0	0	0	0.3	0.9
Method of determining of parameters																																											
Secondary data	0.9	0	0	0	0.9	0.1	0	0	0.8	0.1	0	0	0	0.5	0.3	1	0.8	0.1	0.3	1	0		0	0.1	0	0.1	0.5	0.3	0.3	0.8	0.1	0.3	0	0.9	0	0.1	0.3	0.3	0	0.9	0	0.5	0
Measurement	0	0	0	0	0.5	0.3	0.5	0.1	0.9	0.1	0.9	0.5	0	0.3	0.5	0.5	0	0.3	0.5	0.8	0	0.1	0	0.5	0	0	0	0.5	0	0.5	0	0	0.5	0.9	0.5	0	0.3	0.5	0	0.8	0	0	0
By analytical or numerical model	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
By imitational model	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0.5	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0
Standards	0	0.5	0.5	0.8	0	0.5	0.8	0.8	0	0	0.9	0.9	0.8	0	0.3	0	0	0	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0.1	0.3	0	0.5	0	0	0.8	0.5	0.5
Expert evaluations	0	0	0	0	0.9	0	0.5	0	0.9	0	0.5	0.5	0.3	0.9	0.5	0	0	0	0.5	0.8	0	0.8	0	0.1	0.5	0.5	0	0	0.8	0	0.5	0.3	0.5	0	0	0.5	0	0	0.8	0	0	0.5	0.8
Тип параметров																																											
Quantitative continuous	0	0	0	0	0	0	1	0	0	0	0.8	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0.3	0
Quantitative discrete	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0.5	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fuzzy	0	0	1	0.5	0	0.8	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Scoring	0	0.5	0.5	0.5	0.5	0.8	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.8	0.8	0	0.5	0	0	0	0	0	0	0.5	0	0.8	0	0	0.5	0.8	0.8
Comparative	0	0.5	0.5	0.5	0.1	0.5	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.8	0.3	0	0.9	0.8	0	0.8	0	0	0	0	0	0	0.5	0.5	0.5	0	0	0.5	0.8	0.9
Qualitative	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0.5	0.3	0
Model type																																											
Analytical	0	0.5	0.5	0.5	0	0	0	0	0.8	0	0.5	0.8	0.5	0	0	0	0	0	0	0.5	0	0	0.5	0	0.9	0.5	0.5	0	0.5	0	0.5	0	0.5	0	0	0	0.5	0.5	0	0	0.5	0.8	0.5
Numerical	0	0.8	0.8	0.9	0.8	0.8	0.5	0.9	0	0	0	0	0.9	0	0	0	0	0	0	0	0.5	0	0	0	0	0.5	0.5	0	0.5	0	0	0	0	0	0.9	0	0.3	0	0	0	0.9	0.5	0.8
Dynamic (differential and difference equations)	0	0.8	0.8	0.5	0.5	0.5	0.5	0.3	0	0	0	0.5	0.5	0.3	0	0	0	0	0.3	0.3	0.8	0	0	0.3	0	0.8	0.9	0	0.9	0	0.3	0	0.3	0	0.1	0	0.5	0	0	0	0.8	0.8	0.9
Mathematical programming (linear, integer, convex)	0	0	0	0	0.9	0.3	0	0	0	0	0	0	0	0	0	0	0	0.8	0.3	0.5	0	0.8	0.1	0.3	0.9	0.5	0.5	0	0.3	0	0.3	0	0.3	0	0	0.5	0.5	0	0	0.3	0.5	0.8	0.8
Queueing system simulation	0	0	0	0	1	0.8	0	0	0.9	0.3	0	0	0	0	0	0	0	0.3	0	0.8	0	0	0	0	1	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.9
Markov chains	0	0	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0	0.5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Dependencies between psychological attributes	0	0	0	0	0	0.8	0	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.1	0
Network diagrams	0	0	0	0	0	0.3	0	0	0.1	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0.5	0.5	0	0.5	0.5	0.8	0	0.1	0	0	0	0	0	0.9	0	1	0	0	0	0.5	0.5	0.8
Schedules	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.5	0	0	0	0	0	0	0.5	0	0.1	0	0.1	0.1	0	0.5	0.5	0.5	0	0	0	0.1	0	0	0	0	0.3	0.9
Decision tree	0.5	0.1	0.1	0.3	0	0	0	0	0	0	0.3	0	0	0	0.3	1	0	0	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0.1	0.3	0	0	0	0.3	0.3	0.1
Knowledge representation (semantic network or object-oriented)	0.9	0	0	0	0.9	0.1	0	0	0.8	0.1	0	0	0	0.5	0.3	1	0.8	0.1	0.3	1	0		0	0.1	0	0.1	0.5	0.3	0.3	0.8	0.1	0.3	0	0.9	0	0.1	0.3	0.3	0	0.9	0	0.5	0
Statements, If-Then rules and If-Then management rules	0	0	0	0	0.5	0.3	0.5	0.1	0.9	0.1	0.9	0.5	0	0.3	0.5	0.5	0	0.3	0.5	0.8	0	0.1	0	0.5	0	0	0	0.5	0	0.5	0	0	0.5	0.9	0.5	0	0.3	0.5	0	0.8	0	0	0
Cognitive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Qualitative (including verbal description)	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0.5	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0
Game	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.5	0	0.8	0	0.3	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0.5	0
Dynamic programming	0	0.5	0.5	0.8	0	0.5	0.8	0.8	0	0	0.9	0.9	0.8	0	0.3	0	0	0	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0.1	0.3	0	0.5	0	0	0.8	0.5	0.5
Cybernetic	0	0	0	0	0.9	0	0.5	0	0.9	0	0.5	0.5	0.3	0.9	0.5	0	0	0	0.5	0.8	0	0.8	0	0.1	0.5	0.5	0	0	0.8	0	0.5	0.3	0.5	0	0	0.5	0	0	0.8	0	0	0.5	0.8
Morphological	0	0.1	0.1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellular automatons	0	0	0	0	0	0	1	0	0	0	0.8	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0.3	0
None	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0.5	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4–9 Conversion matrices $B_ц$, $B_с$,$B_д$ → $B_м$ (Continued)

Parameters \ Method	OLAP	Uncertainty analysis	Risk analysis	Analytical calculations, models, methods	Classification trees	Decision trees	Dynamic simulation	Dynamic programming	Discriminant analysis	Chaos identification	Monte Carlo simulation	Operational research, nonoptimizational methods	Operational research, optimizational methods	Causality research	Examination of psychological characteristics	Descriptive research	Exploratory research	Cluster analysis	Cellular simulation	Cognitive analysis	Creative activity	Matrix methods	Multi-criteria selection	Morphological analysis	Neural networks	Nonformalizable methods	Repeating solutions	Knowledge representation	Decision making, qualitative methods	Testing of stochastic hypotheses	Deductive reasoning	Inductive reasoning	Traductive reasoning	Regression analysis	Administration systems with feedback	Pattern matching	Standards, instructions and standard decisions	Game theory	TRIZ/TIPS	Factor analysis	Numerical calculations	Expert conclusion and expert evaluations	Expert systems
↓ Multi-step solution																																											
0	1	1	1	1	1	0.1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	1	0	0	0	0	0	0	0	0	0	0	0.1	1	0	0	0	0.3	0
↓ Availability of several criteria of optimality																																											
0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0.1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0.5	0	0.5	0	1	0.5	0	0.1	0.1	0	1	0	0	0	0	0	0	0	0	0	0.1	0	1	0.1	0.3
↓ Availability of off-the-shelf decisions for different situations																																											
<=0.5	1	1	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1[42]	1	1	1	1	1	0.5[43]	1	1	0	0	0	1	1	1	1	0
<=1	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0[42]	1	0	0	0	0	0.5[43]	0	0	1	1	1	0	0	0	0.3	1
↓ Broad number of experts																																											
<=0.3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.1
<=0.7	0.1	0.5	0.5	0.1	0.1	0.5	0.1	0.1	0.1	0.5	0.1	0.5	0.1	0.5	0.8	0.1	0.3	0.3	0.3	0.5	1	0.8	0.5	0.8	0.1	1	0.3	1	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.8	0.1	0.3	0.1	0.3	1	0.5
<=1	0.1	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.5	0.1	0.1	0.1	0.1	1	0.1	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.1	0.1	0.1	0.1	1	1
↓ High repeatability of the task																																											
<=0.1	0.3	1	1	0.8	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0
<=0.8	1	0.5	0.5	1	0.5	0.5	0.5	0	0.5	0	0	0	0.1	0	0.3	0	0	0	0.1	0.3	0	0.3	0	0	0	0.3	0.1	0.5	0	0	0	0	0	0	0	0.5	0.3	0.5	0	0	0.1	0	0
<=1	1	0.5	0.5	1	1	0.5	0.3	0	1	0	0	0	0.1	0	0	0	0	0	0	0	0	0.1	0	0	1	0.1	1	1	0	0	0	0	0	0	0	0.1	1	0.1	0	0	0	0	1
↓ Availability of uncontrolled events with several outcomes																																											
0	1	1	0	1	1	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1
1	0	0.1	1	0.5	0	1	0	0	0	0.3	0.3	0	0	0	0.3	0	0	0	0.1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0.1	1	0.5
↓ Representation precision of values of parameters																																											
<=0.5	0.1	1	0.3	0	0	0.3	0.3	0	0	0	0	0.3	0	0.5	0.5	0.3	1	0	1	1	1	1	0.3	0.5	0.8	1	0.8	1	1	1	1	1	1	0.1	0	1	0.1	0.1	0.5	0.3	0.3	1	0.9[44]
<=1	1	0	0.8	1	1	0.8	1	1	1	1	1	1	1	0.5	0.8	1	0.5	1	0.3	0	0.5	0.5	1	0.8	0.9	0	0.8	0.9	0.8	0.5	0.1	0.1	0.9[45]	0.9	1	0.8	0.9	1	0.9	0.9[46]	0.9	0.9	0.9[44]

42 The level of experience increases right in the work process.
43 Reasoning by analogy requires availability of the similar cases.
44 The reason is high complexity of expert system creation.
45 Reasoning by analogy is now rather rapidly developing.

Table 4–10 Conversion matrices $<л_7, л_8, л_9, н_2, н_3, н_4, н_5>В_М$

In order to convert a fuzzy-logical quantity into a probability row, one should apply a conversion operation based on the following principle: the q-th conversion matrix Θ_q should have N_q rows for each of the expertly determined range of probability of the availability of the initial variable нq. In the simplest case, there are only two of such ranges: POSSIBLE (range from 0.5 to 1) and IMPOSSIBLE (from 0 to 0.5). If the initial variable is not defined, the result is also indefinite.

The number of columns in the matrix Θ_q corresponds to the number of values of the output variable.

Types of conversion:

$$B_q = \begin{cases} \Theta_{q1}, & \text{if } \quad н_q \leq \quad н_{q1} \\ \Theta_{qp}, & \text{if } \quad н_q \in \quad \left[н_{qp}; н_{q(p+1)}\right) \\ \Theta_{Nq}, & \text{if } \quad н_q \in \quad \left[н_{q(Nt-1)}; н_{q(Nq)}\right) \\ NULL, & \text{if } \quad н_q > \quad н_{q(Nq)} \\ NULL, & \text{if } \quad н_q = \quad NULL \end{cases},$$

where B_q is the result of the q-th conversion; $н_q$ – the initial variable for the q-th conversion; Θ_q – the matrix of the q-th conversion; Θ_{qp} – its p-th row , p = $1 \ldots N_q$; $н_{qp}$ – the p-th boundary value of the range of probabilities of the initial variable.

One should make some notes as to the values of these matrices.

Purpose-Method. Evaluations are based on the matters examined in the previous chapters of the current research. The values that are higher or equal to 0.5 almost invariably correspond to the given examples. The values that are lower or equal to 0.3 are based on references in the literature. For example, it is stated in [45] that decision trees help to determine dependencies between consequences of different decisions. However, numerous disadvantages of this method have been noted, such as the labor intensiveness. Taking all these factors into consideration, there is 0.1 (the application is not excluded) in the row corresponding to "determine relationships between the variables" for decision trees.

Values rarely equal 1, because usually there are many methods to achieve a particular goal and a goal cannot explicitly determine an applicable method.

This fact is one of the reasons for the creation of a decision support system. The current task of method selection cannot be unambiguously solved by building a single table. It also cannot be solved as a fuzzy task, because fuzziness of selection remains rather immense. Not only the goal, but also all the available information should be used for the method selection.

Method of determining the parameters values – method. Usually, data can be obtained by different methods, which is proved by a great number of nonzero values. One should observe the values that are close to 1.

Secondary data is used in OLAP if the exploratory research is based on the literature. In cases that require a classifier (e.g., for building neural networks), and for statements (available information is used), statistical methods can also be applied to already collected data.

Initial data is collected by measurements in the following cases: when a classifier built on the basis of the secondary data is applied (e.g., discriminant analysis); in the tasks where the analysis and solution are required only for one situation (chaos identification).

Analytical and numerical models are applied for simulation; in cases when calculations are performed (decision trees). Data obtained by extrapolation is often applied in calculation tasks, especially the ones that require forecasts.

Data obtained by simulation modelling, except for simulation modelling per se, is applied in a number of other methods, such as multi-criteria selection.

Standards (normatives) are mostly applied in standards and directions.

Expert evaluations determine the application of the methods of work with experts, including building of expert systems. They are also applied in methods of risk and uncertainty analysis; on the initial stage of the introduction of the object (cognitive and morphological analysis); in qualitative methods of decision selection.

Types of parameters – method. The evaluation principle is analogous to the previous case: a value of no less than 0.5 is determined by the existence of a number of examples in the literature. Values of no more than 0.3 mean that there is the possibility of applying a particular method in particular situations. Within the ranges, the values are rather subjective.

This type of conversions is characterized by a large number of nonzero values in the matrix. It can be explained by the fact that the types of parameters can change. For example, in a cluster analysis an assumption can be made about the interval nature of the scoring scale. There is a more precise method of transition from scoring to quantitative evaluation, which is the method of slack variables described, e.g., in [45].

Quantitative evaluations can nearly always can strengthened with a transition to qualitative ones such as "much/little".

Model-method. This is a sparse matrix, because, as has been mentioned before, relationships between a particular model type and a particular method are rather strong. Methods can be uniquely determined by the following models: mathematical programming; simulation of queuing systems; Markov chains; models of relations between psychological attributes; network diagrams; schedules; decision trees; models of knowledge representation; statements; cognitive, qualitative, game models; models of dynamic programming; cybernetic, morphological models, and models of cellular automatons.

Other methods are more universal and can be applied by several methods. A number of methods, not associated with the models, require closer examination. Among these models, and in addition to the nonformalizable methods, OLAP, chaos identification, cluster analysis, and neural networks can be mentioned[43].

Most methods apply numerical models, IF-THEN rules and qualitative models.

An analytical model of a general type is applied in analytical calculations, operational research, regression analysis and, more rarely, in other cases.

A numerical model of a general type also has a wide range of applications, which is evident from the analysis performed in Chapter 3.

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[43] One can argue that this statement is rather controversial. Multi-dimensional arrays of data are used in OLAP cubes; chaos is often identified with the help of a model of the initial system; one can also mention models for other models that have been mentioned. In the current case, the models are specific to the methods and cannot be separated from them. Nevertheless, in the current research, as it has already been mentioned, we are trying to identify the interrelationships between the model already built and the applied method. Thus, an assumption is made, that the models that are used in the above-mentioned methods are not built outside the scope of the application of a particular method.

4.1.8 Obtaining evaluations of the method preferability

Dependencies that determine the output parameters are as follows;

$$\langle B_M \rangle \rightarrow O_1;$$
$$\langle B_M \rangle \rightarrow O_2;$$
$$\langle B_M \rangle \rightarrow O_3;$$
$$\langle B_M \rangle \rightarrow O_4;$$
$$\langle B_M \rangle \rightarrow O_5.$$

The values of evaluations can be found in Table 4–11.

Comments on the values

Evaluation of the adequacy of assumptions for method application. Methods of human reasoning (creative, nonformalizable, expert conclusions) hardly require an initial simplification of a task. It occurs during the solution process.

The most serious assumptions are introduced in cellular simulation and application of method of decision trees.

Other evaluations are based on practical experience. For example, the application of optimization methods of decision-making usually requires the introduction of a number of rather serious assumptions. They can refer not only to the admission of linear dependencies (linear dependence of the time spent on the production of a consignment of goods as regards its size), but also with assumptions associated with the environment, especially the marketing one (whether or not all output goods will be sold). Therefore, optimization methods are evaluated rather low and obtain an 0.5.

Evaluation of the validity of the results. There are no values that equal 1, because there is always a certain influence of the unaccountable factors that would make a decision not completely reliable.

The maximum values equal 0.9 and are determined by the features of a particular method, e.g. its strictness. Thus, OLAP is applied to data bulks and therefore it provides a rather precise evaluation. Uncertainty analysis considers such an important factor as the inaccuracy of the initial data. Dynamical simulation is based on rather adequate models: differential equations (discussed in [62]).

Method \ Evaluations	Adequacy of assumptions	Result veracity	Ease of introduction of a decision support system	Ease of one-time decision	Resulting utility
OLAP	0.9	0.9	0.7	0.9	0.9
Uncertainty analysis	0.8	0.9	0.9	0.7	0.7
Risk analysis	0.7	0.8	0.9	0.7	0.7
Analytical calculations, models, methods	0.4	0.6	0.9	0.7	0.5
Classification trees	0.6	0.8	0.9	0.7	0.7
Decision trees	0.3	0.5	0.4	0.4	0.3
Dynamic simulation	0.6	0.9	0.5	0.3	0.5
Dynamic programming	0.4	0.8	0.6	0.4	0.7
Discriminant analysis	0.4	0.8	0.9	0.7	0.7
Chaos identification	0.5	0.7	0.5	0.2	0.3
Monte Carlo simulation	0.7	0.9	0.8	0.3	0.8
Operational research, nonoptimizational methods	0.7	0.9	0.8	0.5	0.8
Operational research, optimizational methods	0.5	0.8	0.8	0.5	0.7
Causality examination	0.7	0.6	0.2	0.6	0.5
Examination of psychological characteristics	0.4	0.5	0.5	0.5	0.5
Research, descriptive	0.7	0.7	0.9	0.7	0.9
Research, exploratory	0.9	0.9	0.9	0.8	0.9
Cluster analysis	0.8	0.8	0.9	0.7	0.7
Cellular simulation	0.2	0.4	0.6	0.3	0.3
Cognitive analysis	0.6	0.7	0.5	0.9	0.9
Creative activity	1	0.5	1	0.8	0.9
Matrix methods	0.8	0.7	0.9	0.9	0.7
Multi-criteria selection	0.7	0.9	0.8	0.8	0.9
Morphological analysis	0.8	0.8	0.8	0.8	0.7
Neural networks	0.9	0.9	0.9	0	0.7
Non-formalized methods	1	0.5	1	1	0.9
Repeating solutions	0.9	0.7	1	0	0.7
Knowledge representation	0.9	0.8	0.5	0.2	0.3
Decision-making, qualitative methods	0.8	0.8	0.6	0.9	0.9
Testing of statistical hypotheses	0.6	0.7	0.9	0.7	0.7
Deductive reasoning	0.8	0.9	0.4	0.9	0.4
Inductive reasoning	0.9	0.8	0.3	0.9	0.4
Traductive reasoning	0.9	0.7	0.2	0.9	0.4
Regression analysis	0.6	0.6	0.9	0.7	0.5
Control systems with feedback	0.7	0.9	0.7	0.3	0.5
Pattern matching	0.5	0.8	0.9	0.7	0.8
Standards, directions and standard solutions	0.7	0.9	0.7	0.1	0.5
Game theory	0.8	0.7	0.6	0.7	0.7
TRIZ/TIPS	0.9	0.9	0.7	0.9	0.9
Factor analysis	0.8	0.7	0.9	0.7	0.7
Numerical calculations	0.9	0.9	1	0.9	0.9
Expert conclusions and expert evaluations	1	0.8	1	0.9	0.9
Expert systems	0.8	0.9	0.1	0	0.7

Table 4–11 Evaluation of methods

Simulation of queueing systems and other nonoptimizational methods of operational research allow functioning refinements of the researched object to be considered. Exploratory research, TRIZ/TIPS and expert systems often provide qualitative results, which is easier than obtaining a quantitative evaluation. The method of neural networks is based on a large sampling, which, along with special techniques and verifications, provides the accuracy of the result. Deductive reasoning is accurate if the initial data is accurate. Administration systems with feedback are built so that the influence of disturbances is minimal. Standard solutions in most of cases are based on long-term experience. Finally, numerical calculations are often based on observations rather than assumptions. Other evaluations are based on analogous considerations.

The convenience of implementing a decision support system. Implementation does not present any difficulties (evaluation equals 1) when the tasks are only performed by individuals (creative, nonformalizable methods, repeating solutions, expert conclusions) or when numerical calculations are performed. In these cases, the functions of the decision support system are purely auxiliary.

It is rather easy to implement the system (0.9) in cases where standard programs are applied. The research dated from 2009 [221] demonstrates, in particular, that currently there are a number of simple and convenient neural networks.

It is, however, more challenging to implement the system for causality research and reasoning (due to complexity of the subject and low level of formalizability of the task [224]).

The convenience of one-time decisions.

It is assumed that there are suitable specialists in a company, thus the methods that do not require either special software support, or pre-training, are evaluated as 1.

Most of the grades are 0.7 and they are given to the methods that are implemented by statistical packages and analogous programs. They require the package to be installed and practical experience when using it. When one deals with a one-time task, these requirements are often not fulfilled, thus, the methods application can become more complicated.

Values of 0.5 are given to those methods that need extensive computer support, and require considerable preparation work.

Low values (0.2; 0.3; 0.4) are given to those methods where the application is associated with the mastering of rarely used software or with high labor-intensity for the preparation work (e.g., analysis of assumptions, collection of initial data, building a model and its input into a computer, mastering the language that is used for model description and its functions, etc.).

A value of 0.1 is given to directions, because they are rarely made for one-time tasks, and even if they are, it is rather difficult to apply them.

Zero values are given to the methods that are not applicable to one-time tasks.

Evaluation of the utility. Neither of these methods has a unitary values, because it is impossible to obtain a formal solution for a decision-making task. A Decision support system can only provide comparatively useful advice.

The following are graded as 0.9.: marketing research methods, including OLAP as a means of providing information for a decision; the methods of situation comprehension, including TRIZ/TIPS, non-formal and expert methods, as long as they allow work to be carried out in difficult situations; methods of decision-making per se, as playing an important role in solution; calculation methods as applicable to many cases.

Methods, providing significant results, even though they have certain assumptions, are graded as 0.8.

0.7 is given to those methods where the results are not always applicable without additional analysis. Most of these are based on rather serious assumptions.

Methods, based on even more serious assumptions, are graded as 0.5.

Methods of reasoning are graded as 0.4, because they do not normally lead to a decision, but keep the focus on the process of obtaining the decision.

The lowest grade of 0.3 is given to the auxiliary methods or those that provide qualitative solutions (cellular automatons).

A general estimate is calculated as a weighted average value of the partial evaluations, and considers the weighting coefficient of each of them as input by an operator. Thus, the preferences of the decision-maker are taken into consideration.

4.1.9 Result representation

The result should be represented as a list of decision-making methods, ordered by the general estimates, and demonstrating both the general estimate and a set of partial estimates. The possibility of weight correction and the re-calculation of the final estimates should be available. In addition, an estimate should be derived of the quality of the expert system quality; this is examined later in the research.

4.1.10 Ability to self-learn

In order to provide the possibility of adapting a decision-making style in a particular company (a corporate style of such a type has been examined in [199]), and to shifting conditions, the possibility of editing the values of the elementary transformation matrices should be introduced. One option is to do this manually. Another option is automatic adjustment. The latter option is applicable in cases where the system operates in a single-step mode and the decision-maker participates in a particular step.

A layout of an adaptation adjustment for conversion matrix values is as follows: (see Figure 4–2).

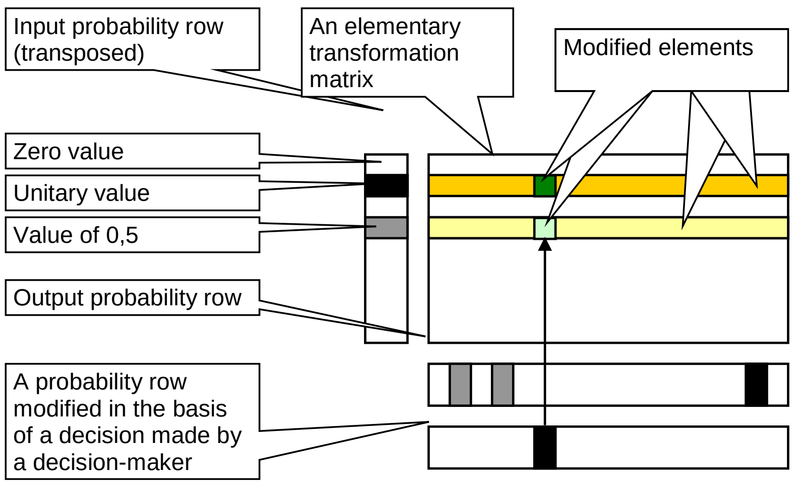


Figure 4–2 Illustration of the matrix transformation adaptation mechanism

1 The probability row for the values of an input variable Bq (shown on the left in an already transposed state) is input in the conversion. For example, it has one unitary value, 1 value of 0.5 and the other values equal 0.

2 The elementary transformation is performed by calculations. The colored rows of the conversion matrix are involved in this transformation. The result is a row of value probability for the B'_q input variable. In a general case, this consists of several non-zero values. One unitary value is demonstrated in the picture (black) and two values of 0.5 (grey).

3 A decision maker makes a decision and informs the system by inputting the selection. In a general case, the decision may not correspond to the recommendations produced by the expert system. This is demonstrated in the figure in the bottom row: the selected solution represents a row, in which there is only one element equal to one, and the other elements are equal to zero.

4 The confidence of decision-makers in the accuracy of their decision is the basis for a conversion matrix adjustment. The transformation should be performed with a manually input command, to eliminate permanent adjustment of matrices.

In order that the same decision is made next time in a similar situation, the values in the cells situated immediately above the value set by the decision maker as 1, should also be set as 1, while the values in the other cells are set as 0.

However,

- the decision, in the end, can be wrong, in spite of the decision-maker's confidence in it, and the database should not immediately implement incorrect knowledge;
- some situations cannot be fully described by a set of input parameters, thus a complicated decision cannot be made.

Therefore, a "soft" adaptation is required, which allows the values of the conversion matrix element to gradually change.

The following adaptation principles are suggested:

- a value increment prevails over a value decrease. In the figure, this means that the cell above the element that corresponds to the decision increases more than the decrease in the values of the rest of the cells in the edited row.
- the changes mostly concern the cells that correspond to the higher probabilities of the values of the input variable. In the figure, the pale

yellow row changes less than the bright orange one, because the latter corresponds to the unitary value of probability, which affects the result more significantly. We also offer the introduction of a quadratic function in order to evaluate the influence of nonzero probabilities: if the input probability equals 0.5, then conversion of the elements of the corresponding matrix row is 4 times weaker than that of the row that corresponds to the probability equaling 1.

Thus, the conversion formula is as follows:

$$\Theta'_{qpr} = \varphi\left(\Theta_{qtr} + \begin{cases} a \times B^2_{qp}, & \text{if } \mathrm{B}'^{\phi}_{\mathrm{r}} = 1 \\ b \times B^2_{qp}, & \text{if } \mathrm{B}'^{\phi}_{\mathrm{r}} = 0 \end{cases} \right)$$

where Θ'_{qtr} is the new value of an element of the q-th conversion matrix; φ (x) is the function of the following type:

$$\varphi(x) = \begin{cases} 0, & \text{if } x < 0 \\ x, & \text{if } 0 \le x \le 1 \\ 1, & \text{if } x > 1 \end{cases},$$

where B_{qp} is the p-th element of the probability row for the values of the input variable of the q-th conversion; B'^{ϕ}_{r} is the value of the probability row for the output values after selection has been completed by a decision-maker, the probability of a single selected element equals 1, the probability of the others – 0. a, b are adjusted coefficients, their initial values are set as a=0.1, b=-0.01.

Thus, the system is capable of adjusting itself in automatic mode. As a result, it adapts to a decision making style of a particular decision-maker and is able to consider new achievements in the area of marketing instrumental methods.

4.1 Indices of and evaluation methods for an expert system

The term “quality of a method selection system”, can be understood as the degree of decision ideality in conditions of correct initial data. An ideal decision is the selection of a single decision-making method on the basis of the initial task data. However, in reality there is more than one method that is equally (or with different degree of success) applicable to a particular task in the area of product management. The outcome of the expert system application is a probability row for each of the analyzed methods. In the perfect case, the applicability of one single method equals 1, while the applicability of the others equals 0. In reality, the decision of more complicated cases often decided on the applicability of all the methods from those that equal 1 to a zero applicability of them all. The task, in this case, is to quantitatively evaluate the quality of the selection; here, it is the quality of ranking the methods by their preferability. This issue is addressed in [213].

4.1.1 Performance criterion of the method selection

It is convenient to illustrate the argumentations by an example. There are 10 options for ranking of 5 objects (solution methods for a marketing task) according to their applicability to a particular situation. These options are represented in Table 4–12.

For the purposes of further discussion, they are also graphically presented in Figure 4–3.

The author failed to find any literature on the issue of ranking quality based on qualitative estimates. However, similar tasks occur, e.g., during an ABC-analysis of assortment [40], an evaluation of industry concentration ratio [114], the identification of property inequalities in a population [267].

On the basis of the literature on these issues, a number of estimates that can characterize ranking quality have been determined. Most are based on the Lorenz curve [81] (Figure 4–4).

In order to build the curve, the following actions should be performed. The researched objects (goods, companies, households; methods in this case) are ranked in descending order with regard to a particular parameter significant to the research (sales volume; family income for households; evaluation of particular method applicability in this case). After which the cumulative distribution curve is built, which is the Lorenz curve.

No	Option for evaluation					The obtained information	$I_{Д}$	I_D	I_{LD}	I_{HH}	I_E
1	1	1	1	1	1	All alternatives that are applicable	0	0	0	0.20	1.60
2	1	0	0	0	0	Perfect scenario: only one alternative is applicable	0.67	0.200	?	1.00	?
3	1	0.9	0.9	0.9	0.9	One alternative is completely applicable, the others are less applicable	0.01	0.000	0.002	0.20	1.61
4	0.1	0	0	0	0	One alternative is almost completely inapplicable, the others are absolutely inapplicable	0.67	0.200	?	1.00	?
5	1	0.9	0.8	0.7	0.6	The first alternative is completely applicable, the others are increasingly less applicable	0.08	0.002	0.041	0.21	1.60
6	0.4	0.3	0.2	0.1	0	The last alternative is completely inapplicable, the others are increasingly more applicable	0.33	0.025	?	0.30	?
7	1	1	0	0	0	Two alternatives are completely applicable, the others are completely inapplicable	0.50	0.075	?	0.50	?
8	1	0.8	0.6	0.4	0.2	The first alternative is completely applicable, the others are increasingly less applicable, while the last one is almost inapplicable	0.22	0.011	0.401	0.24	1.49
9	1	0.5	0.3	0.12	0.06	The applicability decreases exponentially, the last alternative is almost inapplicable	0.38	0.040	1.244	0.36	1.23
10	0	0	0	0	0	None of the alternatives is applicable	?	?	?	?	?

Table 4–12 Examples of alternatives for decision ranking

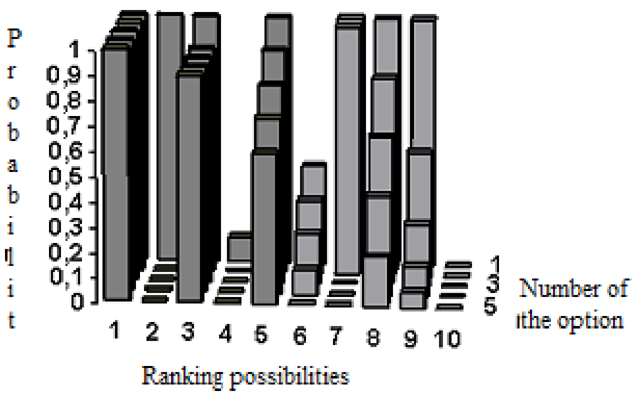


Figure 4–3 Graphic presentation of the different options for the evaluation of a method's applicability

Comments on each option can be found in the middle column of Table 4–12.

In cases where all the goods are sold equally, all the companies have an equal market share, all the households receive an equal income - and in the task under consideration – if all the methods have an equal preferability level, the curve transforms into a straight line (the thin line in the figure).

In case of an unequal volume of sales, method estimates, and other variables the graph becomes a curve (the bold line in the figure).

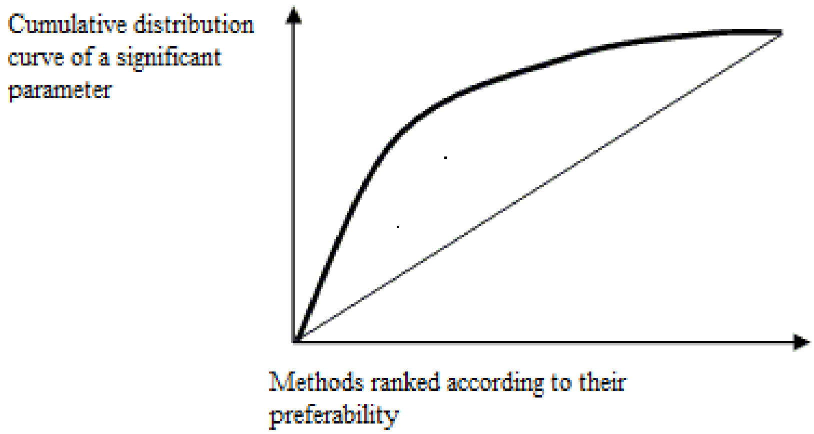


Figure 4–4 A Lorenz curve for the evaluation of a set of research elements

The estimates are based on the distortion of the curve. Among the distortions are the following:

1 The concentration ratio, characterizing the share of a particular number of goods as regards the total amount. This method does not really take into consideration the "tail" (the right-hand part) of the curve. In the current task, it is required that a small number of methods have high estimates, an average number have average estimates, and a large number have low estimates., e.g. it is necessary to consider the whole range. Thus, this method is not applicable to the task.

2 The Lind's index considers the correlation of the most significant objects. It provides little information for the solution of the current task. Its application can be addressed later, at the stage of the examination of the differences in the estimates between the leading methods.

3 The decile dispersion ratio, which presents the ratio of the total share of the 10 percent of the elements that have received the highest estimates by the share of the bottom 10 percent. This ratio does not take into consideration those elements that obtain average estimates. Its ap-

plication is difficult in cases with a small number of elements that form 10 percent of the shares, as in the case under consideration. Moreover, in the task under review it is important to consider estimates of all the elements (methods), while this ratio only considers 20% of them.

4 The Gini coefficient $I_{Д}$ is the ratio of the area that lies between the Lorenz curve per se and the Lorenz curve for an absolutely equal distribution boarded with the axes.

5 A dispersion of (market) shares I_D is applied in order to evaluate the level of market monopolization. As a share in the task under consideration one can take share of probable application of a particular method in the total sum of probabilities of all values.

6 Dispersion of the logarithms of shares I_{LD} plays a similar role.

7 The Herfindahl–Hirschman Index I_{HH} is defined as the sum of the squares of the market shares [of the firms operating on the market]. It ranges from zero, when there are many objects [producers], to 1, when there is only one object [monopolistic producer]. Application of this method is analogous to the application of the dispersion of (market) shares.

8 The entropy index I_E demonstrates the average share of objects [of the companies on the market] weighted by the natural algorithm of its reciprocal quantity. For the task under consideration, its application is similar to the previous cases:

$$I_E = \sum_k Y_k * \ln\left(\frac{1}{Y_k}\right),$$

where Y_k – share of evaluation of applicability of the kth in the total sum of estimates of all the methods.

The five last estimates have been calculated for all the ranking examples (see the right-hand part of Table 4–12). The operation of indices of entropy and dispersion logarithms has proved not to be successful in cases where at least one of the estimates equals zero. This case should be treated as a special one.

The Gini index does not distinguish between options 2 and 4, even though option 2 corresponds to a perfect choice, while option 4 is far from perfect.

The same applies to the Dispersion of (market) shares and to the Herfindahl–Hirschman Index.

In order to eliminate the existing defects of the available estimates, the following principle of evaluation of method selection quality can be utilized.

The selection quality has three aspects:

Maximum applicability I1 demonstrates certainty in the selection of at least one method. Such certainty is useful for a decision-maker and is in the range from 0 (the worst option) to 1 (the best option).

Difference between the maximum and the minimum applicability of different methods I_2 demonstrates how well the result differentiates the methods. Method differentiation according to their applicability is also useful for the decision-makers, as it allows them to exclude with confidence at least some of the methods. It has a range from 0 (the worst option) to 1 (the best option).

Derivation of estimates from a perfect Δ. This is a sum of the moduli of the difference of the obtained estimates and the perfect estimate 1, 0, 0, 0, 0. It demonstrates how confidently only one method can be selected. It has a range from 0 (perfect option) to N_M-1, where N_M is the number of methods.

$$\Delta_{\max} = \begin{cases} N_M - 1, & \text{if} \quad \mathrm{N_M} > 1 \\ 1, & \text{if} \quad \mathrm{N_M} = 1 \end{cases}$$

or $$\Delta_{\max} = \max(N_M - 1;\ 1).$$

In order to ensure the uniformity of the ranges, one should introduce the estimate I3 with 1 as the best value and 0 as the worst.

$$I_3 = 1 - \frac{\sum_{m=1}^{N_M} \left| B_m - \begin{cases} 1, & \text{if} \quad m = 1 \\ 0, & \text{if} \quad m \neq 1 \end{cases} \right|}{\max(N_M\ \text{-}1;\ 1)},$$

where B_m is evaluation of applicability of the m-th method. This estimate is deviation of the obtained probability row from the perfect one that has only unit value while other values equal zero.

In order to consider all three quality aspects, the weighted average value of the three components is introduced:

$$I_n = \frac{d \times I_1 + e \times I_2 + f \times I_3}{d + e + f},$$

where d, e, f are the weighting coefficients. They can be defined on the stage of adjustment of the system according to the preferences of the decision-maker.

Values equal to 1 are taken as the first approximation.

Calculations of the components of the selection quality index are demonstrated in Table 4–13.

Option for evaluation	I_1	I_2	I_3	I_n
1, 1, 1, 1, 1	1	0	0.00	0.33
1, 0, 0, 0, 0	1	1	1.00	1.00
1, 0.9, 0.9, 0.9, 0.9,	1	0.1	0.10	0.40
0.1, 0, 0, 0, 0	0.1	0.1	0.78	0.33
1, 0.9, 0.8, 0.7, 0.6	1	0.4	0.3	0.55
0.4, 0.3, 0.2, 0.1, 0	0.4	0.4	0.70	0.50
1, 1, 0, 0, 0	1	1	0.75	0.92
1, 0.8, 0.6, 0.4, 0.2	1	0.8	0.50	0.77
1, 0.5, 0.3, 0.12, 0.06	1	0.94	0.77	0.90
0, 0, 0, 0, 0	0	0	0.75	0.3
0.5, 0.5, 0.5, 0.5, 0.5	0.5	0	0.38	0.29

Table 4–13 - Calculation of the elements in a method selection quality evaluation

It is evident from the table that the suggested estimate is applicable for all probability values. It successfully determines the perfect value. Options with equal probabilities of all the values have low, but still nonzero estimates. This means that this type of ranking presents information providing certainty.

By managing the values of the weighting coefficients, one can pay attention to a particular aspect of the selection quality.

It is evident that the suggested index does not have the above-mentioned disadvantages of the previous methods.

4.1.2 Utility evaluation of a particular matrix data transformation

In order to evaluate the quality of a particular matrix transformation, one should evaluate the selection quality by regarding all the possible options for the probable values of the input variable, followed by an evaluation of the average selection quality. Due to complexity of the task, and the various occurrence probabilities of the probable input parameters combinations, we suggest the following method.

A conversion matrix proffers a perfect result, if for each value of the input variable with a probability of 1, each output row has only one estimate that equals 1 while all the others equal 0. In other words, the conversion matrix is perfect when for each input probability row consisting of a single 1, the output row also consists of only one 1.

Thus, all the matrix rows in a perfect case should consist of one 1, and the other values should equal 0. Therefore, the following method for the determination of the matrix conversion utility is presented:

The rows of a conversion matrix are organized in a descending order.

For each row the $I_{\Pi qp}$ (utility of the q-th row of the conversion table) value is calculated.

The final $I_{\Pi q}$ value (utility of the q-th conversion table) is calculated as an average value of the rows.

The formula for the calculation of the $I_{\Pi q}$ is as follows:

$$I_{\Pi q} = \frac{\sum_{p=1}^{N_q} I_{\Pi qp}}{N_q},$$

where N_q is the dimensionality of the input probability row; $I_{\Pi qp}$ – evaluation of utility of the Θ_q conversion matrix p-th row.

Figure 4–5 shows evaluations of the conversion matrices utility for various values of the components weights of the quality evaluation.

It is evident that all the matrices have rather a high utility level. The values are highest when the coefficients of importance equal 10; 1; 1, i.e. when the decision-maker wants to verify the methods of applicability. The values are lowest when the coefficients equal 1; 1; 10, i.e. when the decision-maker wants to obtain an unambiguous solution. These facts support the statement that tasks can be solved by various methods.

The "stage – aim" conversion has the lowest utility in all the options, which indicates that a possible reconsideration of the matrix might be suggested or in fact a deletion of this conversion.

4.1.3 A correctness evaluation of the matrix of the elementary matrix conversions

When an expert is completing a conversion matrix, the sums of the columns and rows are automatically calculated. If a column sum equals zero, then one of the values of the final variable will never be selected, which can mean that it is useless to input the value in the system. On the other hand, if a row sum equals zero, some particular values of the input row will result in the output, which would consist of only zero probabilities for all values of a variable. This is the information that helps experts identify potentially incorrect fragments in the system.

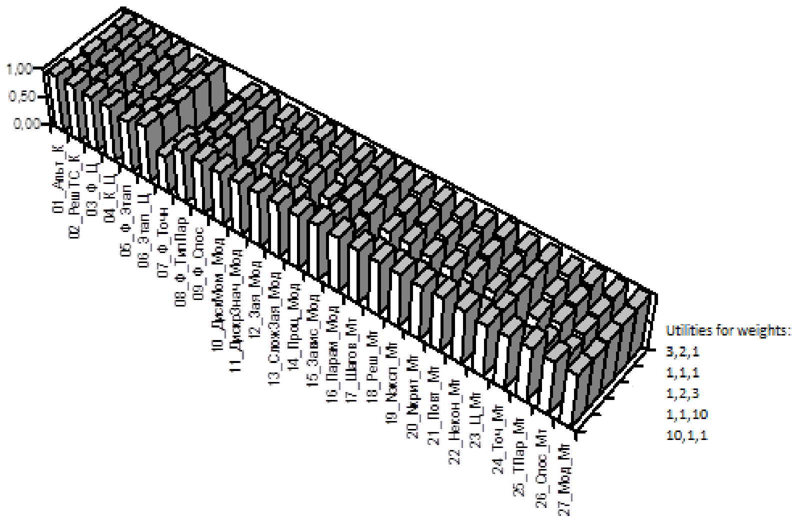


Figure 4–5 Utilities of the conversion matrices for various values of the quality criterion (P_1, P_2, P_3 respectively)

4.1.4 General evaluation of an expert system

The general assessment of an expert system is defined as an average value of the selection quality for all the options of the initial data.

However, we suggest assessing the quality of the expert system on the basis of an operating experience in actual practice due to the following issues:

- the complexity of the calculations for the input quantities conversion into the outputs;
- the different probabilities of the occurrence of different sets of initial data values;
- possible conversion cycling.

The typical approach for expert systems is obtaining a final evaluation of the quality of the system as performed by experts [53].

The utility result is calculated according to a number of test situations.

4.2 Implementation of the expert decision support system in the area of product lifecycle management

Implementation of the expert decision support system in the area of product lifecycle management has been performed according to the methodological principles that have been addressed in [196] and a number of other articles.

Within the framework of the research, a pilot version of the expert system for selection of a decision-making method in the area of product management has been developed. Its aim is to practically verify the obtained results. Thus, the requirements for the pilot version are as follows:

- a high level of flexibility, which facilitates modification possibilities
- an easy input for the conversion matrices (their table form)
- the possibility to perform step-by-step conversions and to view the intermediate results
- the possibility to test various modes, e.g. flexible and strict selection

4.2.1 Fact base format

MS Excel spreadsheets are used as the data storage method in the pilot version of the program. This choice is determined by the fact that two-dimensional pictures are visual and convenient for experts to fill in / complete; it is easy to maintain the sequence of the rows. Moreover, spreadsheets demonstrate the intermediate results in a convenient form, which is advantageous when debugging.

The name of the situation files are Situation99.xls, where 99 is the number of the situation. Each file consists of one worksheet. The table has four columns, starting from A1, and an arbitrary number of rows. The content of the table is provided in the Appendix.

The first column is the name of the variable that describes a particular situation. The content of the cells of the second column depends on the type of variable. If the variable is a logical one, the cell has symbols 0;1, if it is a fuzzy-logical variable, the cell has 0_1 as symbols, and consists of the verbal value of the variable, if it is a string (many-valued) variable.

The third column consists of probabilities. If the variable is logical, the values can only be either 0 or 1, in other cases the value is in a range from 0 to 1.

The forth column is reserved for the row number (the system is intended to be developed as a database in the future).

The name of a rule file is Rules.xls. There is a separate worksheet for each elementary matrix conversion. In addition, there are worksheets $O_1 \ldots O_5$ with evaluations of the methods.

The sheets with tables Θ_q have the following names:

99_A_B,

where 99 is the number of the table setting the procedure for the rule application; A, B are sets of 1 to 5 symbols simplifying the search for a particular rule in order to manually modify it.

The number of rows in the table body corresponds to the number of the input variable values; the number of columns in the table body corresponds to the number of output variable values. The table consists of probabilities.

An operator can edit the content of the situation files, create new, or delete the existing ones. It is necessary to select one of the situation files to work with.

4.2.2 Rule base format

Matrix fuzzy rules in the pilot version are saved as an Excel file. It is intended subsequently to perform the input through a special form representing the data in the form of matrix. The name of the file is Rules.xls, it consists of 27 worksheets of the Θ conversion matrices and 5 worksheets of evaluations.

An operator can manually edit the file.

4.2.3 Operation management

After a situation file is open, the following buttons are activated:

The manual input for the situation allows the adjustment of all the parameter value probabilities. A decision-maker inputs all the available information to raise the level of the decision quality;

- Start button. The calculations start after this button is pressed;
- The result button overviews the set of methods and presents their evaluations. The methods are ranked in the descending order of their preferability;
- The clear the situation button. This makes the open situation completely uncertain;
- The new situation button – creates a new file with a completely uncertain situation.
- Flag - detailed view sets/resets detailed mode of the course of calculations reflection. When this mode is disabled, the application of all elementary matrix operations is performed automatically until the final result is obtained. If the detailed mode is enabled, then before a particular rule is applied, the operator can see all the input variable values and all the output variable values - after the rule has been applied. This allows the decision-maker to correct the estimates obtained by the computer at their discretion.
- The stop button ends the calculations. The data is saved in the situation;
- The continue button in the detailed mode allows the following steps of conversions to be performed;
- The finish button is always visible and serves as a means to exit the program at any moment.
- Text fields for inputting the weights of the selection quality evaluation components are marked as Max, Max-min and Derivation.

- The option buttons - Strict / Flexible selection - correspond to the type of fuzzy logical conversion: logical AND or logical OR respectively.

In order to avoid operational mistakes, the buttons only appear when they can be used. For example, the result overview button is not visible unless a situation is open.

A screenshot of the program window after the situation selection is provided in Figure 4–6.

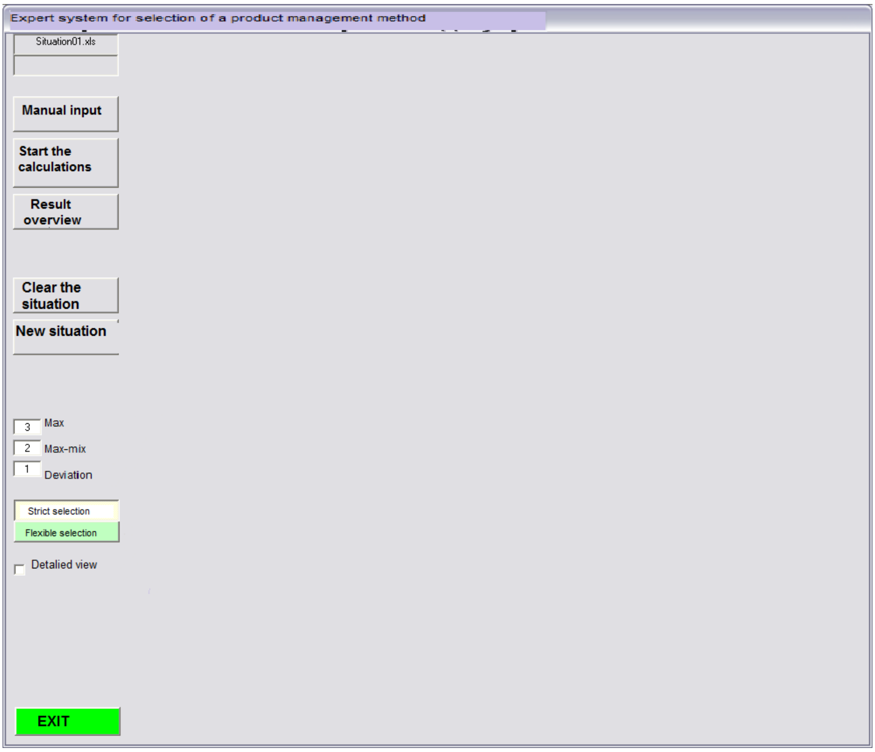


Figure 4–6 Screenshot of the program window after the situation selection

4.2.4 System operation

In the calculation mode, the system applies all the rules in the file one after another according to the name of the worksheets. In order to apply a particular rule, the corresponding fragment of the situation is selected; as a result, intermediate results are obtained for another fragment of the situation. The process continues until all the rules are considered.

The course of the calculations is reflected in the output fields:

- applied rule;
- indication of whether it is the input or the output row that is currently displayed.

The rows of the input data are given as a table with two rows: the value of a variable and the probability. In order to adjust the probabilities a certain set of tools has to be applied:

Sliders allow an operator to set the probability of each value in increments of 0.1, and in increments of 1 for logical variables;

Buttons "+" and "-"allow the zooming in and out of the probability of one value at the expense of the other values. This is convenient if the decision-maker is not certain of the initial data.

A screenshot during the performance of conversions is shown in Figure 4–7.

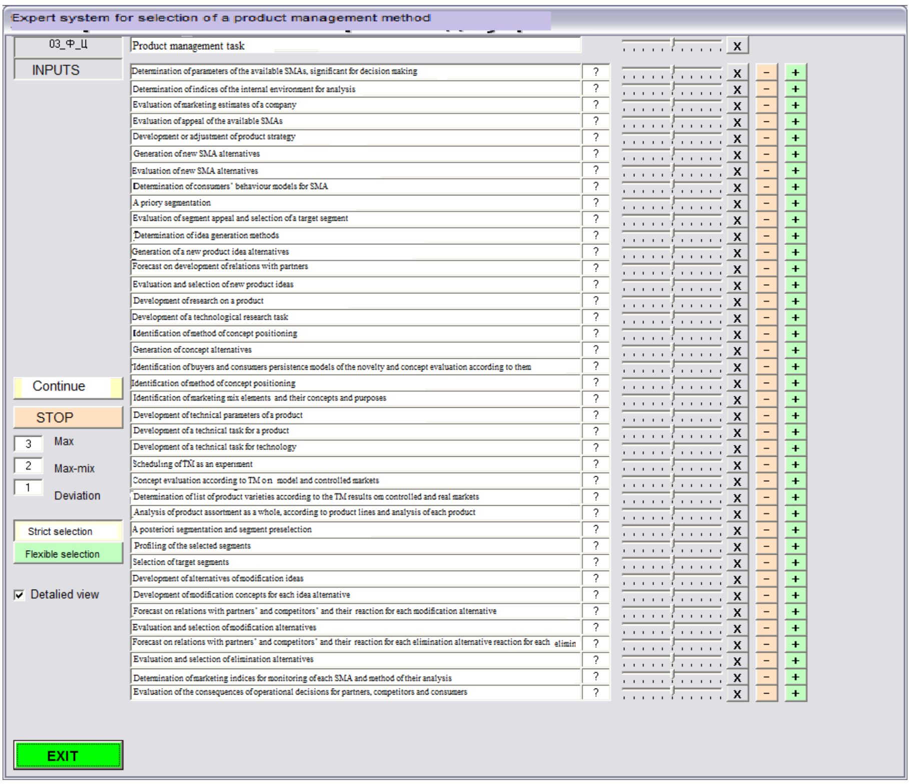
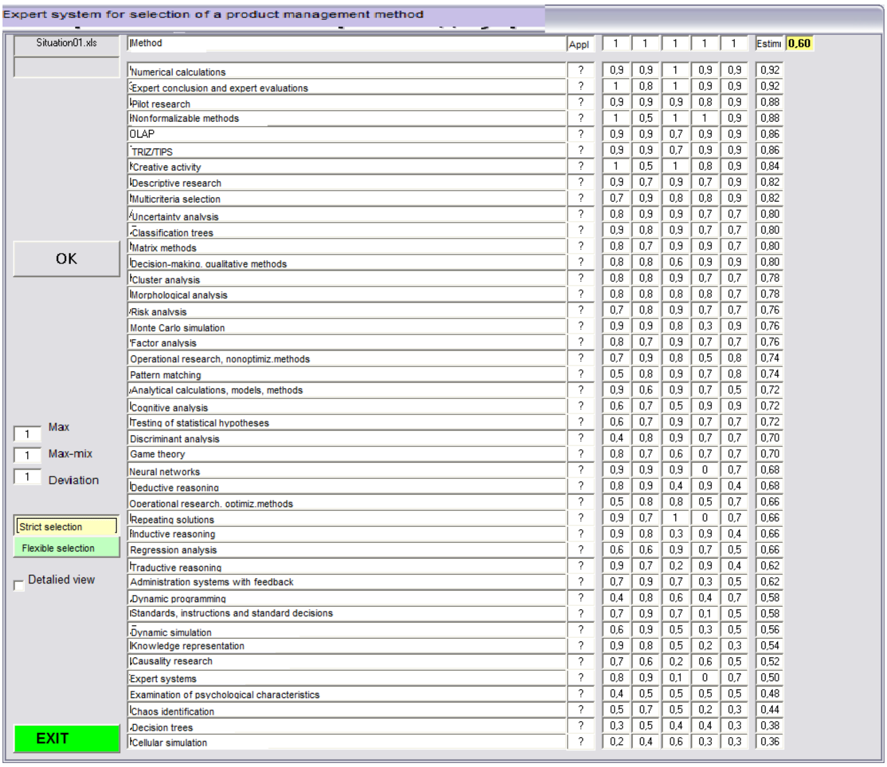


Figure 4–7 Screenshot of the program window during the process of step-by-step conversion

It is evident that the situation is completely uncertain; also one can notice the operating controls for editing the description of the situation. In the single-step mode, one can set parameter values for any situation. The sign INPUTS in the top left-hand corner indicates that the displayable data will be applied in the above-mentioned rule (in this case the aim of a product management task will be defined). After the conversion is complete, it is possible to see how the aims have been defined and adjust the decision if needed. This adjustment can be used for the adaptation of the conversion matrix values to a certain style of decision-making.

4.2.5 The obtained results

The final table is displayed in the result view mode (Figure 4–8).



Method	Appl	1	1	1	1	1	Estim 0,60
Numerical calculations	?	0,9	0,9	1	0,9	0,9	0,92
Expert conclusion and expert evaluations	?	1	0,8	1	0,9	0,9	0,92
Pilot research	?	0,9	0,9	0,9	0,8	0,9	0,88
Nonformalizable methods	?	1	0,5	1	1	0,9	0,88
OLAP	?	0,9	0,9	0,7	0,9	0,9	0,86
TRIZ/TIPS	?	0,9	0,9	0,7	0,9	0,9	0,86
Creative activity	?	1	0,5	1	0,8	0,9	0,84
Descriptive research	?	0,9	0,7	0,9	0,7	0,9	0,82
Multicriteria selection	?	0,7	0,9	0,8	0,8	0,9	0,82
Uncertainty analysis	?	0,8	0,9	0,9	0,7	0,7	0,80
Classification trees	?	0,9	0,8	0,9	0,7	0,7	0,80
Matrix methods	?	0,8	0,7	0,9	0,9	0,7	0,80
Decision-making, qualitative methods	?	0,8	0,8	0,6	0,9	0,9	0,80
Cluster analysis	?	0,8	0,8	0,9	0,7	0,7	0,78
Morphological analysis	?	0,8	0,8	0,8	0,8	0,7	0,78
Risk analysis	?	0,7	0,8	0,9	0,7	0,7	0,76
Monte Carlo simulation	?	0,9	0,9	0,8	0,3	0,9	0,76
Factor analysis	?	0,8	0,7	0,9	0,7	0,7	0,76
Operational research, nonoptimiz.methods	?	0,7	0,9	0,8	0,5	0,8	0,74
Pattern matching	?	0,5	0,8	0,9	0,7	0,8	0,74
Analytical calculations, models, methods	?	0,9	0,6	0,9	0,7	0,5	0,72
Cognitive analysis	?	0,6	0,7	0,5	0,9	0,9	0,72
Testing of statistical hypotheses	?	0,6	0,7	0,9	0,7	0,7	0,72
Discriminant analysis	?	0,4	0,8	0,9	0,7	0,7	0,70
Game theory	?	0,8	0,7	0,6	0,7	0,7	0,70
Neural networks	?	0,9	0,9	0,9	0	0,7	0,68
Deductive reasoning	?	0,8	0,9	0,4	0,9	0,4	0,68
Operational research, optimiz.methods	?	0,5	0,8	0,8	0,5	0,7	0,66
Repeating solutions	?	0,9	0,7	1	0	0,7	0,66
Inductive reasoning	?	0,9	0,8	0,3	0,9	0,4	0,66
Regression analysis	?	0,6	0,6	0,9	0,7	0,5	0,66
Traductive reasoning	?	0,9	0,7	0,2	0,9	0,4	0,62
Administration systems with feedback	?	0,7	0,9	0,7	0,3	0,5	0,62
Dynamic programming	?	0,4	0,8	0,6	0,4	0,7	0,58
Standards, instructions and standard decisions	?	0,7	0,9	0,7	0,1	0,5	0,58
Dynamic simulation	?	0,6	0,9	0,5	0,3	0,5	0,56
Knowledge representation	?	0,9	0,8	0,5	0,2	0,3	0,54
Causality research	?	0,7	0,6	0,2	0,6	0,5	0,52
Expert systems	?	0,8	0,9	0,1	0	0,7	0,50
Examination of psychological characteristics	?	0,4	0,5	0,5	0,5	0,5	0,48
Chaos identification	?	0,5	0,7	0,5	0,2	0,3	0,44
Decision trees	?	0,3	0,5	0,4	0,4	0,3	0,38
Cellular simulation	?	0,2	0,4	0,6	0,3	0,3	0,36

Figure 4–8 The result of the expert system operation

The pilot version of the program consists of seven columns. The first one addresses the name of the method, the second one – the applicability of the methods without considering any partial estimates. The third, fourth, fifth and sixth – the values of the partial criteria. The final row addresses the value of the integral criterion for the preferability of each method of application. The methods are ranked in a descending order using this criterion.

The weights of the criteria are displayed above the columns 3, 4, 5, 6 and 7. Their initial values equal 1. An operator can manually edit the value of each weight and the system will perform a recalculation and a re-ranking at their command.

In a special field, (top left) an evaluation of the ranking quality is displayed.

The result can be saved or printed, if needed.

4.2.6 The parameters of the pilot version

The size of the executable file of the program without the library unit is 116 Kb, the size of the rule base files is 387 Kb, the size of the file with description of a situation is 46 Kb.

The duration of the complete calculation without the display of intermediate results, when performed on a computer with a Core 2 DUO processor with a clock speed 1.2 GHz is around 20 sec.

The dimensionality of the conversion matrices is a maximum of 60, and can be increased to 255 in supra-screen mode.

The limit of the number of matrices is 255.

The number of the methods partial estimates is a maximum of 10.

4.3 Sanity check methods for the developed expert system

In order to demonstrate the system's operability a number of test examples have been developed. They correspond to a wide set of typical situations that occur during decision-making processes.

4.3.1 The complete uncertainty of the situation

This example is given in order to illustrate the system's operability under circumstances where there is a complete absence of any information and the decision-maker does not possess any information about the situation either. In this case, the methods for solving the product management tasks are ranked according to their partial estimates $O_1,\ldots,O_5$, i.e., according to their popularity.

The result of such ranking is demonstrated in Figure 4–8. It is evident that the ranking quality is rather low (0.6). Nevertheless, there are some useful recommendations on the methods application. It is also apparent that neither of the methods has been completely approved, nor completely rejected.

The most preferable methods are numerical calculations; expert conclusions; pilot research; and the informal methods.

The least preferable methods are chaos identification; decision trees and cellular simulation.

Moreover, one can modify the importance of the partial estimates in the top right hand corner (due to the lack of space they appear as hints) and perform recalculations by pressing the OK button.

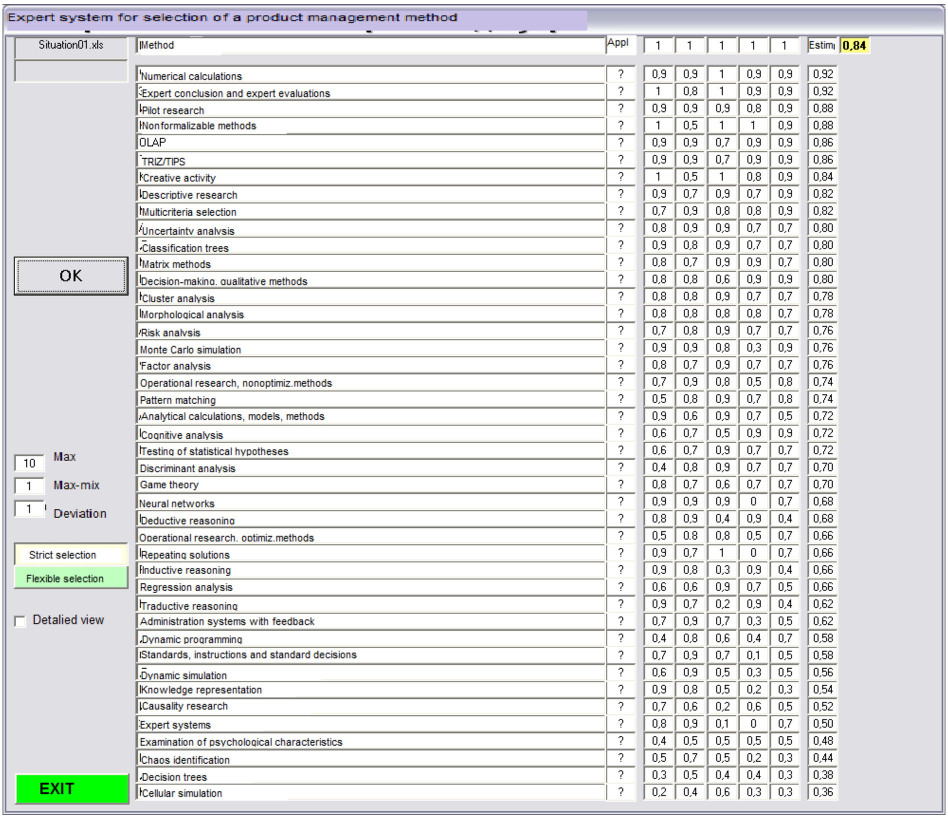
4.3.2 Modification of the importance of the coefficient for the evaluation of the selection quality

If the decision-maker wants to be certain as regards the actual applicability of the methods suggested by the system (in other words, the high values of the estimates of the methods applicability are the most important criterion), they can set the maximum weight of the estimate as 10 and leave the others equal to 1. The result is demonstrated in Figure 4–9.

It is evident that the estimates of the method applicability have not changed. The only thing that has changed is the general estimate of the decision's utility. This has increased to 0.84, because there are a number of methods with estimates close to 1, which, in turn, correspond to the preferences of the decision-maker.

4.3.3 Weight modification of method's partial estimates

The only known fact in this example is that it is a one-time decision. In this case, the weight of the estimate "convenience of a one-time decision" is set as 10, while the weights of the other partial estimates equal 1. The result is represented in Figure 4–10.



Method	Appl	1	1	1	1	1	Estim 0,84
Numerical calculations	?	0,9	0,9	1	0,9	0,9	0,92
Expert conclusion and expert evaluations	?	1	0,8	1	0,9	0,9	0,92
Pilot research	?	0,9	0,9	0,9	0,8	0,9	0,88
Nonformalizable methods	?	1	0,5	1	1	0,9	0,88
OLAP	?	0,9	0,9	0,7	0,9	0,9	0,86
TRIZ/TIPS	?	0,9	0,9	0,7	0,9	0,9	0,86
Creative activity	?	1	0,5	1	0,8	0,9	0,84
Descriptive research	?	0,9	0,7	0,9	0,7	0,9	0,82
Multicriteria selection	?	0,7	0,9	0,8	0,8	0,9	0,82
Uncertainty analysis	?	0,8	0,9	0,9	0,7	0,7	0,80
Classification trees	?	0,9	0,8	0,9	0,7	0,7	0,80
Matrix methods	?	0,8	0,7	0,9	0,9	0,7	0,80
Decision-making, qualitative methods	?	0,8	0,8	0,6	0,9	0,9	0,80
Cluster analysis	?	0,8	0,8	0,9	0,7	0,7	0,78
Morphological analysis	?	0,8	0,8	0,8	0,8	0,7	0,78
Risk analysis	?	0,7	0,8	0,9	0,7	0,7	0,76
Monte Carlo simulation	?	0,9	0,9	0,8	0,3	0,9	0,76
Factor analysis	?	0,8	0,7	0,9	0,7	0,7	0,76
Operational research, nonoptimiz.methods	?	0,7	0,9	0,8	0,5	0,8	0,74
Pattern matching	?	0,5	0,8	0,9	0,7	0,8	0,74
Analytical calculations, models, methods	?	0,9	0,6	0,9	0,7	0,5	0,72
Cognitive analysis	?	0,6	0,7	0,5	0,9	0,9	0,72
Testing of statistical hypotheses	?	0,6	0,7	0,9	0,7	0,7	0,72
Discriminant analysis	?	0,4	0,8	0,9	0,7	0,7	0,70
Game theory	?	0,8	0,7	0,6	0,7	0,7	0,70
Neural networks	?	0,9	0,9	0,9	0	0,7	0,68
Deductive reasoning	?	0,8	0,9	0,4	0,9	0,4	0,68
Operational research, optimiz.methods	?	0,5	0,8	0,8	0,5	0,7	0,66
Repeating solutions	?	0,9	0,7	1	0	0,7	0,66
Inductive reasoning	?	0,9	0,8	0,3	0,9	0,4	0,66
Regression analysis	?	0,6	0,6	0,9	0,7	0,5	0,66
Traductive reasoning	?	0,9	0,7	0,2	0,9	0,4	0,62
Administration systems with feedback	?	0,7	0,9	0,7	0,3	0,5	0,62
Dynamic programming	?	0,4	0,8	0,6	0,4	0,7	0,58
Standards, instructions and standard decisions	?	0,7	0,9	0,7	0,1	0,5	0,58
Dynamic simulation	?	0,6	0,9	0,5	0,3	0,5	0,56
Knowledge representation	?	0,9	0,8	0,5	0,2	0,3	0,54
Causality research	?	0,7	0,6	0,2	0,6	0,5	0,52
Expert systems	?	0,8	0,9	0,1	0	0,7	0,50
Examination of psychological characteristics	?	0,4	0,5	0,5	0,5	0,5	0,48
Chaos identification	?	0,5	0,7	0,5	0,2	0,3	0,44
Decision trees	?	0,3	0,5	0,4	0,4	0,3	0,38
Cellular simulation	?	0,2	0,4	0,6	0,3	0,3	0,36

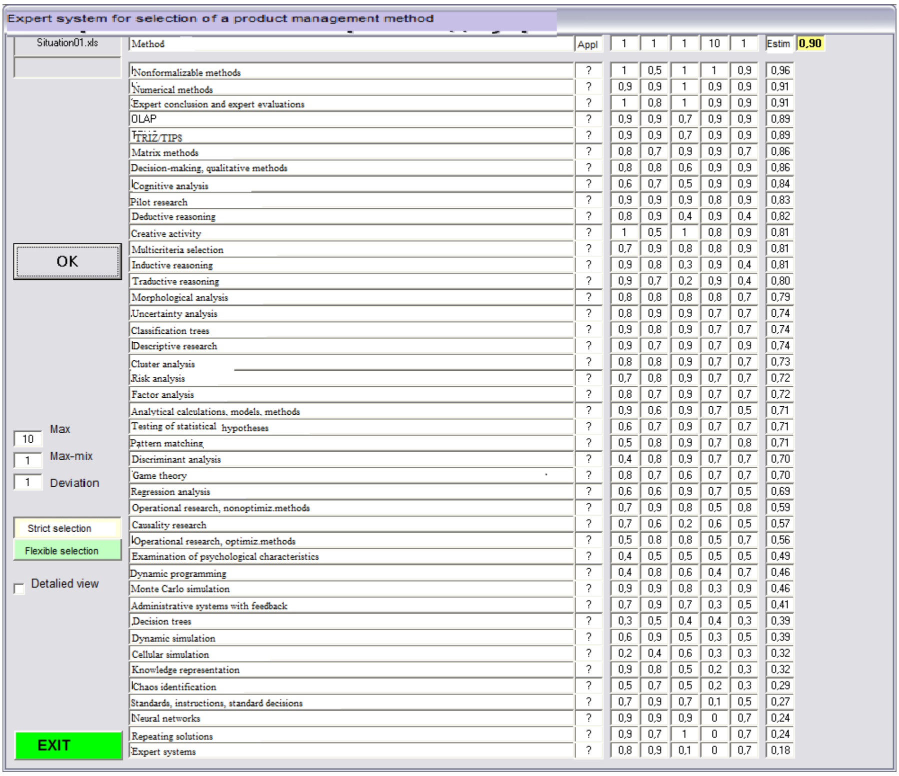
Figure 4–9 The result of the weight modification of the ranking quality partial estimates

It is evident that the utility of the decision has increased. We suggest using the following priority recommendations:

- nonformalizable methods; although they are most easy to apply for one-time tasks solution, they have a significant disadvantage, which is the low reliability of the obtained results (there is an 0.5 in the second column of the partial estimates);
- numerical calculations;
- expert conclusions (this method also has a low estimate for the result's reliability).

On the other hand, such methods as neural networks, repeating solutions and expert systems have also received low estimates. This means that they are hardly applicable for the task under consideration.

The foregoing examples were rather relative and only concerned with the decision-maker preferences. These preferences will be preserved in the following examples.



Method	Appl	1	1	1	10	1	Estim 0,90
Nonformalizable methods	?	1	0,5	1	1	0,9	0,96
Numerical methods	?	0,9	0,9	1	0,9	0,9	0,91
Expert conclusion and expert evaluations	?	1	0,8	1	0,9	0,9	0,91
OLAP	?	0,9	0,9	0,7	0,9	0,9	0,89
TRIZ/TIPS	?	0,9	0,9	0,7	0,9	0,9	0,89
Matrix methods	?	0,8	0,7	0,9	0,9	0,7	0,86
Decision-making, qualitative methods	?	0,8	0,8	0,6	0,9	0,9	0,86
Cognitive analysis	?	0,6	0,7	0,5	0,9	0,9	0,84
Pilot research	?	0,9	0,9	0,9	0,8	0,9	0,83
Deductive reasoning	?	0,8	0,9	0,4	0,9	0,4	0,82
Creative activity	?	1	0,5	1	0,8	0,9	0,81
Multicriteria selection	?	0,7	0,9	0,8	0,8	0,9	0,81
Inductive reasoning	?	0,9	0,8	0,3	0,9	0,4	0,81
Traductive reasoning	?	0,9	0,7	0,2	0,9	0,4	0,80
Morphological analysis	?	0,8	0,8	0,8	0,8	0,7	0,79
Uncertainty analysis	?	0,8	0,9	0,9	0,7	0,7	0,74
Classification trees	?	0,9	0,8	0,9	0,7	0,7	0,74
Descriptive research	?	0,9	0,7	0,9	0,7	0,9	0,74
Cluster analysis	?	0,8	0,8	0,9	0,7	0,7	0,73
Risk analysis	?	0,7	0,8	0,9	0,7	0,7	0,72
Factor analysis	?	0,8	0,7	0,9	0,7	0,7	0,72
Analytical calculations, models, methods	?	0,9	0,6	0,9	0,7	0,5	0,71
Testing of statistical hypotheses	?	0,6	0,7	0,9	0,7	0,7	0,71
Pattern matching	?	0,5	0,8	0,9	0,7	0,8	0,71
Discriminant analysis	?	0,4	0,8	0,9	0,7	0,7	0,70
Game theory	?	0,8	0,7	0,6	0,7	0,7	0,70
Regression analysis	?	0,6	0,6	0,9	0,7	0,5	0,69
Operational research, nonoptimiz.methods	?	0,7	0,9	0,8	0,5	0,8	0,59
Causality research	?	0,7	0,6	0,2	0,6	0,5	0,57
Operational research, optimiz.methods	?	0,5	0,8	0,8	0,5	0,7	0,56
Examination of psychological characteristics	?	0,4	0,5	0,5	0,5	0,5	0,49
Dynamic programming	?	0,4	0,8	0,6	0,4	0,7	0,46
Monte Carlo simulation	?	0,9	0,9	0,8	0,3	0,9	0,46
Administrative systems with feedback	?	0,7	0,9	0,7	0,3	0,5	0,41
Decision trees	?	0,3	0,5	0,4	0,4	0,3	0,39
Dynamic simulation	?	0,6	0,9	0,5	0,3	0,5	0,39
Cellular simulation	?	0,2	0,4	0,6	0,3	0,3	0,32
Knowledge representation	?	0,9	0,8	0,5	0,2	0,3	0,32
Chaos identification	?	0,5	0,7	0,5	0,2	0,3	0,29
Standards, instructions, standard decisions	?	0,7	0,9	0,7	0,1	0,5	0,27
Neural networks	?	0,9	0,9	0,9	0	0,7	0,24
Repeating solutions	?	0,9	0,7	1	0	0,7	0,24
Expert systems	?	0,8	0,9	0,1	0	0,7	0,18

Figure 4–10 The result of a one-time decision

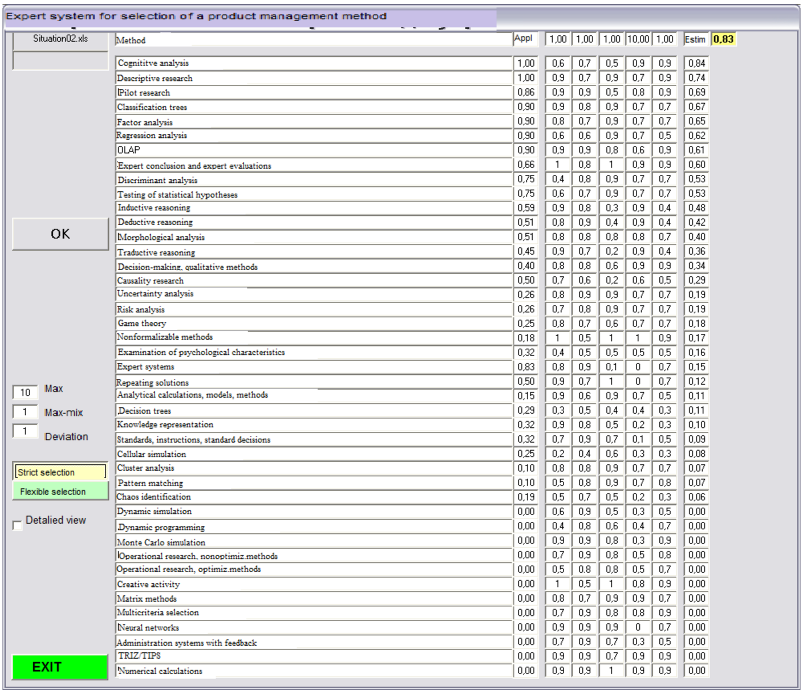
The further examples will concern an explicitation of the situation description.

4.3.4 The necessity to comprehend the situation

In this also rather relative example, only the situation parameter should be input: The stage of decision-making process = To comprehend the situation. The result is represented in Figure 4–11.

It is evident that the cognitive analysis takes the leading place, which completely corresponds to the situation.

A more detailed analysis shows that the applicability of both the cognitive analysis and the descriptive research equal 1. The partial estimates of these methods are not perfect, but the utility of a one-time decision is more important in this case. The third place belongs to the pilot research.



Method	Appl	1,00	1,00	1,00	10,00	1,00	Estim 0,83
Cognititve analysis	1,00	0,6	0,7	0,5	0,9	0,9	0,84
Descriptive research	1,00	0,9	0,7	0,9	0,7	0,9	0,74
Pilot research	0,86	0,9	0,9	0,5	0,8	0,9	0,69
Classification trees	0,90	0,9	0,8	0,9	0,7	0,7	0,67
Factor analysis	0,90	0,8	0,7	0,9	0,7	0,7	0,65
Regression analysis	0,90	0,6	0,6	0,9	0,7	0,5	0,62
OLAP	0,90	0,9	0,9	0,8	0,6	0,9	0,61
Expert conclusion and expert evaluations	0,66	1	0,8	1	0,9	0,9	0,60
Discriminant analysis	0,75	0,4	0,8	0,9	0,7	0,7	0,53
Testing of statistical hypotheses	0,75	0,6	0,7	0,9	0,7	0,7	0,53
Inductive reasoning	0,59	0,9	0,8	0,3	0,9	0,4	0,48
Deductive reasoning	0,51	0,8	0,9	0,4	0,9	0,4	0,42
Morphological analysis	0,51	0,8	0,8	0,8	0,8	0,7	0,40
Traductive reasoning	0,45	0,9	0,7	0,2	0,9	0,4	0,36
Decision-making, qualitative methods	0,40	0,8	0,8	0,6	0,9	0,9	0,34
Causality research	0,50	0,7	0,6	0,2	0,6	0,5	0,29
Uncertainty analysis	0,26	0,8	0,9	0,9	0,7	0,7	0,19
Risk analysis	0,26	0,7	0,8	0,9	0,7	0,7	0,19
Game theory	0,25	0,8	0,7	0,6	0,7	0,7	0,18
Nonformalizable methods	0,18	1	0,5	1	1	0,9	0,17
Examination of psychological characteristics	0,32	0,4	0,5	0,5	0,5	0,5	0,16
Expert systems	0,83	0,8	0,9	0,1	0	0,7	0,15
Repeating solutions	0,50	0,9	0,7	1	0	0,7	0,12
Analytical calculations, models, methods	0,15	0,9	0,6	0,9	0,7	0,5	0,11
Decision trees	0,29	0,3	0,5	0,4	0,4	0,3	0,11
Knowledge representation	0,32	0,9	0,8	0,5	0,2	0,3	0,10
Standards, instructions, standard decisions	0,32	0,7	0,9	0,7	0,1	0,5	0,09
Cellular simulation	0,25	0,2	0,4	0,6	0,3	0,3	0,08
Cluster analysis	0,10	0,8	0,8	0,9	0,7	0,7	0,07
Pattern matching	0,10	0,5	0,8	0,9	0,7	0,8	0,07
Chaos identification	0,19	0,5	0,7	0,5	0,2	0,3	0,06
Dynamic simulation	0,00	0,6	0,9	0,5	0,3	0,5	0,00
Dynamic programming	0,00	0,4	0,8	0,6	0,4	0,7	0,00
Monte Carlo simulation	0,00	0,9	0,9	0,8	0,3	0,9	0,00
Operational research, nonoptimiz.methods	0,00	0,7	0,9	0,8	0,5	0,8	0,00
Operational research, optimiz.methods	0,00	0,5	0,8	0,8	0,5	0,7	0,00
Creative activity	0,00	1	0,5	1	0,8	0,9	0,00
Matrix methods	0,00	0,8	0,7	0,9	0,9	0,7	0,00
Multicriteria selection	0,00	0,7	0,9	0,8	0,8	0,9	0,00
Neural networks	0,00	0,9	0,9	0,9	0	0,7	0,00
Administration systems with feedback	0,00	0,7	0,9	0,7	0,3	0,5	0,00
TRIZ/TIPS	0,00	0,9	0,9	0,7	0,9	0,9	0,00
Numerical calculations	0,00	0,9	0,9	1	0,9	0,9	0,00

Figure 4–11 The result for situation comprehension

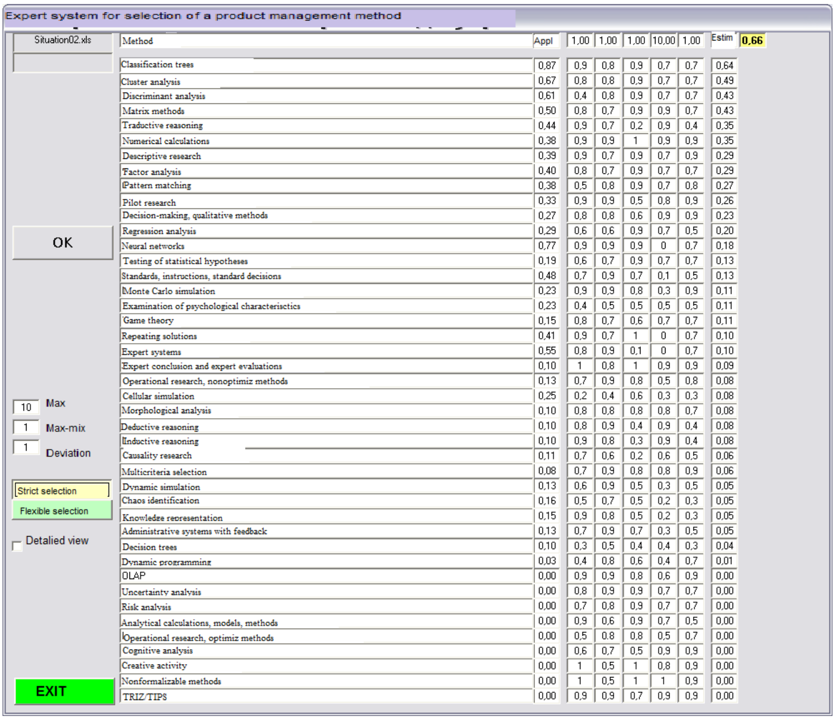
One should note that 12 methods have zero applicability, i.e. elimination has been performed. However, the general utility of the result is not high (0.83), because a method, perfectly applicable to the situation, has not been identified, which was significant for the decision-maker.

4.3.5 A posteriori segmentation

This task has been addressed in section 3.2. The only input task is a posteriori segmentation and segment pre-selection. The result is demonstrated in Figure 4–12.

In this case, classification trees, cluster analysis, and discriminant analysis, i.e., analysis methods for the groups of research elements, are the most acceptable. However, it is apparent that none of the methods is applicable with a probability of 1. The probability estimate is even further from perfect due to the complexity of the application of these methods. Thus, the recommendation for the utility in this case is rather low (0.66).

Nine methods are considered completely inapplicable.



Method	Appl	1,00	1,00	1,00	10,00	1,00	Estim 0,66
Classification trees	0,87	0,9	0,8	0,9	0,7	0,7	0,64
Cluster analysis	0,67	0,8	0,8	0,9	0,7	0,7	0,49
Discriminant analysis	0,61	0,4	0,8	0,9	0,7	0,7	0,43
Matrix methods	0,50	0,8	0,7	0,9	0,9	0,7	0,43
Traductive reasoning	0,44	0,9	0,7	0,2	0,9	0,4	0,35
Numerical calculations	0,38	0,9	0,9	1	0,9	0,9	0,35
Descriptive research	0,39	0,9	0,7	0,9	0,7	0,9	0,29
Factor analysis	0,40	0,8	0,7	0,9	0,7	0,7	0,29
Pattern matching	0,38	0,5	0,8	0,9	0,7	0,8	0,27
Pilot research	0,33	0,9	0,9	0,5	0,8	0,9	0,26
Decision-making, qualitative methods	0,27	0,8	0,8	0,6	0,9	0,9	0,23
Regression analysis	0,29	0,6	0,6	0,9	0,7	0,5	0,20
Neural networks	0,77	0,9	0,9	0,9	0	0,7	0,18
Testing of statistical hypotheses	0,19	0,6	0,7	0,9	0,7	0,7	0,13
Standards, instructions, standard decisions	0,48	0,7	0,9	0,7	0,1	0,5	0,13
Monte Carlo simulation	0,23	0,9	0,9	0,8	0,3	0,9	0,11
Examination of psychological characterisctics	0,23	0,4	0,5	0,5	0,5	0,5	0,11
Game theory	0,15	0,8	0,7	0,6	0,7	0,7	0,11
Repeating solutions	0,41	0,9	0,7	1	0	0,7	0,10
Expert systems	0,55	0,8	0,9	0,1	0	0,7	0,10
Expert conclusion and expert evaluations	0,10	1	0,8	1	0,9	0,9	0,09
Operational research, nonoptimiz methods	0,13	0,7	0,9	0,8	0,5	0,8	0,08
Cellular simulation	0,25	0,2	0,4	0,6	0,3	0,3	0,08
Morphological analysis	0,10	0,8	0,8	0,8	0,8	0,7	0,08
Deductive reasoning	0,10	0,8	0,9	0,4	0,9	0,4	0,08
Inductive reasoning	0,10	0,9	0,8	0,3	0,9	0,4	0,08
Causality research	0,11	0,7	0,6	0,2	0,6	0,5	0,06
Multicriteria selection	0,08	0,7	0,9	0,8	0,8	0,9	0,06
Dynamic simulation	0,13	0,6	0,9	0,5	0,3	0,5	0,05
Chaos identification	0,16	0,5	0,7	0,5	0,2	0,3	0,05
Knowledge representation	0,15	0,9	0,8	0,5	0,2	0,3	0,05
Administrative systems with feedback	0,13	0,7	0,9	0,7	0,3	0,5	0,05
Decision trees	0,10	0,3	0,5	0,4	0,4	0,3	0,04
Dynamic programming	0,03	0,4	0,8	0,6	0,4	0,7	0,01
OLAP	0,00	0,9	0,9	0,8	0,6	0,9	0,00
Uncertainty analysis	0,00	0,8	0,9	0,9	0,7	0,7	0,00
Risk analysis	0,00	0,7	0,8	0,9	0,7	0,7	0,00
Analytical calculations, models, methods	0,00	0,9	0,6	0,9	0,7	0,5	0,00
Operational research, optimiz methods	0,00	0,5	0,8	0,8	0,5	0,7	0,00
Cognitive analysis	0,00	0,6	0,7	0,5	0,9	0,9	0,00
Creative activity	0,00	1	0,5	1	0,8	0,9	0,00
Nonformalizable methods	0,00	1	0,5	1	1	0,9	0,00
TRIZ/TIPS	0,00	0,9	0,9	0,7	0,9	0,9	0,00

Figure 4–12 The result for a posteriori segmentation

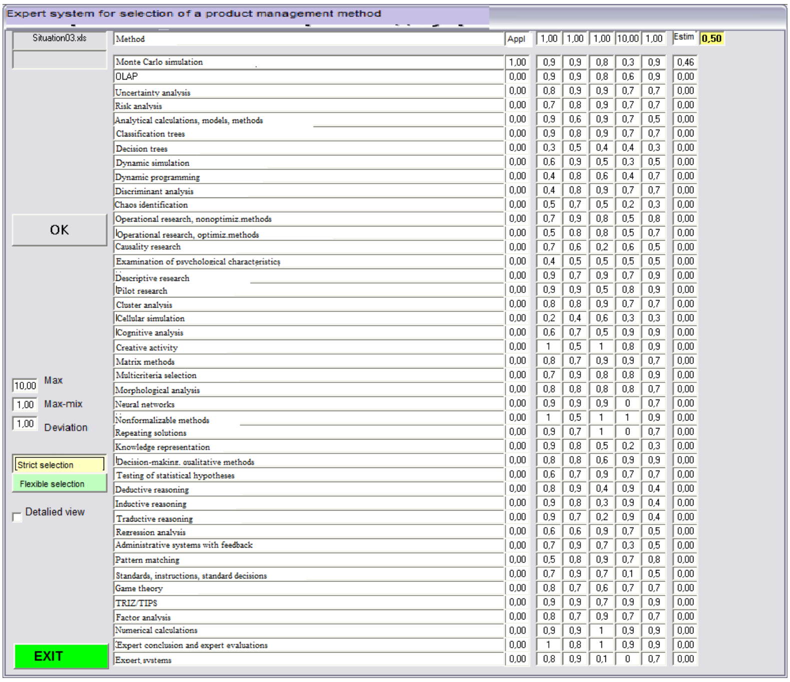
In contrast to the previous cases, there is a wide group of methods in which the applicability to this situation is rather low. The applicability already drops under 0.3 from the seventh method. This fact can be considered useful for method selection.

4.3.6 The queuing system

The system recognizes a queuing system based on the available information: Availability of homogeneous applications = Yes; High complexity of customer service process = Yes.

The result is demonstrated in Figure 4–13.

It is evident that the application of only method is possible, i.e. the Monte Carlo simulation of queuing systems. However, the utility of the selection is rather low (0.5), because the applicability estimate is low. The task under consideration is a one-time task and the application of the Monte Carlo simulation method to one-time tasks is inconvenient.



Method	Appl	1,00	1,00	1,00	10,00	1,00	Estim 0,50
Monte Carlo simulation	1,00	0,9	0,9	0,8	0,3	0,9	0,46
OLAP	0,00	0,9	0,9	0,8	0,6	0,9	0,00
Uncertainty analysis	0,00	0,8	0,9	0,9	0,7	0,7	0,00
Risk analysis	0,00	0,7	0,8	0,9	0,7	0,7	0,00
Analytical calculations, models, methods	0,00	0,9	0,6	0,9	0,7	0,5	0,00
Classification trees	0,00	0,9	0,8	0,9	0,7	0,7	0,00
Decision trees	0,00	0,3	0,5	0,4	0,4	0,3	0,00
Dynamic simulation	0,00	0,6	0,9	0,5	0,3	0,5	0,00
Dynamic programming	0,00	0,4	0,8	0,6	0,4	0,7	0,00
Discriminant analysis	0,00	0,4	0,8	0,9	0,7	0,7	0,00
Chaos identification	0,00	0,5	0,7	0,5	0,2	0,3	0,00
Operational research, nonoptimiz.methods	0,00	0,7	0,9	0,8	0,5	0,8	0,00
Operational research, optimiz.methods	0,00	0,5	0,8	0,8	0,5	0,7	0,00
Causality research	0,00	0,7	0,6	0,2	0,6	0,5	0,00
Examination of psychological characteristics	0,00	0,4	0,5	0,5	0,5	0,5	0,00
Descriptive research	0,00	0,9	0,7	0,9	0,7	0,9	0,00
Pilot research	0,00	0,9	0,9	0,5	0,8	0,9	0,00
Cluster analysis	0,00	0,8	0,8	0,9	0,7	0,7	0,00
Cellular simulation	0,00	0,2	0,4	0,6	0,3	0,3	0,00
Cognitive analysis	0,00	0,6	0,7	0,5	0,9	0,9	0,00
Creative activity	0,00	1	0,5	1	0,8	0,9	0,00
Matrix methods	0,00	0,8	0,7	0,9	0,9	0,7	0,00
Multicriteria selection	0,00	0,7	0,9	0,8	0,8	0,9	0,00
Morphological analysis	0,00	0,8	0,8	0,8	0,8	0,7	0,00
Neural networks	0,00	0,9	0,9	0,9	0	0,7	0,00
Nonformalizable methods	0,00	1	0,5	1	1	0,9	0,00
Repeating solutions	0,00	0,9	0,7	1	0	0,7	0,00
Knowledge representation	0,00	0,9	0,8	0,5	0,2	0,3	0,00
Decision-making, qualitative methods	0,00	0,8	0,8	0,6	0,9	0,9	0,00
Testing of statistical hypotheses	0,00	0,6	0,7	0,9	0,7	0,7	0,00
Deductive reasoning	0,00	0,8	0,9	0,4	0,9	0,4	0,00
Inductive reasoning	0,00	0,9	0,8	0,3	0,9	0,4	0,00
Traductive reasoning	0,00	0,9	0,7	0,2	0,9	0,4	0,00
Regression analysis	0,00	0,6	0,6	0,9	0,7	0,5	0,00
Administrative systems with feedback	0,00	0,7	0,9	0,7	0,3	0,5	0,00
Pattern matching	0,00	0,5	0,8	0,9	0,7	0,8	0,00
Standards, instructions, standard decisions	0,00	0,7	0,9	0,7	0,1	0,5	0,00
Game theory	0,00	0,8	0,7	0,6	0,7	0,7	0,00
TRIZ/TIPS	0,00	0,9	0,9	0,7	0,9	0,9	0,00
Factor analysis	0,00	0,8	0,7	0,9	0,7	0,7	0,00
Numerical calculations	0,00	0,9	0,9	1	0,9	0,9	0,00
Expert conclusion and expert evaluations	0,00	1	0,8	1	0,9	0,9	0,00
Expert systems	0,00	0,8	0,9	0,1	0	0,7	0,00

Figure 4–13 The solution for homogeneous complex applications

It is evident from the examples that the system is operable and provides useful results even under the conditions of incomplete information about a situation.

4.3.7 Conclusion

In order to sum up the research results, we briefly formulate the features of the developed fuzzy matrix expert system.

1. All the information available to the decision-maker is applied.
2. The system operates under the conditions of incomplete information (uncertainty of the decision-maker).
3. The results are ranked according to the preferentiality of both the partial criteria and the generalized estimates; the result is applied by the operator for decision-making.

4 Calculation of a ranking quality for the reasoned decision-making is performed.

5 The general estimate considers the preferences of the decision-maker, who can set the corresponding weighting coefficients.

6 Automatic adaptation is made of the initial values of the conversion matrices to a definite application of the system in consideration of those decisions actually made.

7 A complex of the auxiliary measures for advancing the method selection quality has been developed.

7.1 Calculation of the result with the use of different techniques and summarizing their results.

7.2 Control over the correctness of the elementary conversion matrix.

7.3 Utility evaluation of the elementary conversion matrices.

7.4 Utility evaluation of the set of estimates.

7.5 Utility evaluation of the obtained decision.

The following significant results have been obtained in this chapter:

8 The formulae for knowledge transformation in an expert system have been developed. The formulae consider the matrix knowledge representation, the fuzziness and incompleteness of the knowledge about a particular situation, including the initial assumptions of the decision-maker.

9 A complex of estimates as regards the quality of the expert system's operation has been suggested. It includes:

- an index of the system's quality evaluation, which is defined as a weighted sum of the partial indices and allows the priorities of the selected product policies to be considered;
- an evaluation of the matrices correctness for each matrix rule and its utility. This provides the possibility of verifying and adjusting the expertly input parameters, which, in turn, simplifies the development and debugging of the expert system.

10 A scheme and formulae for the automatic adaptation of the expert system have been suggested. They allow the system to adapt to the subjec-

tive specifics of a particular decision-maker, the qualifications of the employees, and the features and changing parameters of customers.

11 An approval of the developed approaches, methods, and algorithms has been performed as well as a demonstration of the suggested solution's operability.

5 SCIENTIFIC AND PRACTICAL RECOMMENDATIONS AND THE ECONOMIC FEASIBILITY OF PRODUCT LIFECYCLE MANAGEMENT COMPUTERIZATION

The expert system under consideration does not require a high level of qualifications for the installation, adjustment, and application.

In this chapter, the parameters of the operational version of the developed expert system will be described, and scenarios for the implementation of the tools into practice will be presented. In addition, the economic feasibility of the system introduction will be addressed.

5.1 Structure and parameters of the operational version of the expert support system for decision making in the area of product lifecycle management

An operational version of the product should have the following structure.

1 Knowledge files.

1.1 The rules file - according to the conversion mechanisms defined earlier. The initial values of the elements of the conversion matrix and the partial estimates should be specified by the example of several companies that execute product management functions.

1.2 The file of the situation drafts (a completely indefinite situation).

1.3 The files of several standard situations.

2 Reference information

2.1 Brief hints on each value that appears in each cell.

2.2 Detailed reference information for solving practical issues related to the application of a particular method. This should be analogous to the reference systems of such applications as the statistical packages. The current research is an appropriate base for such systems.

3 Functions

3.1 Input mode and mode for the manual and Windows interactive (cursors, flags, etc.) adjustments of situation parameters at any stage.

3.2 Support mode for decision-making in the area of method selection: selection of a situation from a set of the available ones; step-by-step and automatic calculations: possibility of weight adjustments for the decision parameters.

3.3 Working with the situation files (reserve storing, copying, deletion).

3.4 Printing out the obtained result – ranked by the preferentiality of the sets of methods.

3.5 The possibility to obtain information about the essence and application of each method.

3.6 Adjustment mode for the parameters of the expert system: input of the values of the conversion matrix elements with representation as a matrix; verification of the input accuracy and an indication of the empty rows and columns; calculation of the conversion matrices quality and their modifications as a result of adjustment; possibility of automatic adaptive recalculation of a conversion matrix at the command of the operator.

3.7 Modification mode for the structure of the expert system: input of the new values of variables (extension of a probability row); deletion of variables; deletion of values; modification of names and values of variables; sequence modification of variables values, consistency facilitation of dimensionalities of all matrix rules, as well as situation files under modification of the values of variables; facilitation of sequence consistency of the values of variables in all conversion matrices and all situations; input of new variables of any applicable type: logical, fuzzy-logical, textual; order modification for the rules application; deletion of conversion matrices.

3.8 Service functions: saving changes at the command of the operator; making an inquiry about saving changes in parameters; possibility to cancel the changes made (obligatory- the last one; ideally – all changes that have been made during the session).

4 Interface requirements: intuitiveness (the basis is the interface of the pilot version); application of standard Windows tools; hints and ease of switching to the reference system; shortcut menus.

5 Possible extensions – integration with software aimed at supporting the decision-making with the use of selected methods.

One of the prospective options of the software for such a system implementation is a relational database management system, because:

- it can perform fast data selection from the files. One of the disadvantages of the pilot version performed in Excel is the slow operational speed. A trial launch of an analogous system in Access demonstrated that it operates at least 20 times faster;
- it allows a data integrity control to be organized. It is required, e.g., that the number of conversion matrix inputs corresponds to the number of the values of the variables in the task description;
- it has developed means for processing the following: the formation of complex queries, crosstab queries in particular; reports with calculations, dialog forms;
- there are means for the implementation of service features;
- it has a number specialists available for system development.

5.2 Details concerning the implementation of the developed system

There are several ways that the system can have a practical application:

5.2.1 Independent introduction

The first option is the installation of an immediately operational system.

In such a case, the system's suggestions for general cases can be initially used, and later, after a certain level of competency with the program is achieved, one can perform a gradual adaptation of the system. According to preliminary evaluations, about one week is needed in order to self-study the automatized set of tools of adaptive possibilities, and about 100 solutions for a final adjustment.

This option is applicable for small and medium-sized businesses that have information system specialists as employees.

5.2.2 Third-party introduction

The second option is an introduction by a consulting company that performs system adaptations tailored to the needs of a particular company. A consultant, who is an expert systems specialist, takes part in the implementation of the system, and after becoming acquainted with the decision-making style of the company applies the methods, and adapts the system on the basis of this information. It is suggested in this case that a mechanism of automatized matrix conversion be applied.

This method is applicable to medium-sized businesses with a large number of decision-makers (more than 40?).

5.2.3 Unique introduction

The last option is the development of a system "from scratch". Only a software wrapper is used in this case, and experts input all the data.

Experts in the area of decision-making methods, identify those methods that are predominantly applied in the company, evaluate their adequacy, suggest other methods, and if necessary express their opinion to a knowledge base engineer, who then enters the data into the expert system. This option is applicable to medium-sized and large companies.

It should be noted that in this case there is a high possibility of changes in company's activities in the area of product management when this option is applied. The approximate time taken for the introduction is 6-12 months.

5.2.4 System modification

It should be noted that modification of the expert system structure is not an urgent issue. This is explained by the following facts:

- the system is well developed in respect of the stages of the product management process, applicable methods, and other variables;

- additional expert specifications for the possible values of all the variables will be conducted as a part of the development process of an operational version of the tool.

System modification may be required in the following cases:

- when developing a new method or expanding the set of product management methods applied in a company;
- in cases where the company only applies some methods in order to simplify a task (input of a smaller number of probabilities into a situation). After an automatized adaptation is performed, the non-applied methods will not be selected, and the reporting of the unused values of the variables can be disabled.
- in order to provide correspondence between decision-making styles it may be necessary to introduce new variables, as well as their new values or new rules. It is advisable that the developers perform these operations.

5.3 Development projections: integration with other applications.

It is assumed that in the long term the system under development will become the integrating element for a whole series of data acquisition and decision-making tools:

- data acquisition tools (tools for compiling questionnaires, electronic surveys, etc.)
- statistical packages;
- simulation tools, e.g., simulation of queuing systems or dynamic simulation;
- spreadsheets;
- database management systems;
- expert systems;
- neural networks;
- other decision support tools.

Detailed analysis of particular software items is beyond the scope of the current research and is also unpractical due to the frequency with which it is updated.

However, the possibility to develop an integrated module toolset for decision-support opens up. Currently, there are a number of systems that apply most of the methods that have been addressed in the current research, such as Statistica and PASW[44],. These systems also include additional modules, as well as tools developed in Russia, such as Deductor, a tool for data analysis [186].

After a system for a decision-making method selection is introduced, a situation can occur where an application of a particular method is required on a regular basis, but this method requires special software and operational specialists (e.g., frequent application of neural networks or systems of dynamic simulation). This can require not only a decision on the purchase of particular software, but also on the company's organizational structure modification.

5.4 Evaluation of the factors that determine the economic feasibility of product lifecycle management computerization

As has been noted before, there are two main groups of factors that determine the economic feasibility of the introduction of the suggested expert decision support system: factors of the increase in effect and factors of the cost reduction.

Due to the introduction of the suggested methodology, companies acquire a toolset for more precise consideration of the requirements of the different consumer segments. This tool set includes: a reasonable segmentation, a considered analysis of the needs in different segments, the generation of new product ideas or ideas of the existing products modification, concept development, control over other stages of the development that are taking place. On the one hand, it provides the development of the products with unique features such as an increased level of customer satisfaction, which leads to a reduction in the consumer's total expenses as regards product use, and in the end leads to an increase in the level of consumer loyalty level by

[44] Also known before 2009 as SPSS.

offering a wide range of competitive advantages. On the other hand, the whole process of the introduction of new products and their modification accelerates while the probability of failure decreases. As a result, a company receives a wide range of competitive advantages in product quality as well as in speed of innovation implementation. This not only insures high profits, but also improves the image of the company, which, in turn, provides additional competitive advantages.

The quality of decision making improves, because the methodology directs market specialists towards the application of all the available information and operates even in conditions of uncertainty about the values of the situation parameters.

The above-described competitive advantages are permanent because the developments are recommended to be applied on a regular basis.

Introduction of the suggested developments allows a significant decrease in the number of high-skilled jobs in the area of product management (data acquisition, analysis technique selection and analysis per se, interpretation of the analysis results and decision making on their basis). This, in turn, allows a company to hire fewer specialists in marketing and analytics and to engage fewer highly-qualified workers into product management. Obtaining decisions through computer tools decreases the labor intensiveness of the process and increases its efficiency.

Finally, it should be admitted that this methodology allows the number of applied methods to be expanded. Thus, the above-mentioned advantages can be expected to continue over a long period. Therefore, the research task has been fulfilled.

5.4.1 Conclusion

6 Scientifically substantiated scenarios for the implementation of client-oriented product management in small and middle-sized enterprises have been developed; the scenarios allow the practical application and improvement of the system.

7 A toolset that includes interrelated software, informational and methodical support has been established. The toolset makes the implementation of the developed methodology of product lifecycle management possible in small manufacturing enterprises.

CONCLUSION

The development of the toolset has reached the stage of experimental validation. The requirements for a commercial version of the product have been formulated. The potential market for the product and methods for its improvement have been identified.

The following significant results have been obtained.

1 The system of client-oriented product lifecycle management in small manufacturing enterprises has been developed, the management tasks have been specified according to the defined stages of the management process; this provides an opportunity for the application of a wide range of methods for the activity under consideration.

2 A scientifically substantiated methodological background has been presented of the formation of a complex of interactive intelligence system for all the stages of product, pricing, promotion and distribution management. This system will allow an increase in the operating effectiveness of the “manufacturer-consumer” system in small manufacturing enterprises.

3 Based on the typical features identified for the formulation and solving of tasks in the area of product management, a general scheme has been developed for decision-making during product management tasks - according to the stages of the lifecycle. This general scheme includes goal setting, a description of the marketing situation, method selection and evaluation, and a solution to the marketing task itself. This scheme is characterized by the diversity and typification of the task solution stages in the area of product management, as well as by the application of intellectual tools. These features expand the commonly applied set of methods towards the subjective specifications of the decision-maker and simplify the task solution in different areas of marketing activity and issues that occur in real situations.

4 A substantial and mathematical problem statement has been performed in the area of method selection for solving product management tasks. The essence of the statement is the determination of the correspondence between the method parameters and the suggested list of fuzzy parameters in a situation. The type of results obtained is a preferential measure of each method application. This allows the valid-

ity of decisions in the "manufacturer-consumer" system to be raised due to the maximum use of fuzzy and incomplete information about a situation.

5 A new classification of the methods for solving product management tasks has been suggested. This takes into consideration the purposes of the simulation, the types of dependencies, the type of task parameters, the method of parameter determination, the dynamics of the processes that occur in the simulating object, the discreteness of the sampling instances and the formation of control actions, and the availability of homogeneous events or actions. The new classification has become the basis for the introduction of a set of variable types that describe the parameters of the managed product and the market situation, such as logical, fuzzy-logical, and probability rows; a list of these variables has also been introduced. This newly introduced set of variables provides an adequate reflection on the situation and the maximum use of information (including incomplete information) in order to obtain reasoned decisions.

6 A system of methods and models for product lifecycle management has been developed. This includes a selection of SMAs and a prospective market segment with the use of neural networks. An evaluation of the market segment prospectivity has been obtained by the following means: a cluster analysis of customers' satisfaction with product innovations; a forecast on the speed of market penetration with the help of reservoir modelling supplemented with elements of cognitive maps; an evaluation of the sales dynamics with the help of a refinement of the knowledge about a particular market situation. These elements broaden the possibilities of product lifecycle management by using intellectual methods that can be applied in conditions of incomplete knowledge about a particular situation and the absence of a quantitative model.

7 A general structure has been obtained of the conversion of different types of data (probability rows, logical and fuzzy-logical variables, etc.) about a situation into preferential application measures for each of the product management methods applicable to a particular situation. This structure allows results to be obtained in conditions of incomplete and fuzzy knowledge about a situation, as well as taking into consideration the subjective preferences of the decision-maker.

8 Formulae for the conversion of data in an expert system have been elaborated. The formulae consider a matrix representation of rules, fuzziness, and the completeness of the information about a situation, as well as the initial presumptions of the decision-maker.

9 A system of estimating the performance of an expert system has been suggested. This includes indices of the performance evaluation, which are formed as the weighted sum of partial indices, consideration for the priorities of the selected product policies, and an evaluation of the reasonableness of the matrices for each particular matrix rule and its utility. The latter creates a possibility to verify and edit the input of parameters by experts, which simplifies the development and adjustment of the expert system.

10 A scheme and formulae for the automatic adaptation of the expert system have been suggested. These would allow the system to adapt to the subjective specifications of the decision-maker, the qualifications of employees and the changing parameters of the consumers.

The theoretical value of the current research is determined by the following factors:

- The development of a methodology for the formation of an expert decision support system in the area of product management, according to the stages of the product's lifecycle. This evolves the theoretical basis for a toolset for designing an information system for economic entities, as well as significantly contributing to the formalized representation of method development for product management processes.
- The proposal of an expanded system of models, methods, and procedures for product management according to the stages of the product's lifecycle. This proposal considers the nature of the stages and management tasks, and this can improve and supplement the toolset for situation analysis and optimal solution development.
- Principles have been formulated for the interactive conversion of fuzzy and incomplete knowledge about a problematic situation as regards the method selection of a solution for the product management task. These principles are based on artificial intelligence algorithms

and self-adaptation to real applications, which, in turn, helps to develop methods and means of knowledge accumulation.

Overall, the theoretical aspects of the current research form a major scientific breakthrough.

The practical value of the current research includes the following:

- A fuzzy matrix expert support system for decision making in the area of product management has been developed and introduced; the system raises the level of decision validity and efficiency in product management.
- Scientific and practical recommendations have been addressed on the introduction of such systems into small-sized enterprises that belong to a real sector of economic activity.
- A complex of models, methods, and procedures for product management have been applied in the study process: courses “Marketing research”, “Theoretical aspects of decision-making and decision implementation” and “Product management”, thesis projection on bachelors’ and masters’ levels.

We hope that the results of the development will be widely applied in practice.

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APPENDIX

Parameter	Values	Prob.	Num.
Product management task	Determination of the parameters of the available strategic business areas, and their significance for decision making		100
Product management task	Determination of the indices of the internal environment for analysis		200
Product management task	Evaluation of the marketing estimates of a company		300
Product management task	Evaluation of the attractiveness of the available strategic business areas		400
Product management task	Development or adjustment of the product strategy		500
Product management task	Generation of alternatives for new strategic business areas		600
Product management task	Evaluation of the alternatives for the new strategic business areas		700
Product management task	Determination of consumers' behavior models for the strategic business area		800
Product management task	A priori segmentation		900
Product management task	Evaluation of the attractiveness of the segment and the selection of a target segment		1000
Product management task	Determination of idea generation methods		1100
Product management task	/ Generation of alternatives for the new product ideas		1200
Product management task	Forecast of the development of relationships with partners		1300
Product management task	Evaluation and selection of new product ideas		1400
Product management task	Planning the research on the product		1500
Product management task	Planning the technological research task		1600
Product management task	Identification of the methods for concept generation		1700
Product management task	Generation of concept alternatives		1800
Product management task	Identification of the models of the novelty acceptance by buyers and consumers and concept evaluation according to them		1900
Product management task	Identification of the method for concept positioning		2000
Product management task	Identification of the marketing mix elements and their concepts and purposes		2100
Product management task	Development of the technical parameters of the product		2200
Product management task	Development of the technical task for the product		2300
Product management task	Development of the technical task for the technology		2400
Product management task	Scheduling of test marketing as an experiment		2500

Parameter	Values	Prob.	Num.
Product management task	Concept evaluation according to test marketing on model and controlled markets		2600
Product management task	Determination of list of product varieties according to the test marketing results on controlled and real markets		2700
Product management task	Analysis of product assortment as a whole, according to product lines and analysis of each product		2800
Product management task	A posteriori segmentation and segment preselection	1	2900
Product management task	Profiling of the selected segments		3000
Product management task	Selection of target segments		3100
Product management task	Development of alternatives of modification ideas		3200
Product management task	Development of modification concepts for each idea alternative		3300
Product management task	Forecast on relations with partners' and competitors' and their reaction for each modification alternative		3400
Product management task	Evaluation and selection of modification alternatives		3500
Product management task	Forecast on relations with partners' and competitors' and their reaction for each elimination alternative		3600
Product management task	Evaluation and selection of elimination alternatives		3700
Product management task	Determination of marketing indices for monitoring of each SMA and method of their analysis		3800
Product management task	Evaluation of the consequences of operational decisions for partners, competitors and consumers		3900
Stage of decision making process	To comprehend a situation	1.00	4000
Stage of decision making process	To build a model of the situation	0.75	4100
Stage of decision making process	To generate alternatives	0.00	4200
Stage of decision making process	To obtain evaluation of alternatives and to select the best one	0.00	4300
Stage of decision making process	To calculate a solution	0.00	4400
Stage of decision making process	To classify a situation	0.75	4500
Stage of decision making process	To comprehend a decision	0.3	4600
Objective	To learn value of variables	0.00	4700
Objective	To learn relations between variables	0.10	4800
Objective	To build model of a situation	0.3	4900
Objective	To build a system of knowledge formalization	0.00	5000

Parameter	Values	Prob.	Num.
Objective	To gather data about past decisions and their accuracy	0.3	5100
Objective	To develop alternatives	0.00	5200
Objective	To obtain quantitative evaluations of consequences of a decision	0.00	5300
Objective	To obtain qualitative evaluations of consequences of a decision	0.00	5400
Objective	To determine predictability of system behavior	0.00	5500
Objective	To obtain quantitative evaluation of a system after decision implementation	0.00	5600
Objective	To obtain qualitative evaluation of a system after decision implementation	0.00	5700
Objective	To obtain probability of occurrence of events	0.00	5800
Objective	To obtain fuzzy evaluations of alternatives	0.00	5900
Objective	To select the best decision	0.00	6000
Objective	To select admissible solutions	0.00	6100
Objective	To completely rank the available alternatives	0.00	6200
Objective	To partly rank the available alternatives	0.00	6300
Objective	To determine admissibility of an available alternative	0.00	6400
Objective	To generate the best solution	0.00	6500
Objective	To generate an admissible solution	0.00	6600
Objective	To determine class of an available situation foe decision-making	0.75	6700
Objective	To build a classifier of new situations by solutions	0.50	6800
Objective	To build an automatic control system	0.00	6900
Objective	To find a multi-step solution	0.00	7000
Objective	To eliminate current problems	0.00	7100
Objective	To reflect solution process in natural language	0.98	7200
Solution class	Selection		7300
Solution class	Classification		7400
Solution class	Generation		7500
Type of dependencies	General mathematical		7600
Type of dependencies	Magnitude and its rate of change		7700
Type of dependencies	Linear		7800
Type of dependencies	Cause-and-effect		7900
Type of dependencies	Stochastic		8000
Type of dependencies	Tabular (numerical)		8100
Type of dependencies	Algorithmic		8200
Type of dependencies	Unpredictable		8300
Type of dependencies	Indefinite		8400
Model type	Analytical	1.00	8500
Model type	Numerical	1.00	8600
Model type	Dynamic (differential and difference equations)	1.00	8700
Model type	Mathematical programming (linear, integer, convex)	0.81	8800

Parameter	Values	Prob.	Num.
Model type	Queueing system simulation	0.86	8900
Model type	Markov chains	0.44	9000
Model type	Dependencies between psychological attributes	1.00	9100
Model type	Network diagrams	1.00	9200
Model type	Schedules	1.00	9300
Model type	Decision tree	0.53	9400
Model type	Knowledge representation (semantic network or object-oriented)	1.00	9500
Model type	Statements, If-Then rules and If-Then management rules	0.99	9600
Model type	Cognitive	0.78	9700
Model type	Qualitative (including verbal description)	0.27	9800
Model type	Game	0.86	9900
Model type	Dynamic programming	0.39	10000
Model type	Cybernetic	1.00	10100
Model type	Morphological	0.39	10200
Model type	Cellular automatons	1.00	10300
Model type	None	0.77	10400
Type of parameters	Quantitative continuous	1.00	10500
Type of parameters	Quantitative discrete	1.00	10600
Type of parameters	Fuzzy	0.00	10700
Type of parameters	Scoring	1.00	10900
Type of parameters	Comparative	0.75	11000
Type of parameters	Qualitative	0.10	11100
Method of determining of parameters	Secondary data	0.00	11200
Method of determining of parameters	Measurement	1.00	11300
Method of determining of parameters	By analytical or numerical model	0.00	11400
Method of determining of parameters	By imitational model	0.00	11500
Method of determining of parameters	Standards	0.00	11700
Method of determining of parameters	Expert evaluations	0.10	11800
Availability of solution alternatives	0;1		11900
Availability of solutions for standard situations	0;1		12000
Discretion of sampling and control instants	0;1		12100
Discretion of values of control actions	0;1		12200
Availability of homogeneous applications	0;1		12300
The need for process consideration	0;1		12400
Multi-step solution	0;1		12500

Parameter	Values	Prob.	Num.
Availability of several criteria of optimality	0;1		12600
Availability of uncontrolled events with several outcomes	0;1		12700
Complexity of process of attendance on customers	0_1		12800
Availability of off-the-shelf decisions for different situations	0_1		12900
Broad number of experts	0_1		13000
High repeatability of the task	0_1		13100
Representation precision of values of parameters	0_1	0.90	13200
Method	OLAP	0.00	13300
Method	Uncertainty analysis	0.00	13400
Method	Risk analysis	0.00	13500
Method	Analytical calculations, models, methods	0.00	13600
Method	Classification trees	0.87	13700
Method	Decision trees	0.10	13800
Method	Dynamic simulation	0.13	13900
Method	Dynamic programming	0.03	14000
Method	Discriminant analysis	0.61	14100
Method	Chaos identification	0.16	14200
Method	Monte Carlo simulation	0.23	14300
Method	Operational research, nonoptimizational methods	0.13	14400
Method	Operational research, optimizational methods	0.00	14500
Method	Causality research	0.11	14600
Method	Examination of psychological characteristics	0.23	14700
Method	Descriptive research	0.39	14800
Method	Exploratory research	0.33	14900
Method	Cluster analysis	0.67	15000
Method	Cellular simulation	0.3	15100
Method	Cognitive analysis	0.00	15200
Method	Creative activity	0.00	15300
Method	Matrix methods	0.50	15400
Method	Multi-criteria selection	0.08	15500
Method	Morphological analysis	0.10	15600
Method	Neural networks	0.77	15700
Method	Nonformalizable methods	0.00	15800
Method	Repeating solutions	0.41	15900
Method	Knowledge representation	0.15	16000
Method	Decision making, qualitative methods	0.27	16100
Method	Testing of stochastic hypotheses	0.19	16200
Method	Deductive reasoning	0.10	16300
Method	Inductive reasoning	0.10	16400
Method	Traductive reasoning	0.44	16500

Parameter	Values	Prob.	Num.
Method	Regression analysis	0.29	16600
Method	Administration systems with feedback	0.13	16700
Method	Pattern matching	0.38	16800
Method	Standards, instructions and standard decisions	0.48	16900
Method	Game theory	0.15	17000
Method	TRIZ/TIPS	0.00	17100
Method	Factor analysis	0.40	17200
Method	Numerical calculations	0.38	17300
Method	Expert conclusion and expert evaluations	0.10	17400
Method	Expert systems	0.55	17500
Adequacy of admissions	0_1		17600
Result validity	0_1		17700
Convenience of introduction of the decision support system	0_1		17800
Convenience of a one-time decision	0_1		17900
Solution utility	0_1		18000
Weight of components of selection quality index	Maximal grade	10	18100
Weight of components of selection quality index	Difference between maximal and minimal grades	1	18200
Weight of components of selection quality index	Deviation from perfect selection	1	18300
Weight of partial method estimates	Adequacy of admissions	1.00	18400
Weight of partial method estimates	Result validity	1.00	18500
Weight of partial method estimates	Convenience of introduction of the decision support system	1.00	18600
Weight of partial method estimates	Convenience of one-time solution	10.00	18700
Weight of partial method estimates	Solution utility	1.00	18800
Adjustments	Detailed demonstration mode	0	18900
Adjustments	Soft selection	0	19000

ISBN 978-951-765-834-8