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Ladies and Gentlemen,

Foundation of Management (FoM) journal was established at the Faculty of Management at Warsaw University of Technology in order to provide an international platform of thought and scientific concepts exchange in the field of managerial sciences.

This new publishing forum aims at the construction of synergic relations between the two parallel trends in managerial sciences: social and economical – originating from economic universities and academies and the engineering trend – originating in from factories and technical universities.

Three of the great representatives of the engineering trend in managerial sciences - American Frederic W. Taylor (1856-1915) – developer of high speed steel technology and the founder of the technical with physiological trend in scientific management, Frenchman Henri Fayol (1841-1925), the author of basics of management and the division and concentration of work as well as the Pole Karol Adamiecki (1866-1933) graduate of the Saint Petersburg Polytechnic University and the professor of Warsaw University of Technology, creator of the time-scale system elements scheduling theory and diagrammatic method as well as the basics of the division of work and specialization – have, on the break of the XIX and XX century, all created the universal foundations of the management sciences. Therefore the title of the Foundation of Management is the origin of the scientific and educational message of the journal that is aimed at young scientists and practitioners – graduates of technical and economic universities working in different parts of Europe and World.

The target of the establishers of the Foundation of Management journal is that it will gradually increase its influence over the subjects directly linked with the issues of manufacturing and servicing enterprises. Preferred topics concern mainly: organizational issues, informational and technological innovations, production development, financial, economical and quality issues, safety, knowledge and working environment – both in the internal understanding of the enterprise as well as its business environment.

Dear Readers, Authors and Friends of the Foundation of Management – our wish is the interdisciplinary perception and interpretation of economic phenomena that accompany the managers and enterprises in their daily work, in order to make them more efficient, safe and economic for suppliers and receivers of the products and services in the global world of technological innovation, domination of knowledge, changes of the value of money and constant market game between demand and supply, future and past.

We would like for the Foundation of Management to promote innovative scientific thought in the classical approach towards economic and engineering vision of the managerial sciences.

The Guardian of the journal's mission is its Programme Committee, which participants of which will adapt to current trends and as an answer to the changing economic and social challenges in the integrating Europe and World.

Tadeusz Krupa

CONTENTS

NEURAL NETWORKS USAGE IN THE EVALUATION OF EUROPEAN UNION COFINANCED PROJECTS

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Abstract: Research concerns the implementation of modern computing technologies in the evaluation of projects cofinanced by the European Union. Crucial element of this research is the enrichment of currently used evaluation methods with modern mechanisms basing on artificial intelligence. The article deals with the possibility analysis of neural networks usage in such applications.

Key words: evaluation of European projects, modern computing technologies, neural networks.

1 Introduction

Scientific research on modern, bread and crucial issues useful in expansion of the management theory and enrichment of management practice were firstly realized in the Institute for Organization of Production Systems. Currently the research is continued in the Faculty of Management at the Warsaw University of Technology. The author of the article, basing on past experience and research in the process of formulation of new paradigms of management theory, points out the issue (not very popular nowadays) of management and assessment of projects cofinanced by the European Union (EU project evaluation).

Project management (also known as enterprise management) is currently a subject to intensive research worldwide (especially in Anglo-Saxon countries). In Poland this discipline is relatively less researched. European Project is a new concept, which stands for a management of a project of particular type. It fulfills all systematic disciplines determined by the theory of management. Additionally it fulfills the requirements determined by the European Commission. These disciplines are connected with the possibility to gain cofinancing of the project by the European Union. The author has a considerable experience with methods and systems of evaluation of European problems.

First experience with projects cofinanced by the EU was gathered in Poland during 2004-2006. Apart from problems connected with the lack of experts who could evaluate applications, there were no proper IT tools present that would aid the management of the union funds. Difficulties with implementation of IT System for Monitoring and Finance Control of Structural Funds and Cohesion Fund were also one of major issues. There are no effective tools which would support the decision making for the implementation and mediating experts. This is the reason for relatively low effectiveness of the cofinancing projects application evaluation process. In current financial perspective, considerably larger amount of financial resources was dedicated to Poland that in the previous programming period. Lack of proper tools supporting the project evaluation process can lead to the loss of union funds.

Therefore the issue of European project evaluation is extremely important and still up-to-date. Moreover it was not properly researched even in countries with considerable traditions and experience in EU funds management. Research difficulties are connected with the fact that methodology and terminology in the scope of European project are far from completion and coherency. In Polish theory of management there was no research of possibility of using computing technologies (including neural networks) for the evaluation of European projects.

The genesis of the research originates from the necessity and possibility to undertake interdisciplinary methodological research on European projects evaluation. Author provides proof for the usefulness of new computing technologies that can be supplementary for currently used project evaluation methods. These technologies can be based on the system with neural networks.

2 European project evaluation process

Evaluation (also known as assessment) has many definitions. Therefore the evaluation of project realization can be determined according to different points of view of different criteria and applications etc. One of the classic definitions claims that evaluation is “activity acknowledged as efficient or inefficient in the universal of synthetic meaning" [11]. According to the author of the definitions "in general meaning efficiency is every factor of a job well done, which means that efficiency is effectiveness, economy etc.". On the other hand the synthetic sense is expressed in the generalization and research of many virtues of a job well done.

With the participation of Poland in the European Union all research dealing with the European project evaluation gain meaning in successive years. However, research advancement level should not be compared with other countries, which have been members of the EU for many years.

During 1991-1999 the MEANS (Methods of Evaluating Structural Policies) program was realized under the direction of Committee of Independent Experts and supported by European Commission. Teams of theorists and practitioners elaborated evaluation systems that, with minor modifications, are still in use. Six volume paper edition and updated Internet version are the main source of information about methodological guidelines of European Commission in the scope of evaluation of European and other projects [6]. The author (to certain extent) includes these guidelines in his research, focusing on proposition of new methods for evaluation that are supplementary for currently used methods.

The following definition of evaluation is most common in the publications of European Commission. Evaluation of a policy, program or project is a judgment on its value including previously taken assumptions and criteria based on gathered and analyzed information [9].

Evaluation of EU cofinanced projects is a process consisting of few distinguishable stages [6]:

- structuring of the project evaluation process,
- data gathering,
- data analysis,
- summary of the research and formulation of project evaluation,
- editing of the evaluation process report,
- use of evaluation process results.

The results of performed process structuring are certain assumptions and aims of the evaluation process of a given project. The following stage of data gathering assures specification of the subjective and objective scope of the research as well as gathering data about evaluated project. Aim of next evaluation process stage is the assessment analysis of data stored during data gathering stage. Results of this stage should allow the realization of one of the final evaluation stages – evaluation formulation. In other words: giving judgment based on gathered analysis results. Number of methods can be associated with every stage:

- structuring of the project evaluation process method,
- data gathering method,
- data analysis method,
- formulation of project evaluation supporting method.

These methods were described and characterized e.g. in monograph [5]. The article focuses on the presentation of issues concerning the use of neural networks in the data analysis stage of the European projects evaluation process.

Literature dealing with evaluation of European projects (e.g. [10]) lists, among others, the following methods:

- general evaluation method:
  - GIS (Geographical Information Systems),
  - Shift-Share,
  - Macro-economic model,
- detailed (deepened) evaluation method:
  - Comparison groups,
  - Regression analysis.

The following section of the article focuses on the possibility of using neural networks in regression analysis.

3 Regression analysis in the process of European projects evaluation

Primary and secondary data gained in the data gathering phase can be subjected to different statistical analysis, also used many other data analysis methods. There are many software tools supporting the analysis process (Statistica from Statsoft, www.statsoft.pl).

Also the commonly known Excel spreadsheet (among other functions) allows using different statistical methods e.g. linear and non-linear regression models. Possible uses of this popular program for statistical calculations and forecasting are described in many publications.

Descriptive statistics can be used to perform the analysis of gathered data (connected with the realization of the project). It is used to show relations between variables. Especially the regression equations are used to research and describe the relations between variables. Regression function is an analytical way of assigning of the explained variable value (dependent) to particular values of explanatory variables (independent).

When solving the regression problem one should aim at determining a formal description method (regression model) of real relations present due to the realization of the project. Created regression model should represent those real relations. Regression equation is a basic element of the created model, which includes:

- input variables (independent, explanatory) – of qualitative or quantitative character,
- output variables (dependent, explained) – usually of quantitative character (in most cases there is one quantitative variable).

Root-cause analysis is another one of the significant concepts. It is used to study the relations between the cause and effect. In case of using such analysis to evaluate the EU projects, it is necessary to assess:

- cause in the form of implementation of a particular project,
- real effects, which could have appeared as a result of the implementation.

Root-cause analysis can be of two kinds:

- inductive – research of real causes of particular effects (these causes can result from the realization of the project or be totally independent),
- deductive – qualitative and quantitative validation of the hypothesis (based on gathered empirical data), which assumes direct influence of project implementation on the appearance of positive effects.

Regression analysis is one of the deductive methods to research the causes. It is used to answer the following question: did the realization of European project contribute to positive effects in the region? Two kinds of factors are explanatory variables in this case:

- connected with the realized European project,
- other factors, not connected directly with the implemented project.

Factors mentioned above can be described with variables: nominal (step) and continuous variable. Relations between the variables can be linear or non-linear. Regression analysis is basing on a logical model of an event and many empirical observations.

The concept of regression is connected with econometric model, which can e.g. be used to perform the summary evaluation of structural funds and cohesion fund influence on Polish economy [12]. Econometric models can be used to evaluate the effects of a complex project in minor scale e.g. in certain region.

Econometric models have three of the following forms:

- Time series models

Seldom used with relation to the project effects evaluation due to the considerable amount of data necessary to perform such analysis. In practice they are currently possible to be used e.g. in case of pre-accession funds (longer period of functioning in Poland than the structural funds) where variables stand for quarterly funds or monthly observations. There are many, relatively easy to operate, software programs suitable for analysis, smoothing, extrapolation and forecasting of time scales. In simple cases one can use a spreadsheet (e.g. Excel) or some other software available in the market e.g. [7].

- Multi-equation econometric models

Used to perform the regional, national and international economical systems functioning simulations. They can be used as an evaluation tool for program (many projects) influence on social and economical situation of a region, country etc. Such complex models will not be presented in this article due to its seldom use in the EU cofinanced project evaluation.

- Single-equation regression model (single-equation econometrics model).

They are used in quantitative analysis of the relations between the Y dependent variable and the X_1, X_2, ... X_n independent variables.

Macro-economic models are one of the most complex evaluation methods, because they need to take into account a great number of factors, which need to be identified and relations between these factors have to be established. Estimation of effects resulting from the cofinancing e.g. with the use of structural funds can be achieved through a comparison analysis of two models. One of the models describes region or economy of the whole country before the cofinancing, second one relates to the case when researched area was replenished with European funds. Usually as a result of financing particular investments is realized, which influence the situation in EU member countries and their regions.

Macro-economic models will not be described because of set object of research. Such models are usually used e.g. for the evaluation of structural funds effects or the operational programs on national or regional level. Seldom are they used in the analysis of a single project, because such econometrical models are a very complicated analysis tool. Elaboration of such models is much more costly than the other analysis methods. On the other hand use of ready econometrical models is convenient, quick, precise and usually guarantees solid data analysis results. However, their usefulness in most projects is relatively low.

In case of ex-ante analysis, during the construction of the model, experience, gained in the creation of single-dimensional econometrical models designated for ex-post evaluation for similar projects, can be very useful. They allow a simpler and faster finding of statistically significant and non-correlated independent variables. Preparation of a model for ex-post evaluation is, in general, easier. Estimation of a preliminary model can be relatively easily performed on the basis of gathered data, which relates to the realization period of a researched project. Regression analysis (especially the research of statistical significance of model elements and partial regression factor) allows determining the degree of influence of project's realization on the explained variable.

It is also possible to perform a relatively precise evaluation of the degree of the influence. In this case the regression analysis is much more precise method than other, previously mentioned, methods (displacement analysis and comparison groups).

The ex-post evaluation with the use of regression analysis is usually performed few years after the completion of the project, due to the significance of long-term effects of the project. Resources used in the realization of the project, expected and unexpected effects and the general efficiency of the project is analyzed. Previously created econometric regression model can be used in the analysis (see Figure 1).

Typical problem that is solved with the regression equations is the analysis leading to determination of the percentage of positive results, reached with the evaluated project (see Figure 2). Such analysis (different than in other data analysis methods) enables to reach relatively precise results. For example Shift-Share displacement analysis allows only gaining an approximate orientation in the level of implemented project's influence on the situation in the region. Let alone the use of regression equations allows a proper verification of the estimated project results.

Next chapter of the article describes the rules of using neural networks for the constriction of regression models that are useful in the data analysis necessary in project evaluation.

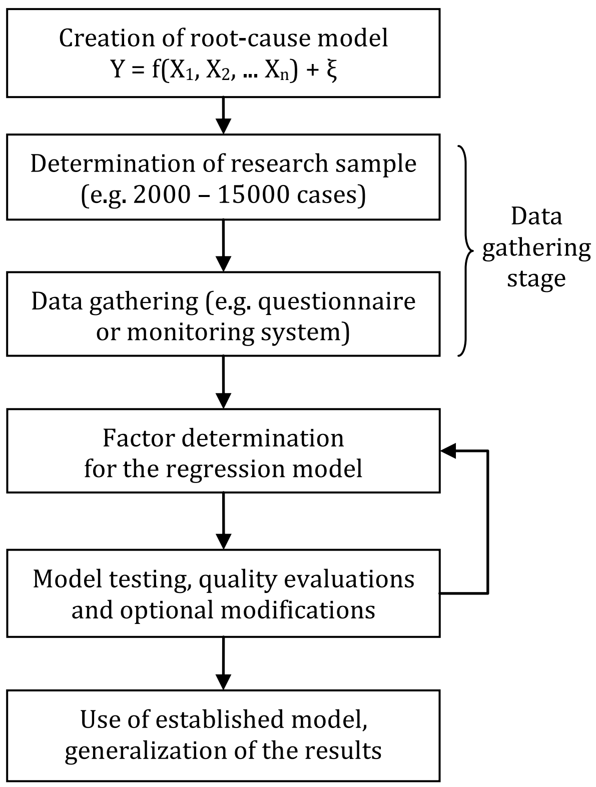


Figure 1. Creation and application of econometric regression model *(source: self study on the basis of [10])*

4 Use of neural networks for the constriction of regression models

Artificial intelligence instruments can be of great value in the project data analysis process [2, 4]. Artificial intelligence is a new branch of IT science, which deals with both the search of new possibilities of computer usage and new methods of programming and new methods of computer problem solving [14].

In the classical set theory there are only two possible variants: given element can be either the part of the set or not. However, in many sciences and techniques such approach is not sufficient. It does not give a full description of a researched event or phenomenon. Many medical, economical, political and other concepts (connected with project realization) have the, so called, non-acute character. They are described with common language, which usually does not allow precise definition of corresponding numeric values.

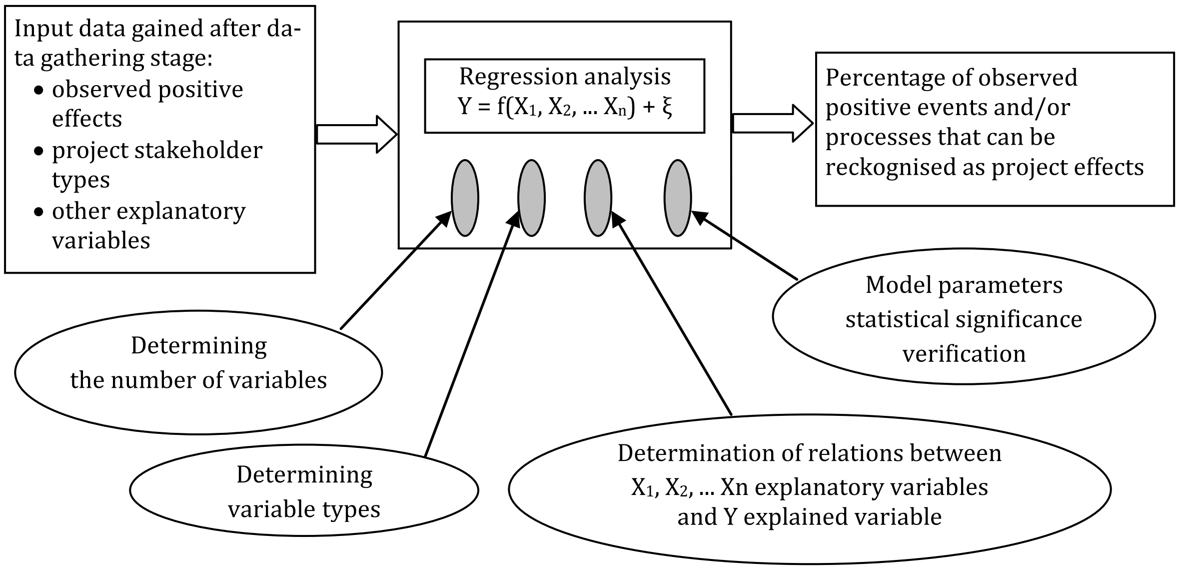


Figure 2. Example of regression model application
(source: self study on the basis of [10])

In such cases it is possible to determine the boundary area the scope that can, but does not have to, include elements significant for the realization of project evaluation process. Finding proper tools to analyze non-acute concepts allows the elaboration of decision making algorithms in uncertain conditions.

Concluding in uncertain conditions takes place when gathered data concerning a problem, which needs to be solved, is incomplete, e.g. processed data is not completely defined or is measured with set error margin. Artificial intelligence (or computational intelligence) methods are specially designed for such purposes.

One of the subclasses of artificial intelligence is the artificial neural networks. Their functioning is based on neural network learning process or the supervised learning process, which results in construction of event models, with the use of random algorithms.

Neural networks are the mathematical models, created in biological sciences, used for the projection of living organisms' nervous systems functioning. Research in this area of science has a long history. Firstly, it was used to solve problems from the area of technical sciences. Gradually neural networks started to be used in management sciences (e.g. to forecast social and economical events [3, 8]).

Neural networks, as a modeling instrument for complex social and economical processes, can support the decision making processes in the evaluation of projects. It enables the generalization of gathered data and approximation of any relationships. Neural networks are showing the knowledge in the process of learning through numerous trials. They allow to automatically creating the model, which projects the complex relations between the input variables (independent) and the output variable – dependent (see Figure 3). Creation of such model is based (generally) on selection of the neural network, determination of its structure as well as selection of the network parameters in the learning process by the evaluator.

Neural networks have many different uses, one of which is the data analysis. In further deliberations the topic of basic rules for neural networks usage in research of economical events useful in evaluation of European projects, will be presented. Neural networks are especially useful in case of considerable diversity and low precision level of input data. It is not necessary to establish a primary model selection. Network itself chooses the model what is the result of the nature of neural networks. Neural network tolerates large, unsorted data collections. It has a higher number of freedom degrees than the classical static models.

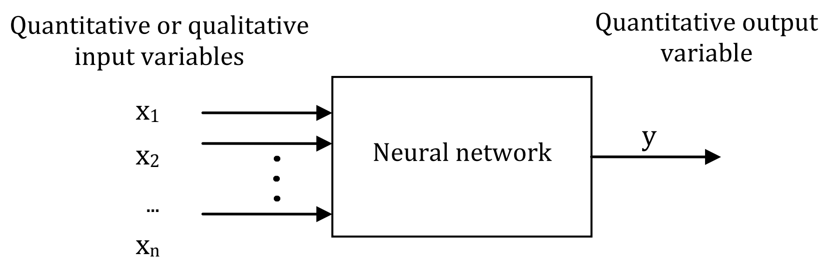


Figure 3. Use of neural regression model for representation of relations between input (explanatory) variables and the output (explained) variable
(source: self study)

Usefulness of neural models is determined by their significant features. Using the relations that are present in neural networks does not require formulation of assumptions, which are difficult to validate. They characterize with the ability to approximate any non-linear relations. They enable the generalization of learning results of training data into new data. Creation of neural model is based on the analysis of available historical data. This way the main relations of the researched event are estimated in the descriptive model. Such models are most useful in case when the evaluator does not know the rules characterizing the creation of analyzed relations. They are especially useful in description of changing, complex social and economical events.

Use of neural networks requires a proper preparation of considerable amount of historical data, according to the character of variables and the used type of network. It is connected with relatively large financial resources necessary for the determination of the neural network. It is usually assumed that the number of learning samples should be 10 to 20 times greater than the number of weights in the network [1]. There is no empirical evidence on a direct and unambiguous relationship between the number of samples from the learning set and the precision of the results. However, in extreme cases of little data (similar to the number of weights), network is not able to generate correct results.

Mathematical model is the projection of a fragment of social and economical events characteristics and their linear and non-linear relations. It modifies its parameters according to the information coming from the environment. It consists of many interrelated processing elements – the neurons. Each of the neurons can be a multivariable function, which computes one output value, based on many input values. Input network information is introduced into the entrances of successive neurons. This process lasts until the signal processed by the network reaches the output layer or when the process finishing criterion is met.

The following networks types are the most common:

- unidirectional, when neurons are placed in layers – one can distinguish the input, tacit and output layer through which the signal is transferred (starting through input, next through tacit and finishing at output layer),
- recurrent, when neurons placed in layers, as mentioned above, transfer signals two ways, due to feedbacks,
- cellular, when neurons are not grouped into layers and transfer information only to neighboring neurons.

Deliberations, in this point of the article, are limited to the methods connected with the possibility the primary type of neural networks in the data analysis – unidirectional networks. Research using four types of neural networks will be presented, in the following part of the article.

Effective functioning of neural networks is dependent on the proper value of its parameters. Successive determination of these parameters, with the method of successive approximation, is the learning process of the neural network. This process is based in the use of gathered information, which is the learning set. One can distinguish the basic iterative stages of network learning process:

- stimulation of the network with signals coming from the environment,
- stimulation effect, expressed through the changing parameters of the network,
- transformation of network relations into information, coming from the environment, which results in network parameters' value changes.

Effectiveness of neural networks in the data analysis process is expressed through the possibility of description and analysis of any relations and their generalization. Neural network can provide an answer, based on input information processing, to the formulated problem, due to this fact. Therefore, regularities originating from a particular reality – the environment of the researched project – are in the disposal. The functioning of the model is based on an assumption that gathered information (research sample) is the typical representatives of the whole population of data. Desirable feature of the neural network functioning model is the ability of proper formulation of answers for input values, which are not a part of current data collection. Usefulness of unidirectional neural networks in the process of European project evaluation results from a fact that social and economical events are of non-linear character. These networks are able to approximate any non-linear relations and to their generalization. They have an adaptive character and can support the description of relations that change with time. That is why, in the existence of new information, process of further learning of the network takes place. Sometimes it can have the character of a small correction, which includes the transformations of the real system. Especially the unidirectional neural networks can be useful to evaluate the effects of the project.

For example, they can be used to solve a regressive issue, which relies upon the determination of the percentage of positive effects, which can be included in the results of the evaluated project effects. It is usually solved with the use of classical regression equations.

5 Neural model's research

The aim of the research is to determine the possibility to use neural networks in the process of European project evaluation. Neural models can be a significant supplement for other data analysis methods hitherto used in project evaluation process.

Any neural network, which accepts the real value vectors as input and creates signals with real values at output, can be used in the process of regressive data analysis, after the data gathering stage.

The research includes the following network types:

- linear – equivalent of the linear regression function,
- unidirectional three-layer – perceptrons MLP (Multilayer Perceptron),
- RBF (Radial Basis Function),
- GRNN (Generalized Regression Neural Networks).

The simplest neural network has only one output and one or more inputs. Regardless of the type of network, the number of input and output neurons is the same for given conditions. Usually the output layer consists of one neuron (which corresponds to the explained variable). Number of neurons in the input layer depends on the set number of explanatory variables (input). Doubts connected with the selection of the architecture apply only to tacit layers of the network (e.g. the number of layers and neurons present in these layers).

It is not necessary to determine the network architecture for linear networks, because there is no tacit knowledge in them. RBF and GRNN networks have strictly determined number of layers. RBF has always three layers and GRNN respectively four layers. Perceptrons can practically be built of any number of layers. Usually they consist of three layers.

Regressive model built with the use of selected network type, which has a particular architecture, should be subjected to a learning process. Regressive statistics can be used to evaluate taught network models. Only the taught model with positive evaluation can be later used in the data analysis for the evaluation of European projects.

Empirical data collection (result of data gathering stage) used for data analysis should be divided (e.g. through drawing of lots) into three of the following sub-sets:

- Learning

Statistical measures determined for the subset allow evaluating the ability of the set to approximate. Network functioning indicators, for the learning subset, determine the ability of the network to properly recall of input data and suitable output variable, which are both presented during the learning process. However, too high ability to approximate is not negative. It leads to, so called, "over-learning" of the network. Over-learned network does not generalize knowledge, but instead tries to adjust everything to prior data. The essence of the problem is the proper preparation of the regression model, which will aid the data analysis in the evaluation process for different projects (not only the projects presented during the learning stage). The negative over-learning of the network (too high approximation ability) can be reduced with the determination of statistical measures for the next validation subset.

- Validating

Statistical indicators counted for this subset allow monitoring the learning process of the network. They support the search of proper moment to break the learning process. Increase of error number of the validating subset usually means the decrease of the ability of the network to generalize (the probability of over-learning increases).

- Testing

Statistical measures for this subset assure the finishing research which validates the practical usefulness for given neural model (or the lack of it). It is tested in order to check the reactions of the taught and validated network reacts on input data that is different than the one presented in the beginning of the learning process.

Therefore, the comparison of statistical measures for particular sets allows evaluating the quality of elaborated neural regression model. Network is taught with the data from the learning set. This learning process is broken due to the simultaneous process of network validation. Evaluation of network's ability to generalize knowledge, with the use of testing data, is performed in the end of the learning process.

Measures that determine the quality of neural regression model are determined for three subsets according to presented rules. For example, in Statistica, software designated for statistical analysis with the use neural networks, the following parameters are designated to evaluate the taught models (regression statistics) [13]:

- Data Mean – determined on the basis of real values of dependent variable (output, explained) – used in evaluation of European project,
- Standard Deviation of Data - Data S.D., calculated for real values of dependent variable,
- Error Mean – average value of the result of subtraction of two values of explained variable: real and calculated,
- Error S.D. – standard deviation of errors – for the explained variable,
- Abs. E. Mean - average absolute error – arithmetic mean determined for the absolute value of subtractions of: real values of explained variable and its values at the output of the model,
- S.D. Ratio: data standard deviation ratio – standard deviation of errors and standard deviation of real data (both parameters determined above),
- Correlation: the standard Pearson-R correlation – determined between real and output values of the model (dependent variable).

The highest significance in the evaluation of neural models' quality has: the quotient of standard deviations and real and output values correlation. The first one (non-negative) parameter for created models should have the values of 0,1 ... 0,2. The smaller its value is the better. The number of deviations close to zero determined the good quality of the model. If it is higher than one (or close to it), designed model can be rejected (standard deviation of the errors is comparable to the standard deviation of real data).

It is difficult to estimate in case of deviation's quotient in the range of: 0,3 ... 0,7. Finally the quality of the model depends on whether the results reached with it are acceptable in particular case. Correlation of real and output values in the model takes values from the 0 to 1 range. It is better when the value is close to one (the closer the better).

Example of a regression problem, which can be attempted to solve with the use of neural regression model, is the relations study of input variables characterizing positive effects (observed during data gathering) after the end of realization of Sectoral Operational Programme: Improvement of the competitiveness of enterprises.

Essence of the presented example is the demonstration of possibilities of neural regression model. Previously mentioned Statistica Neural Networks software was selected for the usefulness analysis of data in European project evaluation process.

Selected project deals with capital investments in enterprise's fixed assets, equipment, new technologies and training. Relatively technologically similar enterprises (or groups of enterprises) were subjected to the research, located in a distinguished local or regional market. Analyzed enterprise collective consisted of 100 cases. Explained variable was determined as: median of number of new workplaces in the first year after the finishing of the project.

Dependent variable was set as the median of number of new workplaces, because this parameter is actually an average (median is usually called the middle value or second fractal).

Median is the most resistant to outstanding elements, Contrary to other types of mean (e.g. arithmetic, geometric, winsdor etc.). In most cases this feature, which is a considerable immunity to disturbances, is said to be an advantage. However, in some cases, the lack of influence on its value can cause major errors, even for large and extreme observations. In analyzed case study, the lack of influence on the final result of extraordinary (outstanding) data can be treated as an advantage.

In the analyzed case, six exemplary independent variables, connected with the realization of the project, were distinguished:

- number of employees, who have finished trainings (cofinanced by the project) that increase their professional competences,
- number of new introduced technologies,
- number of employees with secondary and higher education,
- percentage of project participants who evaluate the project positively,
- increase of enterprise income in given sector (percentage),
- number of new products launched into market.

Works on neural regression model were started with the research of the usefulness of linear network. In general, if it is possible to describe the relations with the six, above mentioned, independent variables and one dependent variable with the simplest linear regression function, it is not necessary to search fore more complex models. However the lack of possibility to gain proper description of these relations between variables with linear network indicates that they have a non-linear character. 6-1 architecture linear network experiment results (six neurons in the input layer and one in the output layer) can be treated as a reference point for further research with other types of networks useful to solving regression issues.

Statictica Neural Network software can determine regression statistics, which allow evaluating the linear regression model describing relations between six explanatory variables and one explained variable, when this tool is used to model neural networks.

One can deduct, basing on the reached statistical measures values results, for example that the relation is of non-linear character. What especially indicates that fact is e.g. high value of standard deviation quotient (higher than 0,5 – 0,6) and relatively low correlation value (lower than 0,7 – 0,8). In such case it is necessary to start the creation of non-linear models, which base e.g. on RBF and GRNN perceptrons.

Relatively low value of standard deviations quotient (of 0,2 - 0,3) and proper correlation value (higher than 0,8) also should not discourage to further experiments for the linear model. One should check the parameter values for non-linear networks.

The following research programme, connected with the construction of neural models, was realized (see Figure 4):

- network selection (one of the three mentioned above),
- determination of model's architecture (number of tacit layers and neurons in these layers),
- performing of the learning, validation and network testing processes,
- evaluation of reached regression model and decision making about the finishing of the search or another beginning from the network selection stage and its architecture,
- use of built model for the regression analysis.

Number of neurons in the input layers of all networks that can be used in this analysis equals six. It is equal to the number of explanatory variables. Output layer consists of one neuron (corresponding to the explained variable). Issues connected with the network structure selections concern only the tacit layers of the network. RBF has always three layers and GRNN respectively four layers. Perceptrons are usually built of three layers.

Network type and structure can be selected intuitively after gaining of some experience in this matter (using the experience from previously realized projects). However this method can lead to creation of models with insufficient number of layers and neurons, with unsatisfactory approximation abilities. On the other hand using networks with too high number of neurons can cause the network to have limited ability to generalize the knowledge gathered in the learning process.

It is possible to use the automatic tools for automatic network parameters searching in order to avoid the listed problems with the network type and structure selection. For example, the Statistica Neural Networks software enables the option of automated network set browsing with different types and structures (so called Intelligent Problem Solver). This option is especially useful in the construction of the regression model later used in data analysis for project evaluation processes.

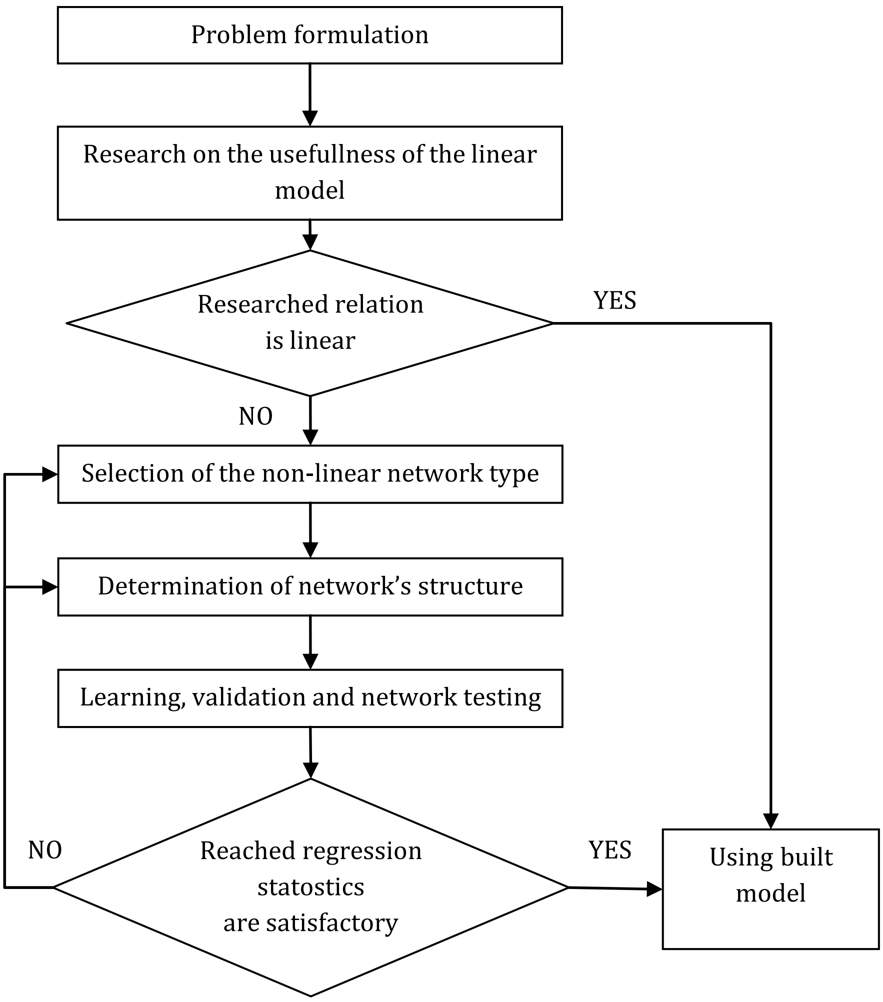


Figure 4. Construction of neural regression model
(source: self study)

Intelligent Problem Solver gives numerous solutions without the necessity for long-term and time-consuming research that require an number of decisions, such as network type and architecture selection, input and other variables selection. Process of construction of separate neural models is tiresome, time-consuming and requires considerable experience from the person performing the experiment. Relatively easy finding of a proper solution, in comparison with the linear statistical approach, is not possible. Successive experiments (with other types and neural architectures) not always lead to the revealing of new, better results.

Mentioned tool is definitely helpful in the network architecture selection process realization. Often it provides better results in comparison with the results reached by the network designers, which only use their intuition.

6 Experiment results

Researched possibilities of using the neural networks in European project evaluation process were realized during the solving of ex-post project realization in the Sectoral Operational Programme: Improvement of the competitiveness of enterprises (six input variables and one output variable). It is a regression problem, because the output variable usually takes continuous numerical values. The assumption is to use linear and non-linear regression techniques. It is not necessary to search for the functional form of regression curve. It is one of the basic advantages of neural networks. They can be treated as “black boxes” with six inputs and one output. Result form is decided by the number of neurons and connections between them. This number should correspond to the complexity of non-linear regression curve. The higher the number is, the more complicated form the curve has.

Figure 5 presents three windows form Statistica NN 6.0 software: spreadsheet window (with data), interface of Statistica NN (with indicated problem type – regression) and the active window of variable selection (with one output variable highlighted – dependent and six input variables - independent).

After the determination of variables the network types were selected, which would later be taken into consideration in the regression model construction process. Author decided to use the linear, GRNN, RBF and three-layer perceptron networks. Others regression analysis parameters were as follows:

- number of maintained networks: five,
- network maintenance selection criteria: "maintain the balance between the error and diversity of the network",
- time of optimization – number of tested networks: 10,
- maximal number of tacit neurons: for the RBF network - 25 and for the second preceptron – 10,
- linear activation function for the perceptron,
- communicates: "current information about the better network".

After the finishing of construction process and the automatic selection of five best (for this particular analysis) neural networks, one can review the "Summary model report" (see Figure 6) and the worksheet that includes descriptive (regression) statistics of created and recorded models (see Figure 7). Summary model report is presented in the form of table with columns that include indicators of the, so called, "quality" of learning, validation and testing as well as errors determined for the three data subsets. This "quality" is calculated as the quotient of standard deviation of the remainder and standard deviation for dependent variable (in analyzed case: median of new workplaces number).

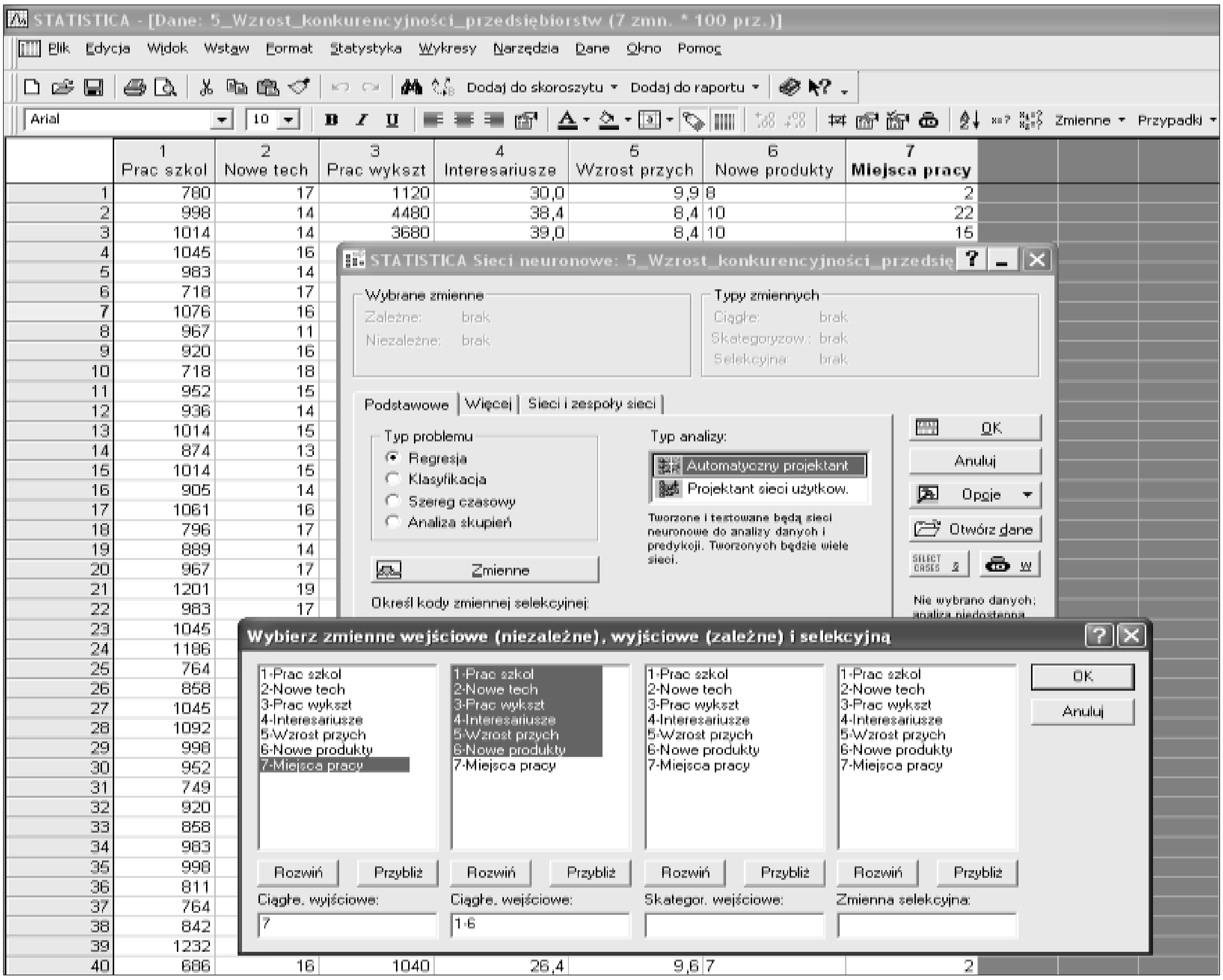
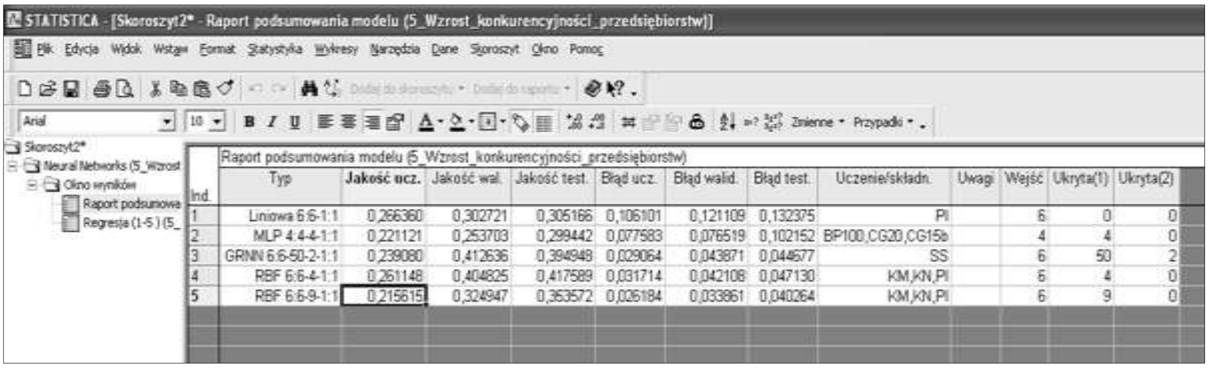


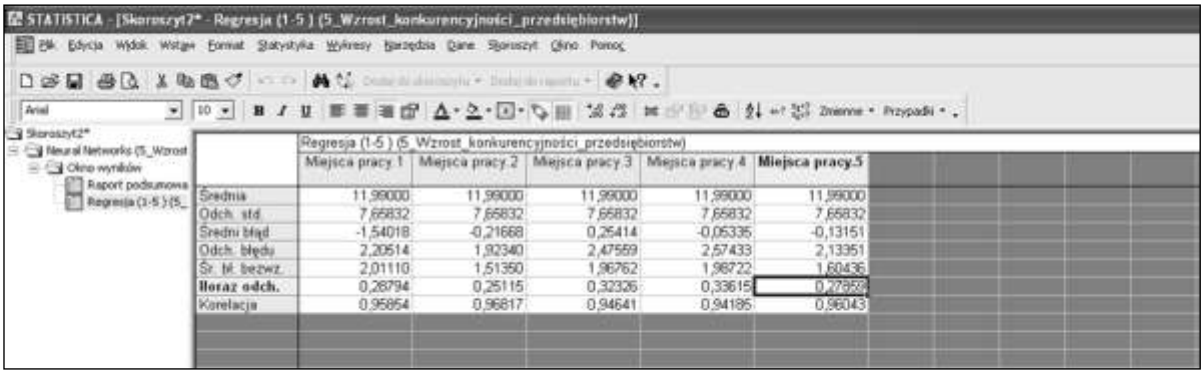
Figure 5. Variable selection window in Statistica Neural Networks 6.0
(source: self study with the use of Statistica software)



Raport podsumowania modelu (5_Wzrost_konkurencyjności_przedsiębiorstw)

Ind.	Typ	Jakość ucz.	Jakość wal.	Jakość test.	Błąd ucz.	Błąd walid.	Błąd test.	Uczenie/składn.	Uwagi	Wejść	Ukryta(1)	Ukryta(2)
1	Liniowa 6:6-1:1	0,266360	0,302721	0,305166	0,106101	0,121109	0,132375	PI		6	0	0
2	MLP 4:4-4-1:1	0,221121	0,253703	0,299442	0,077583	0,076519	0,102152	BP100,CG20,CG15b		4	4	0
3	GRNN 6:6-50-2-1:1	0,239080	0,412636	0,394948	0,029064	0,043871	0,044677	SS		6	50	2
4	RBF 6:6-4-1:1	0,261148	0,404825	0,417589	0,031714	0,042108	0,047130	KM,KN,PI		6	4	0
5	RBF 6:6-9-1:1	0,215615	0,324947	0,353572	0,026184	0,033861	0,040264	KM,KN,PI		6	9	0

Figure 6. Summary report for the work results of the automatic designer
(source: self study with the use of Statistica software)



Regresja (1-5) (5_Wzrost_konkurencyjności_przedsiębiorstw)

	Miejsca pracy 1	Miejsca pracy 2	Miejsca pracy 3	Miejsca pracy 4	Miejsca pracy 5
Średnia	11,99000	11,99000	11,99000	11,99000	11,99000
Odch. std.	7,65832	7,65832	7,65832	7,65832	7,65832
Średni błąd	-1,54018	-0,21668	0,25414	-0,05336	-0,13151
Odch. błędu	2,20514	1,92340	2,47559	2,57433	2,13351
Śr. bł. bezwz.	2,01110	1,51350	1,96762	1,98722	1,60436
Iloraz odch.	0,28794	0,25115	0,32326	0,33615	0,2785[illegible]
Korelacja	0,95854	0,96817	0,94641	0,94185	0,96043

Figure 7. Regression statistics of five created neural models
(source: self study with the use of Statistica software)

In case of resignation form using the used neural regression model predicted values of dependent variable would be based on the arithmetical average from the values in the learning set. In such case the mentioned quotient ("quality") would be equal to 1. Remainder would be the result of division of output variable value and the average value. Numerator and denominator of the quotient of deviations would have the same value.

Summing up, the value of deviation quotient close to unity (or higher) disqualifies given neural model. It indicates that the model, determined with a considerable amount of time, is similar (or even worse in case of values exceeding 1) to the determined average of dependent variable value.

Mean error (subtractions) between real and determined values has a relatively low value (from -0,05 to 0,25 for four models). Absolute values were not calculated from these subtractions.

Standard deviations from errors' series (approximately 1,9 ... 2,5) indicate the insignificant deviations of errors from the mean value. This parameter is significant from the point of view of the most important measure of the model – deviation quotient.

Average absolute error was determined (contrary to the error described above) with the calculation of absolute values from the subtractions between theoretical values (data) and the values at the output of the model. Relatively low averages (approximately 1,5 ... 2,0) determined from subtraction differences indicate that the model was properly elaborated.

Correlation indicators are in the last row of regression statistics table (previously described). Indicators, reached in an exemplary analysis, close to one (approximately 0,94 – 0,96) indicate that the models were properly created. Deviation quotient is also at satisfactory level (0,25 – 0,34). The lower its value is the better.

In the selection of the neural network from the five reached models it is necessary to bear in mind the linear network parameters as a reference point for the comparative analysis. All non-linear networks reach lower values of errors in comparison with a linear network. It indicates the non-linear character of the analyzed regression issue.

7 Summary

Review of currently used European project evaluation methods was performed in the process of the research realization. Special attention was drawn to the use of regression analysis in this application. Examples of a multi-criterion European project evaluation problem solving were presented. Moreover the use of modern computing technologies for the construction of regression models was proposed. Elaboration focused in the use of learning systems, which base on neural networks, in the project evaluation.

Models, which use neural networks, have many desired and significant features. They are non-linear, non-parametrical and do not assume the outline of the input and output relation modeling function. They do not require assumptions on forms and parameters of random variable distribution. Models are resistant to disturbances present in real-life systems. They allow gathering additional knowledge sufficient and necessary for regression data analysis as well as the selection of data relevant for evaluation purposes with simultaneous elimination of irrelevant factors. In case of classical statistical methods it is necessary to determine the relations between the explanatory variables and the explained variable as well as justification of these relations. However, it is not necessary to use e.g. neural networks. Formulated feature is at the same time certain limitation of the neural network application possibilities, because the result reaching process cannot be justified with particular relations.

Method feature analysis (advantages and disadvantages) that are included in artificial intelligence (especially neural networks) leads to a conclusion that the methods can be significant supplement for other (classical) data analysis methods (e.g. regression equation).

Example presented in the article shows examples of neural network usage in the construction of regression model, indicating that they are useful in regression analysis, similar to the classic single-equation regression equations. In case of classical methods usage that bases on neural networks both methods can complete each other. There are no problems in using these methods simultaneously.

Results reached from the data analysis method, which bases on neural networks, create empirical basis for the formulation of project evaluation, thus the realization of the final stages of European project evaluation.

Author used the network type and structure intuitively, using previous experience. However, this approach led to the creation of networks with not-satisfactory parameters (e.g. improper number of neurons or layers). Wrongly selected models can include e.g. too little number of neurons. This leads to insufficient approximation ability. In other cases it can result in relatively low ability of the network for generalization of the knowledge gathered in the learning process.

IT tools from the Statistica Neural Networks software proved to be a significant improvement in the network type and architecture selection process. These tools are especially useful in the construction of regression model used in evaluation process of EU cofinanced projects. Use of such tools usually enables reaching better regression parameters in comparison with the results gained with intuition or trial and error.

Results in the scope of neural model implementation look promising and can be used in the European project evaluation systems. Further experiments, with the use of artificial intelligence methods, in this field are planned. Authors interests are especially focused on the knowledge bases built with the use of the rough set theory.

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TRANSFORMING NETS

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Abstract: T-nets are constructed on the basis of experience gathered during experiments performed on the flow models of production systems [1, 4 and 6-12] and experience from colored Petri nets simulations. Transforming net is functioning in an asynchronous manner due to the initiation of transformers in specific periods of time. Possibilities to time-flow tasks are imminent features of T-nets – resources are gathered in the accumulators; resource transformations are described by the transformers. Task decomposition and task result synthesis is performed in a continuous manner. T-net plays the role of virtual model of real task realization processes. The existence of such model allows to monitor and asses the progress of realized tasks as well as calculations and simulation of task realization strategy.

Key words: accumulator, alternative and parallel dispersing and gathering transformers, colored and transforming Petri net, correctness and functioning, multitask transforming net, task decomposition, task realization strategy, transforming net (t-net), transforming network design.

1 Introduction

Transforming net referrers directly to the concept of organizational scheme task [4-6 and 13]. Task's operational scheme is represented by a network of partial tasks connected with parallel and alternate connections (gathering and dispersing). In case of transformational nets one is dealing with the change of resource level and tasks related to it, connected with network operators. Tasks and resources are represented by event identifications (markers) in the transforming network (T-net), whereas task realization process is supervised through markers flowing through network accumulators A and markers performed by the T transformers.

T-net is constructed on the basis of experience gathered during experiments performed on the flow models of production systems [1, 4 and 6-12] and experience from colored Petri nets simulations. It seems to eliminate ambiguity met in event modeling performed with marker flow through positions and transitions in Petri nets. Possibility to apply many practical constraints on its structure is one of the essential T-net advantages.

In general, the scheme illustrating process flow in selected object can be similar to the one presented in the Figure 1a. Tasks (processes) flow to the object from the left side (marked as: a, b, c, d, ...); task (process) realization results leave the object from the right side (marked as: w^a, w^b, w^c, w^d, ...); process tasks are planned from the top (marked as: p^a, p^b, p^c, p^d, ...) and the planning results are flowing downwards (marked as: r^a, r^b, r^c, r^d, ...).

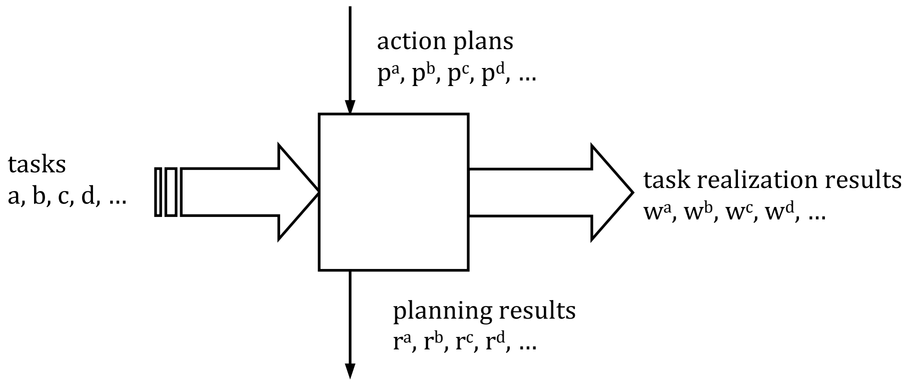

Figure 1a. Task processing scheme *(source: self study)*

The two main factors of a T-net are its accumulators A_i (see Figure 1b) and alternative $T_j^{V<}$, $T_j^{V>}$ (see Figure 1c) and parallel $T_k^{\&<}$, $T_k^{\&>}$ (see Figure 1d) transformers.

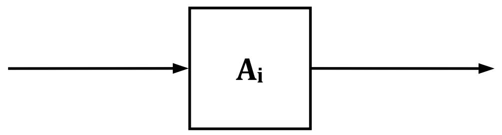

Figure 1b. T-net accumulator *(source: self study)*

Gathering and forwarding the incoming markers is the main task of the A_i accumulator. The accumulator has only one input and one output, which receives and forwards markers to transformers connected to it. Accumulator's capacity can be limited to a given number of markers.

Alternative transformers (see Figure 1c) can be divided to:

- dispersing alternative transformers $T_j^{V<}$,
- gathering alternative transformers $T_j^{V>}$.

Parallel transformers (see Figure 1d) can be divided to:

- dispersing parallel transformers $T_j^{\&<}$,
- gathering parallel transformers $T_j^{\&>}$.

Modeling of transforming processes is presented in the following structure:

- elements of transforming net structure (see point 2),
- transforming net functioning (see point 3),
- transforming net and color Petri nets (see point 4),
- multitask transforming net (see point 5),
- transforming net modeling (see point 6),
- design of transforming nets (see point 7).

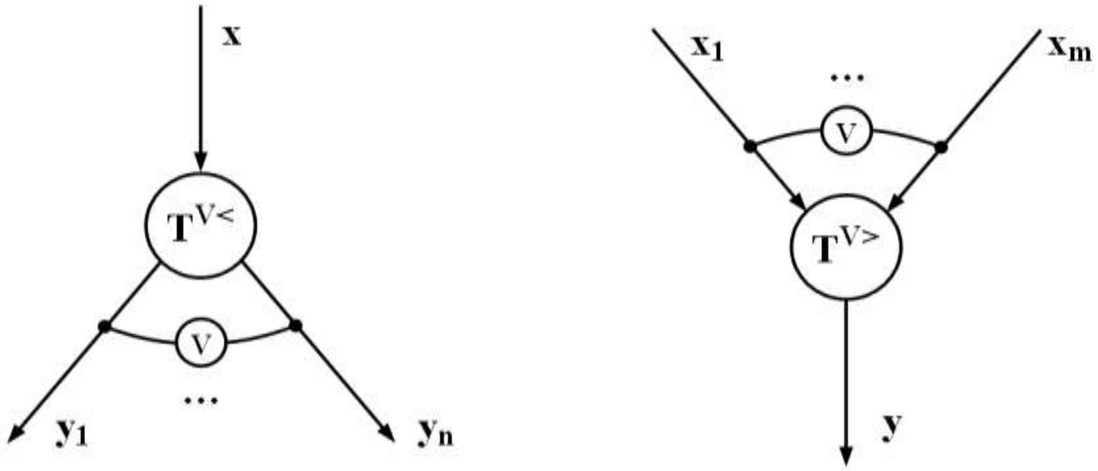

Figure 1c. T-net alternative transformers
(source: self study)

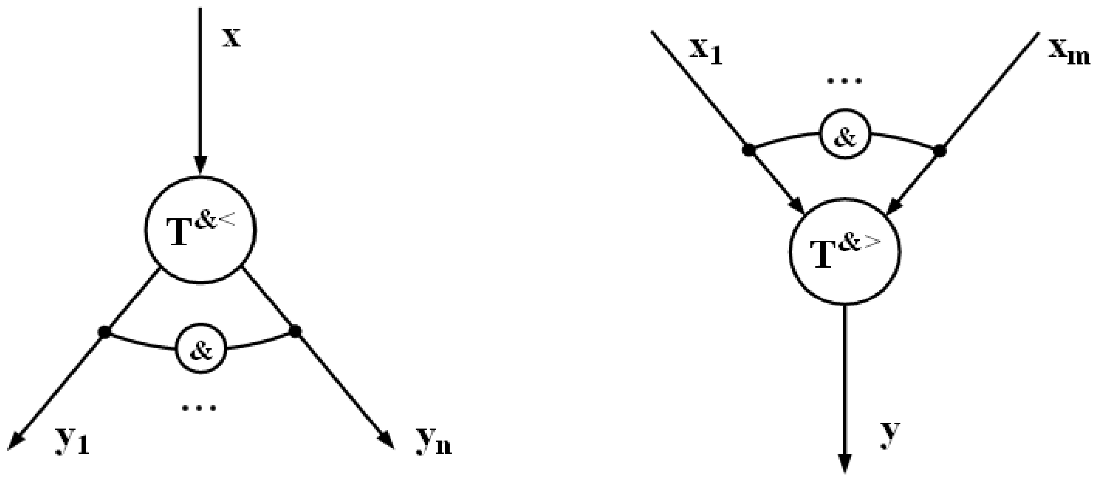

Figure 1d. T-net parallel transformers
(source: self study)

2 Elements of transforming network structure

Transforming net (T-net) is constructed from five types of elements:

- dispersing alternative $T^{V<}$ and gathering $T^{V>}$ transformers as well as parallel dispersing $T^{\&<}$ and gathering $T^{\&>}$ transformers, which perform operations on task identifications (markers) that are present in transformer supplying accumulators; event markers are relevant to tasks and resources connected with them (see Figure 1a),
- accumulators A_x, which take and forward event markers x to T^V and $T^{\&}$ transformers connected with them (see Figure 2a and Figure 2b); certain accumulator of x type can store different event markers (connected with certain events),
- arcs that connect transformers and accumulators,
- event markers,
- functions that are responsible for marker processing in the transformers and for rules that order markers in the accumulators.

Canonical (basic) T-net schematics are presented in the Figure 2a and Figure 2b. Symbols & and V represent relations between the accumulators and transformers. Circeled & and V symbols are omitted in graphic T-net schematics because of the specific character of marker processing by, so called, transformer operating functions. The V symbol stands for the relations between transformer incoming and outgoing arcs and determine the necessity for an alternative (single – see Figure 2e and Figure 2f) introduction (or leading out) of a marker from a single input or output of the transformer. The & symbol stands for the relations between transformer incoming and outgoing arcs and determine the necessity for parallel (simultaneous) introduction (or leading out) of a marker from all inputs or outputs of the transformer (single – please see Figure 2g and Figure 2h).

Possible sub-schematics created on the basis of canonical T-net schematics are presented in the Figure 2c.

Important structural features of the T-nets are as following:

- transformers cannot be directly connected,
- accumulators cannot be directly connected,
- accumulator can have only one input and one output,
- transformer can only have one input and many outputs or single output and many inputs,
- properly constructed net should have at least one starting accumulator without any input (see Figure 2d),
- properly constructed net should have at least one finishing accumulator without any output (see Figure 2d).

Listed features were elaborated on the basis of: task operational schematics function analysis [1, 5 and 13], Petri net model [11] and with the rules of characterization theory taken into consideration [2, 3].

Event markers can be described with letters a, b, c, ... preceded with a number that indicates how many times did the marker appear. Partial marker appearance is not allowed.

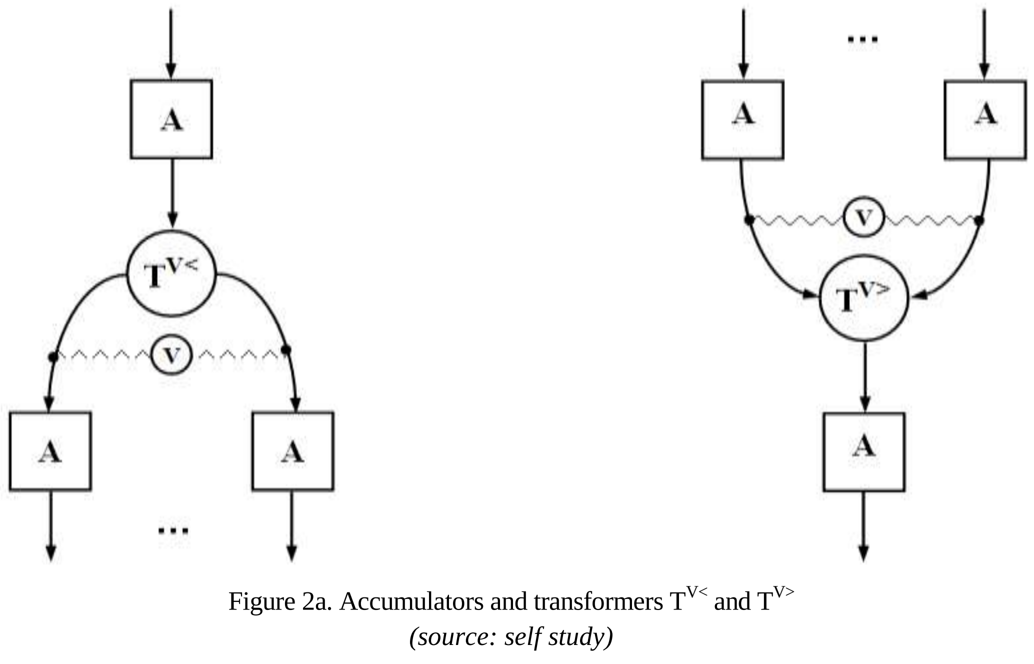

Figure 2a. Accumulators and transformers $T^{V<}$ and $T^{V>}$
(source: self study)

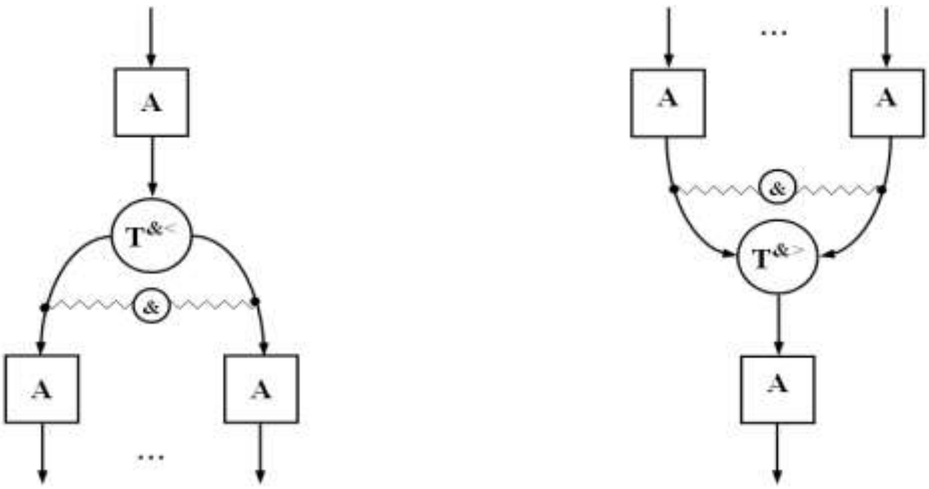

Figure 2b. Accumulators and transformers $T^{\&<}$ and $T^{\&>}$
(source: self study)

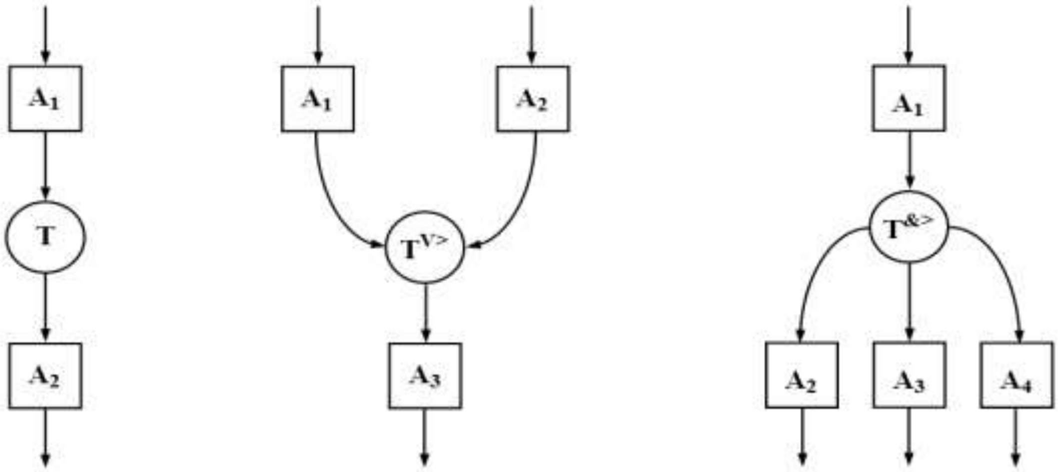

Figure 2c. Examples of T-nets
(source: self study)

In general, functions responsible for marker in transformers processing, so called internal transforming functions, have the following form:

- internal transforming function $T^{\&>int}$
  $T^{\&>int} = \{ \&_{in} x_i \rightarrow y_i \}$
- internal transforming function $T^{V>int}$
  $TV^{>int} = \{ V_{in} x_j \rightarrow y_j \}$
- internal transforming function $T^{\&<int}$
  $T^{\&<int} = \{ x_i \rightarrow \&_{out} y_i \}$
- internal transforming function $T^{V<int}$
  $T^{V<int} = \{ x_j \rightarrow V_{out} y_j \}$

where:

V_{in} - input accumulator alternative selection operation symbol,

V_{out} - output accumulator alternative selection operation symbol,

$\&_{in}$ - simultaneous (conjunctive) input accumulator selection symbol,

$\&_{out}$ - simultaneous (conjunctive) output accumulator selection symbol,

x, y - event markers,

i, j - arc indexes connected conjunctively and alternatively with the transformer.

Internal transforming functions decide about the T-net functioning, which describes the process of transformation of incoming and outgoing event markers. Due to the process of gathering the markers in accumulators, process course and transformation is conditioned by two factors:

- availability and order (priorities) of markers in the accumulators,
- initiation of marker transformation (priorities) according to certain plan or strategy.

Examples of rules used to order the event markers in the accumulators:

- LIFO rule (markers that were last in the accumulator are served first),
- FIFO rule (markers that were first in the accumulator are served first),
- priority rule (markers with highest priorities, resulting from specific task realization plan, are served first).

The main task of a dispersing alternative transformer $T_j^{V<}$ is to take one marker from the connected accumulator (input marker) and transform it to a single outgoing marker and simultaneously, after certain τ_j time delay, transfer it to a connected accumulator through one of alternative outputs of the $T_j^{V<}$ transformer.

The main task of a gathering alternative transformer $T_j^{V>}$ is to take one input marker from one of connected accumulators and transform it to a single outgoing marker and simultaneously, after certain τ_j time delay, transfer it to a connected accumulator through one of alternative outputs of the $T_j^{\&>}$ transformer. Process flow is presented in the Figure 2f.

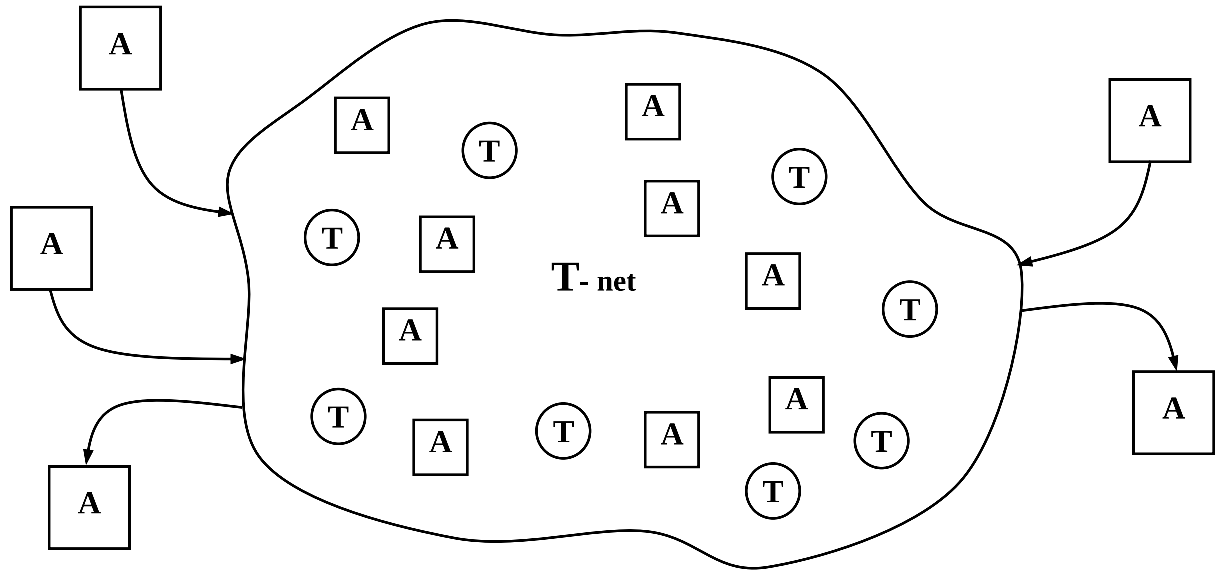

Figure 2d. Starting and finishing T-net accumulators
(source: self study)

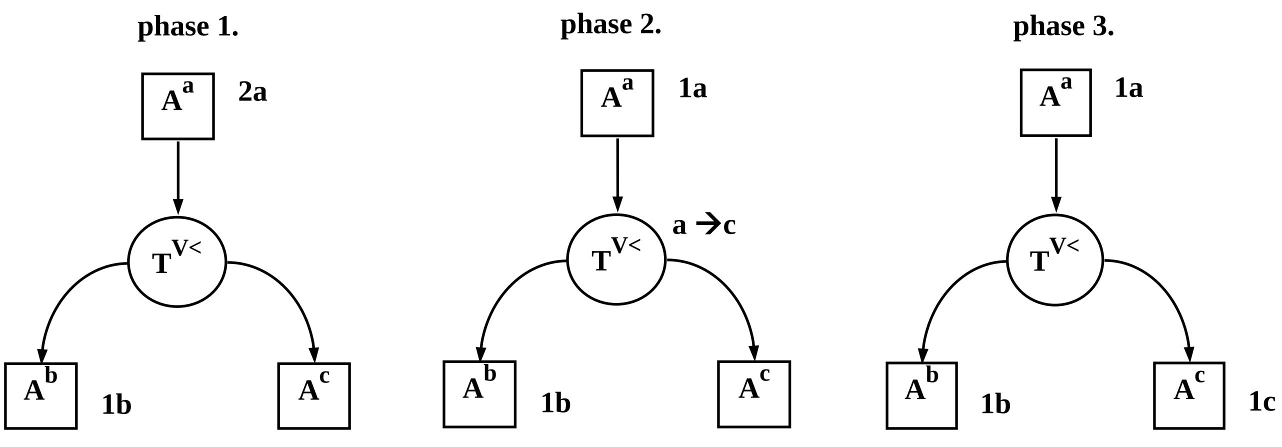

Figure 2e. $T_j^{V<}$ alternative dispersing transformer marker flow phases
(source: self study)

The main task of parallel dispersing transformer $T_j^{\&<}$ is to take one marker from the connected accumulator (input marker) and transforming it into a series of single outgoing markers and simultaneously, after certain τ_j time delay, transfer it through all parallel outputs of $T^{\&<}$ transformer one by one to a connected accumulator. Process flow is presented in the Figure 2g.

The main task of parallel gathering transformer $T_j^{\&>}$ is to take one input marker from all connected accumulators and transforming it into a single outgoing marker and simultaneously, after certain τ_j time delay, transfer it through a single output of $T_j^{\&>}$ transformer to connected accumulator. Process flow is presented in the Figure 2h.

Transformer with only one input and one output section is called the basic transformer and marked as T_i without the distinguishing of its type (see Figure 2i).

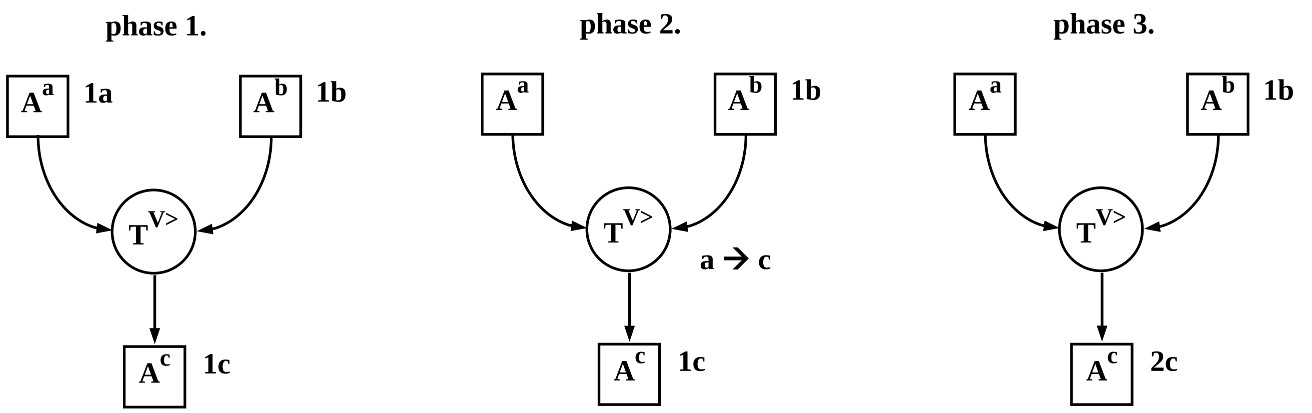

Figure 2f. $T_j^{V>}$ alternative gathering transformer marker flow phases
(source: self study)

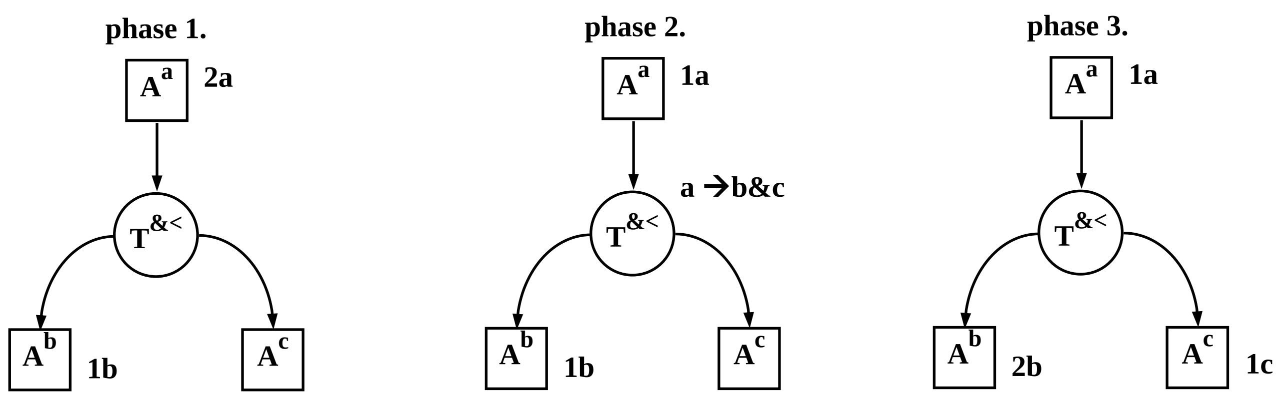

Figure 2g. Marker flow phases through dispersing parallel transformer $T_j^{\&<}$
(source: self study)

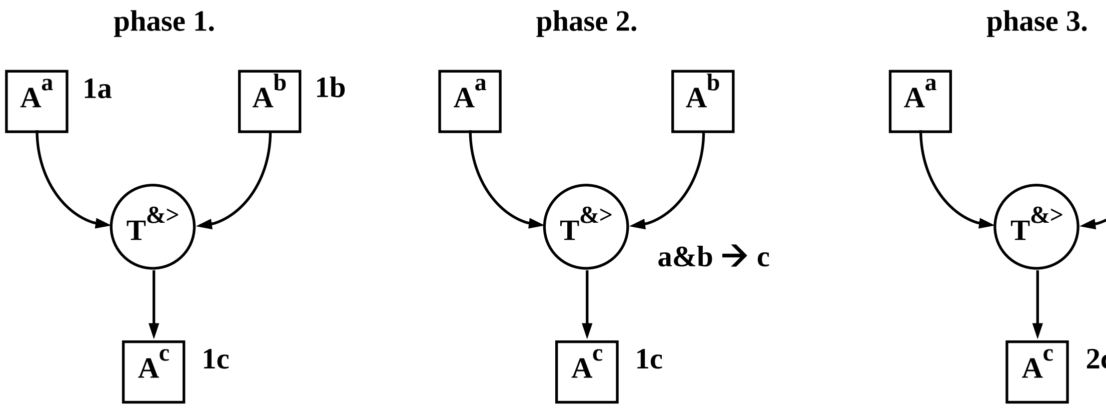

Figure 2h. Marker flow phases through gathering parallel transformer $T_j^{\&>}$ *(source: self study)*

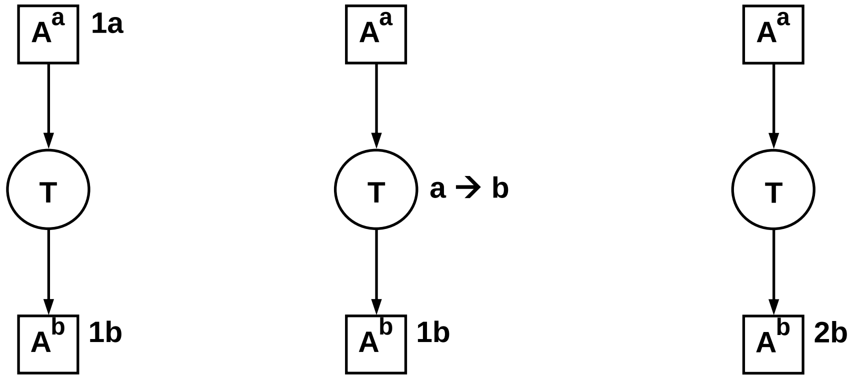

Figure 2i. Basic transformer *(source: self study)*

3 Transforming net functioning

Transforming net functioning can be described with a collection of internal transforming functions { T^{int} } (see point 2).

Transforming net is functioning in an asynchronous manner due to the initiation of transformers in specific periods of time. Transformer can be in out of two allowable states:

- I standby, when:
  - transformer is not processing any incoming event marker sequence due to redundancy of its output accumulators what blocks the intake of markers (see Figure 3a); (maximum capacity of the accumulator is marked as max |A|),
  - transformer is not processing incoming event marker sequence due to redundancy of input accumulators what prevents T^{int} projection from realization (see Figure 3b),

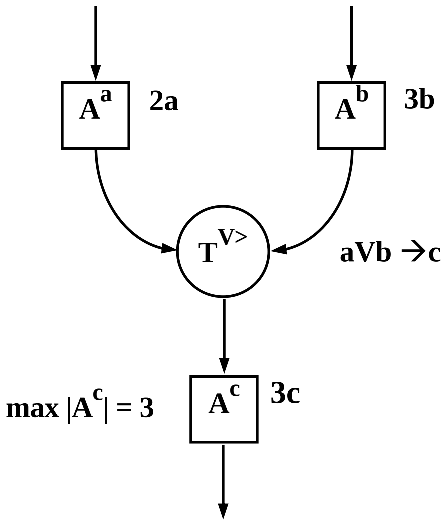

Figure 3a. Transformer in standby phase due to redundancy of the output accumulator *(source: self study)*

- II during transformation, which
  - starts form the selection of T^{int} projection (phase 1.), for which an event sequence, fulfilling this projection, will be found in input accumulators and simultaneously a space will be provided to take event markers, created as a result of chosen projection realization, in output accumulators (see Figure 3c),
  - afterwards event marker selection, from suitable input accumulators, is performed (phase 2.); these markers are, in certain τ time period, transformed according to T^{int} projection into event markers that suit the accumulators in the outgoing arcs (see Figure 3c),
  - it ends with the transfer of produced event markers (phase 3.) to the output accumulators (see Figure 3c).

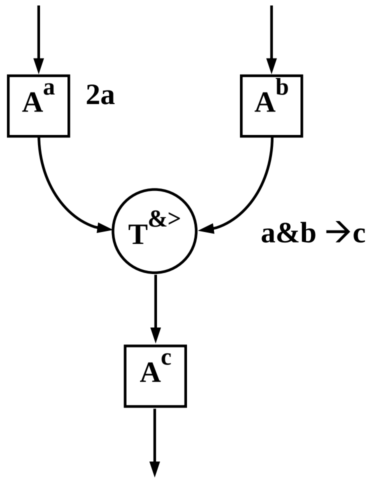

Figure 3b. Transformer in standby phase due to lack of required markers in input accumulators
(source: self study)

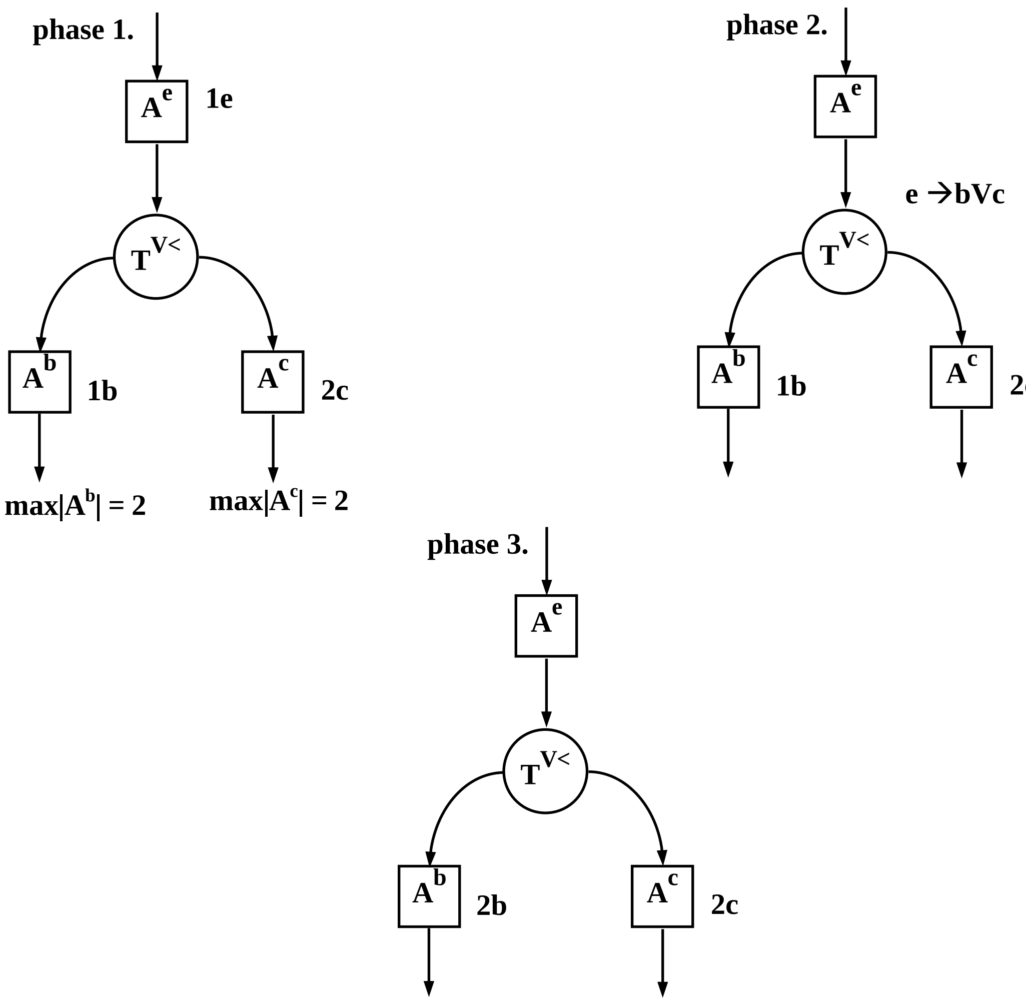

Figure 3c. Example of event markers transformation
(source: self study)

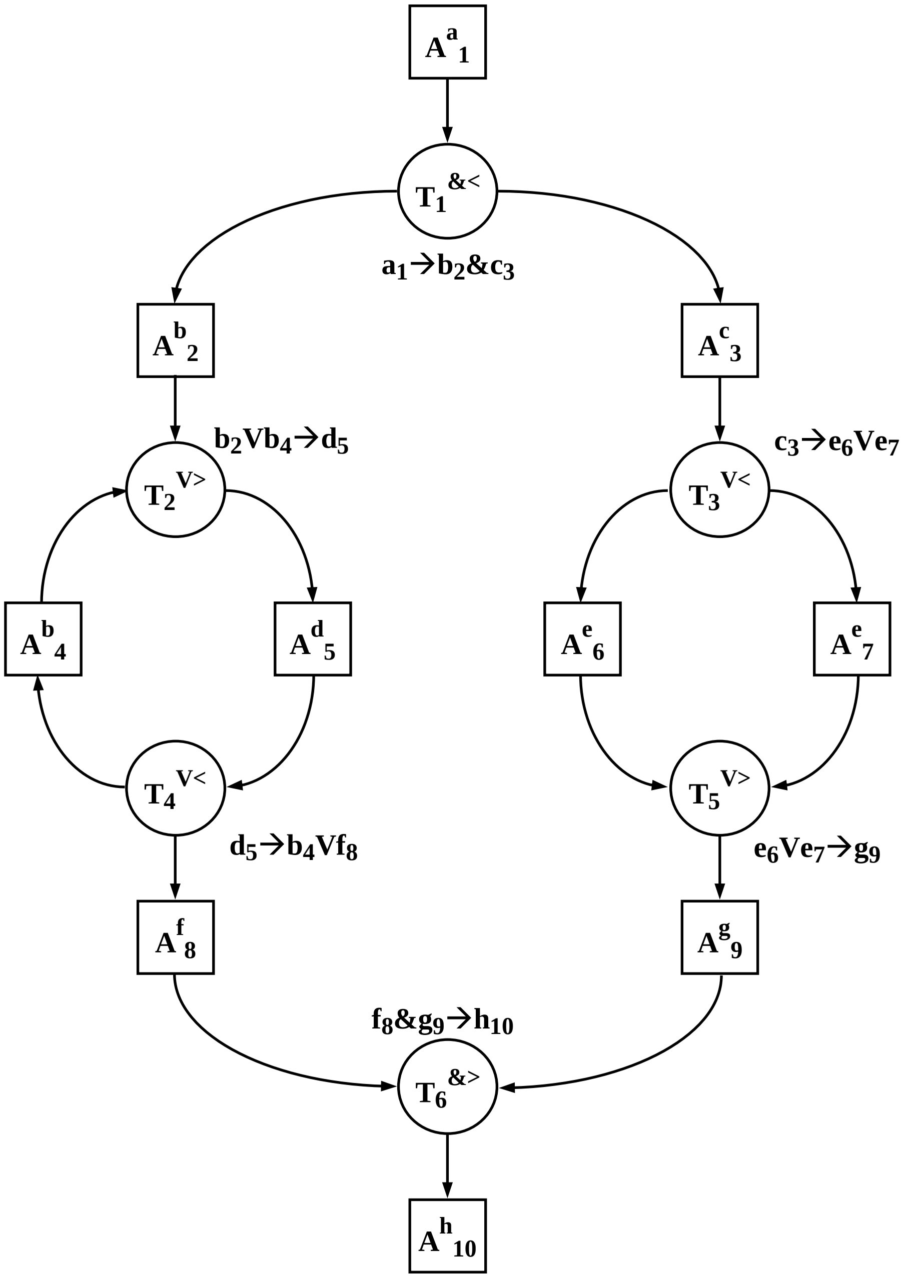

Figure 3d. T-net functioning example *(source: self study)*

Example of a T-net functioning, consisting of six $T_1 – T_6$ transformers and ten $A_1 – A_{10}$ accumulators, is presented in the Figure 3d:

- $T_1^{\&<}$ transformer (see Figure 3d) realizes the internal transforming function T_1^{int}, in the form of a projection: $a_1 \rightarrow b_2\&c_3$ of type a markers collected from $A^a{}_1$ accumulator and changed for type b and c markers transferred to $A^b{}_2$ and $A^c{}_3$ accumulators,
- $T_2^{V>}$ transformer realizes the internal transforming function T_2^{int}, in the form of a projections: b_4 V $b_2 \rightarrow d_5$ of type b markers collected from $A^b{}_2$ or $A^b{}_4$ accumulators and changed for type d markers transferred to $A^d{}_5$ accumulator,
- $T_3^{V<}$ transformer realizes the internal transforming function T_3^{int}, in the form of a projection: $c_3 \rightarrow e_6$ V e_7 of type c markers collected from $A^c{}_3$ accumulator and changed for type e markers transferred to $A^e{}_6$ and $A^e{}_7$ accumulators,
- $T_4^{V<}$ transformer realizes the internal transforming function T_4^{int}, in the form of a projection: $d_5 \rightarrow b_4$ V f_8 of type d markers collected from $A^d{}_5$ accumulator and changed for type b and f markers transferred to $A^b{}_4$ and $A^f{}_8$ accumulators,

- $T_5^{V>}$ transformer realizes the internal transforming function T_5^{int}, in the form of a projections: $e_6 \vee e_7 \rightarrow g_9$ of type e markers collected from A^e_6 or A^e_7 accumulators and changed for type g markers transferred to A^g_9 accumulator,
- $T_6^{\&>}$ transformer realizes the internal transforming function T_6^{int}, in the form of a projections: $f_8 \& g_9 \rightarrow h_{10}$ of type f and g markers collected from A^f_8 and accumulator and changed for type h markers transferred to A^h_{10} accumulator.

4 Colored and transforming Petri net

Transforming net functioning can be presented in the representation of colored Petri net.

Figure 4a presents a situation where Petri net transition plays a role of a conjunctive connection from the incoming side. In phase 2., activation of t_1 transition with z marker takes place; in T-nets z&z→z projection realization corresponds with this event.

All considered examples of event modeling in Petri net with T-nets relate to the situation where the internal transforming function T^{int} describes x marker projections of different types (colors); markers of the same color are always present in both of its sides.

Figure 4b presents a situation where Petri net transitions are in conflict for two different markers b and z. In this situation p_1 position plays the role of the alternative connection from the output side. Conflict resolution can happen in two "symmetrical" ways – after phase 1., accordingly phases 2, 2' as well as 3 and 3' take place. Special attention should be drawn to the fact that two Petri net transitions are modeled with one transformer $T^{V<}$, which can process b and z markers only in sequential manner what as a result causes the process to by prolonged by one time step (phase 4).

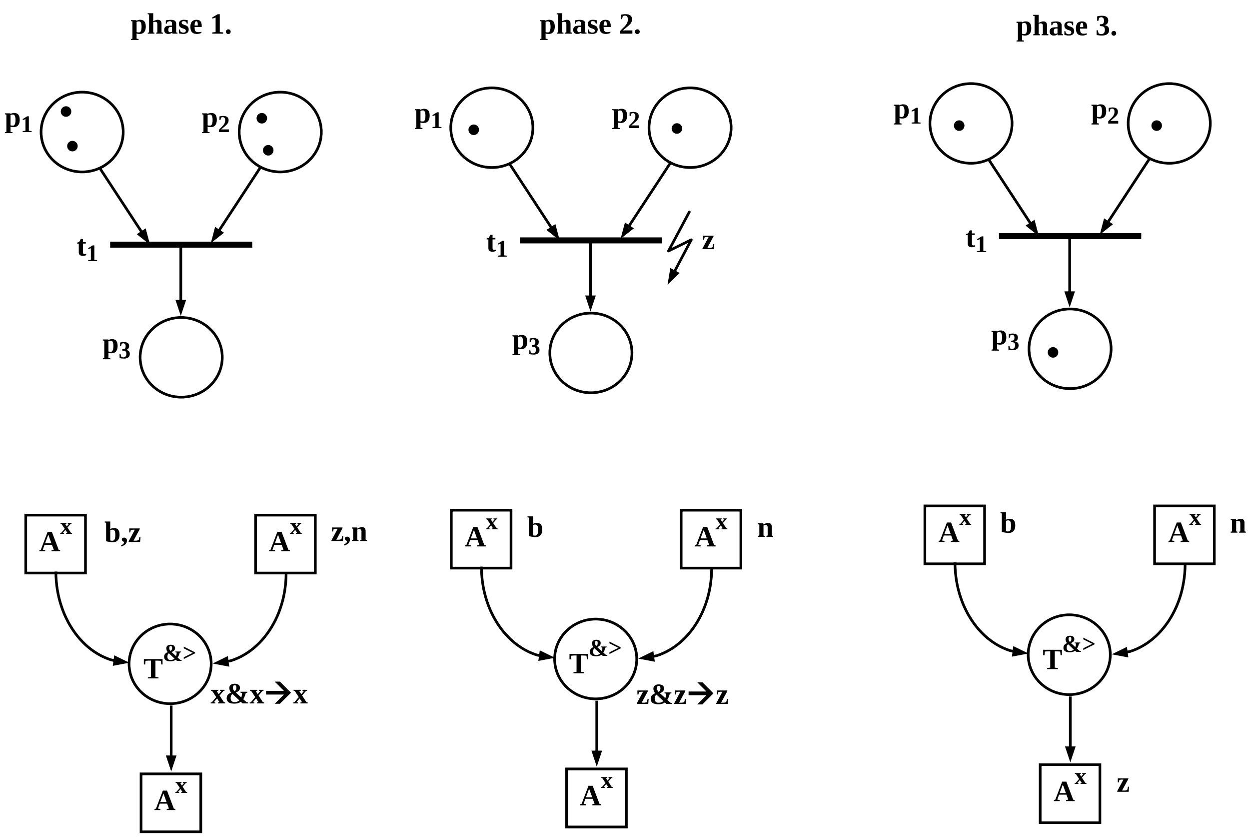

Figure 4a. Examples of marker transformation phases in Petri net and in T-net
(in this case: t_1 transition plays the role of conjunctive connection from the incoming side).
(source: self study)

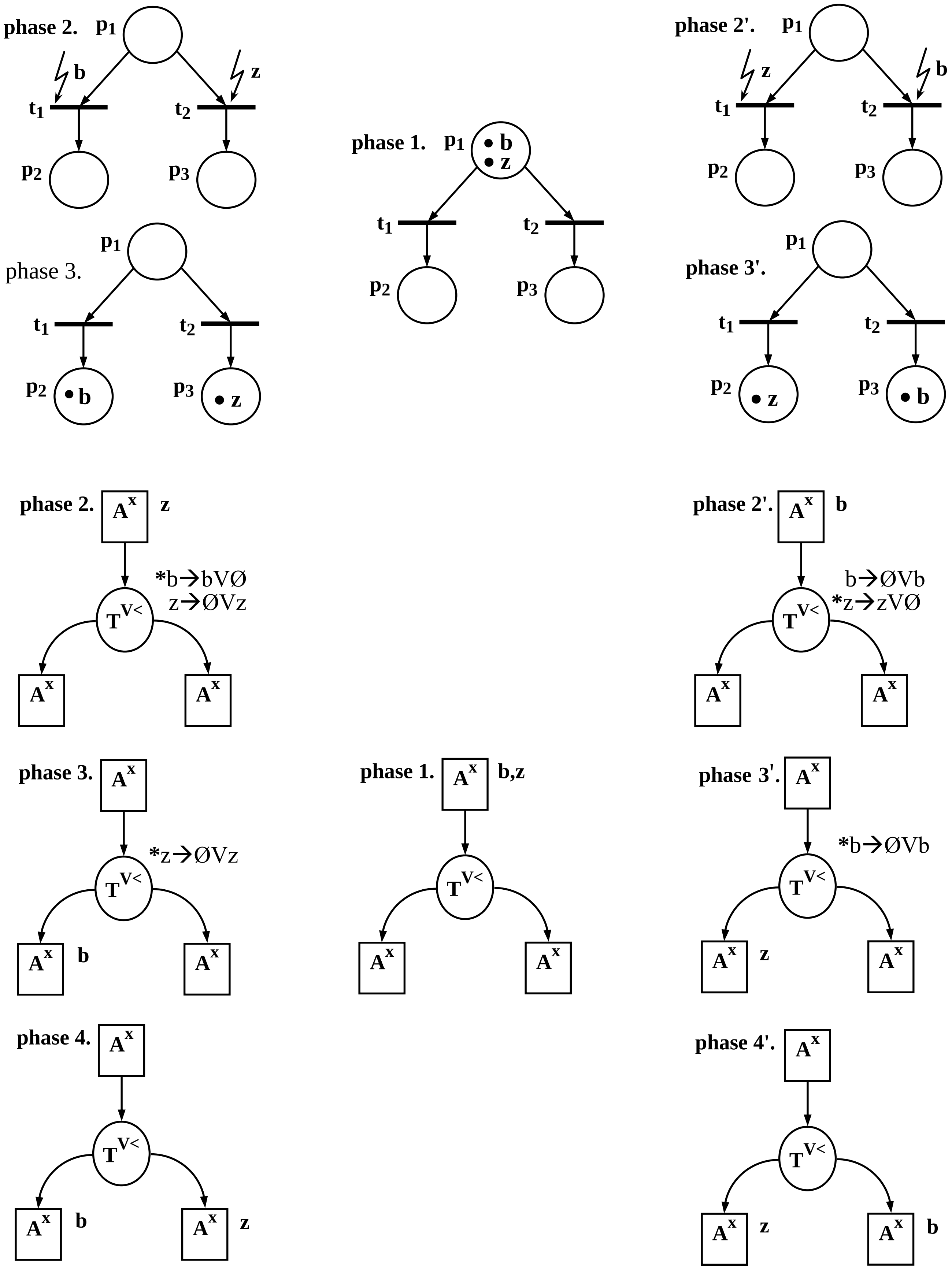

Figure 4b. Examples of marker transformation phases in Petri net and in T-net
(in this case: p_1 position plays the role of alternative connection from the outgoing side)
(source: self study)

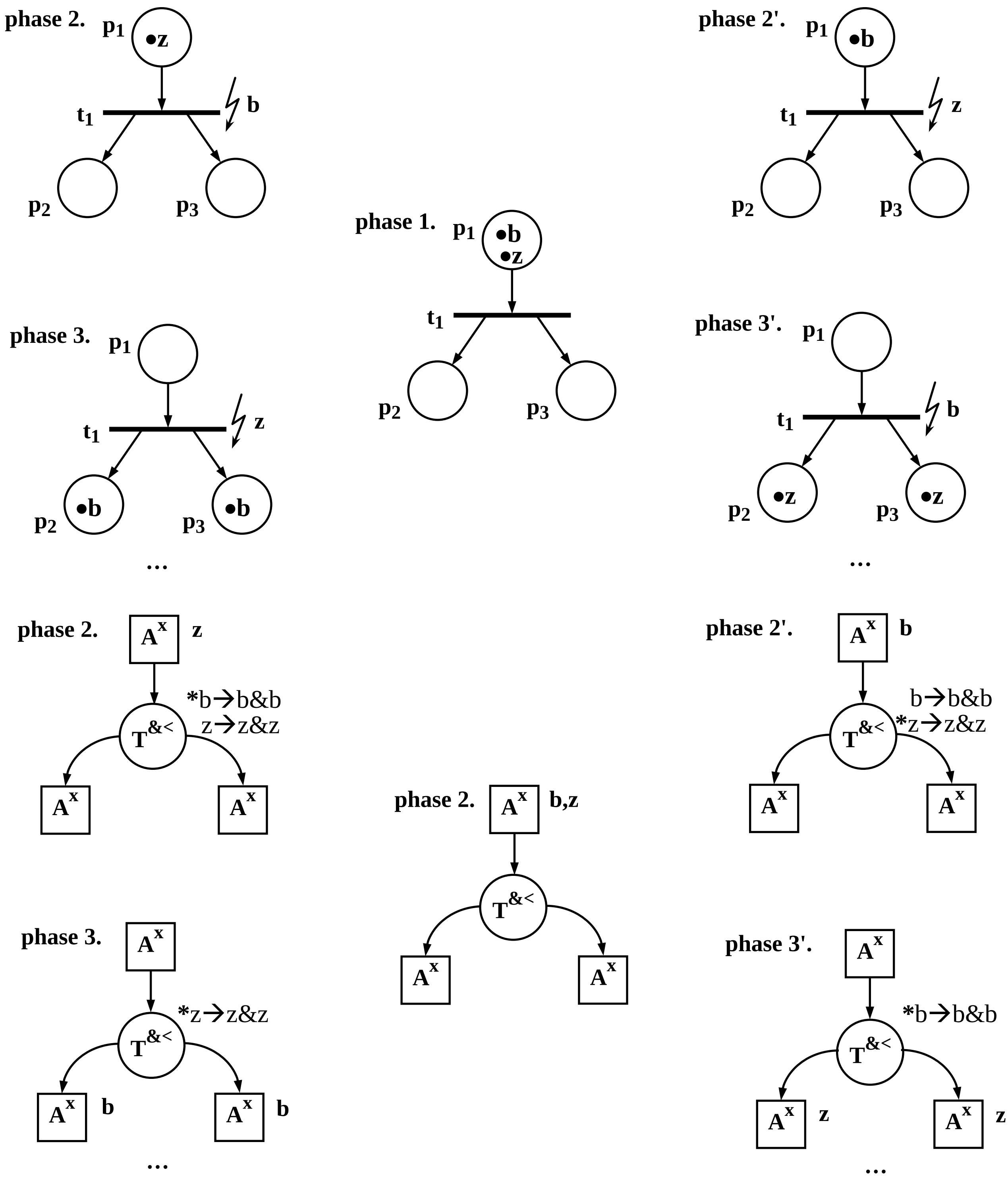

Figure 4c. Examples of marker transformation phases in Petri net and in T-net
(in this case: t_1 transition plays the role of conjunctive connection from the outgoing side)
(source: self study)

Figure 4c presents a situation where the Petri net transition plays the role of conjunctive connection from the outgoing side. Finally, in the following phase 4., markers b, z appear at the p_2 and p_3 positions. In this case both t_1 transition and corresponding $T^{\&<}$ transformer are functioning similarly and sequentially transforming the markers.

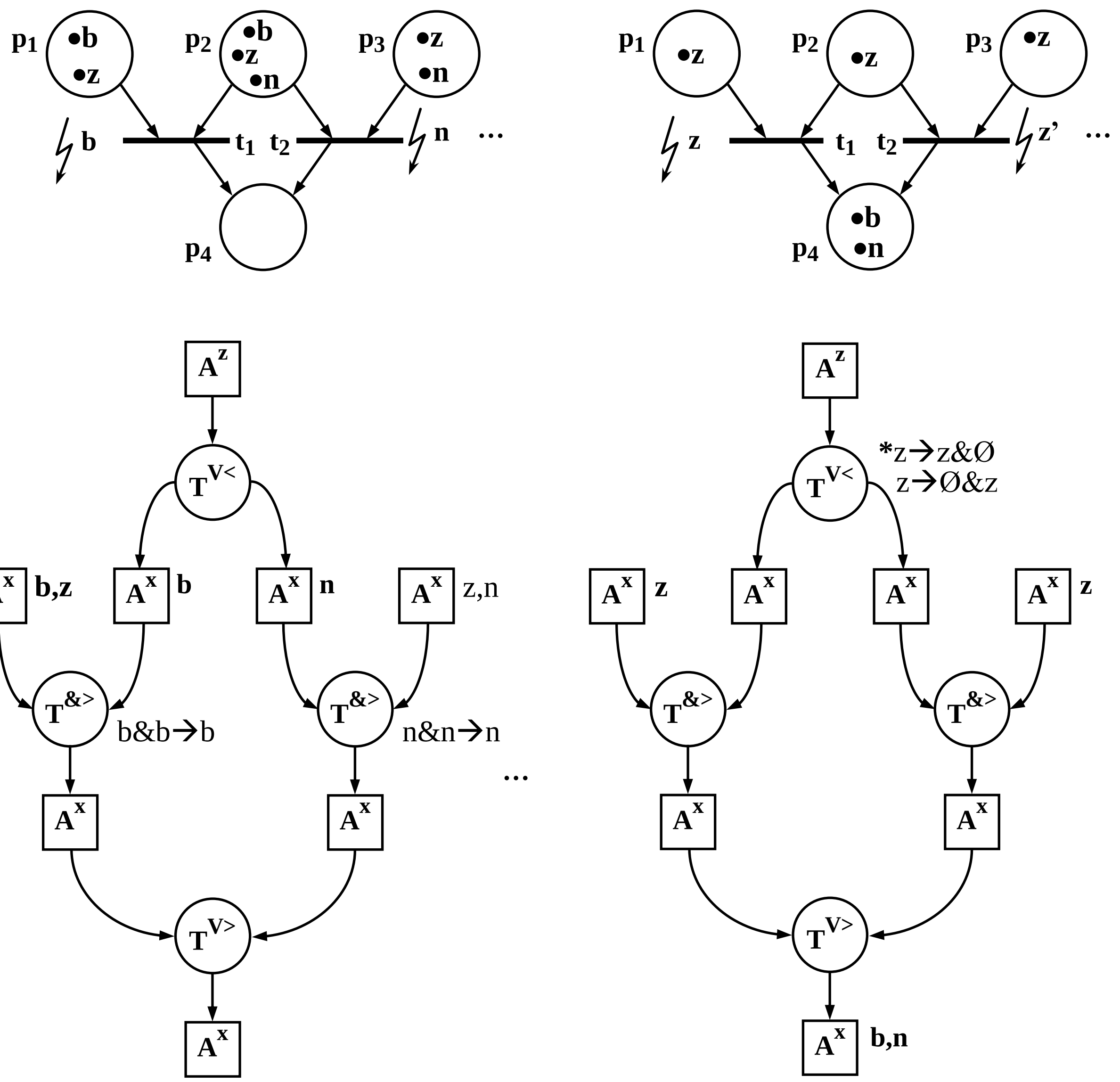

Figure 4d. Examples of marker transformation phases in Petri net and in T-net
(in this case: p_2 position supplies two transitions – in T-nets buffer can only supply one transformer)
(source: self study)

Figure 4d presents a situation where p_2 position as well as t_1 and t_2 Petri net transitions create a configuration that is no allowable for direct depiction and T-net symbolism, due to the fact that one transforming net accumulator can be connected to only one transformer from input and output side. Similar situation can be found in a Petri net where, for example, p_2 and p_4 positions were connected to two transitions (there is no limitation for the number of mutually connected transitions and positions). In given example the T-net is two times bigger than the modeled Petri net, whereas there are no situations (conflicts) present that would require suitable solving mechanisms.

5 Multitask transforming net

Multitasking is one of the natural features of transforming net. One can interpret a single processed marker as a task, in order to test this feature. It is necessary to assume at this point that tasks can be subjected to a multilevel decomposition (disaggregation) until the basic tasks layer and its results can be merged (aggregated) in the opposite direction (from elementary resources tasks to complex resources tasks).

Possibility to time-flow tasks is immanent features of T-nets – resources (their markers to be precise) are gathered in the accumulators; resource (marker) transformations are described by the transformers. Interpretation of desirable (expected) resources (markers) in accumulators is a remaining problem.

The essence of multitasking, in T-net interpretation, is based on such planning (addressing in time to proper accumulators) and coordination (priorities of task markers in accumulators, projection variants in transformers consistent with marker priorities) of task flow (according to Figure 1a) that is realized according to the aim function expressing the commitment of natural or automatic "system administrator".

The way the aim function is "translated" into decomposition and task flow placement in T-net accumulators is not the subject of this elaboration at this point.

T-net multitasking will be considered with the assumption that its structure was designed to perform specific task class, which unambiguously determine the sub-collection of output accumulators (final tasks) – and simultaneously that realization of tasks assigned to input accumulators (cooperation tasks) for given net is assured (see Figure 2d).

Every T-net accumulator determines through its markers a single type of task consistent with the type of these markers. Many accumulators for the same type of task can be present in one net (processing the markers of the same type), powering different T-net transformers.

For example, net is in the form presented in the Figure 5a (see point 1). The X_P task starts the process of task realization and the X_Q task finishes it. Tasks do not have a dedicated space (infrastructure) for task realization. Tasks in the task net are connected by alternative and parallel connections. X_k and X_l tasks control the order of task selection with $A^<$ alternative dispersing connections.

Tasks are realized as predicate functions, which on the basis of task input data determine the order of following tasks (with the numbers 0 or 1), in order to make this process possible.

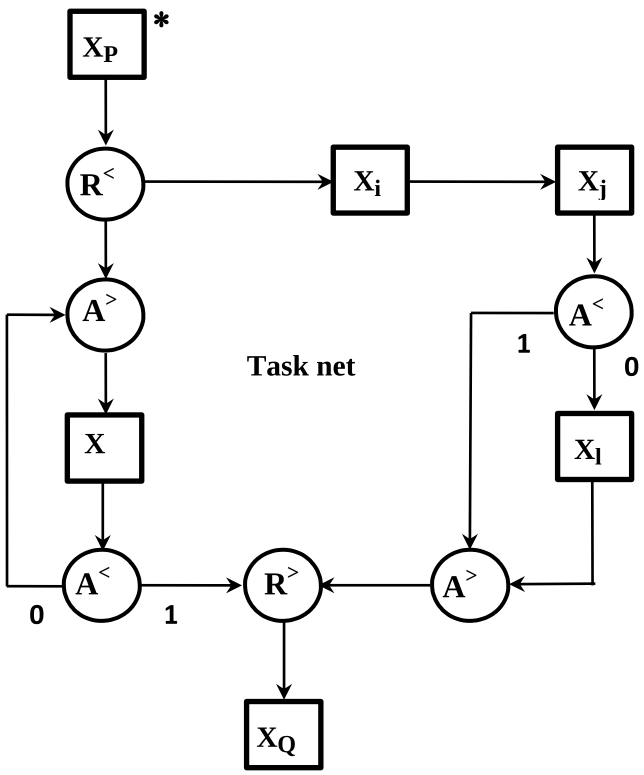

Figure 5a. Initial state of net tasks activity (* - active net element, X - task, **R**$^<$ - parallel dispersing connection, **R**$^>$ - parallel gathering connection, **A**$^<$ - alternative dispersing connection, **A**$^>$ - alternative gathering connection)
(source: self study)

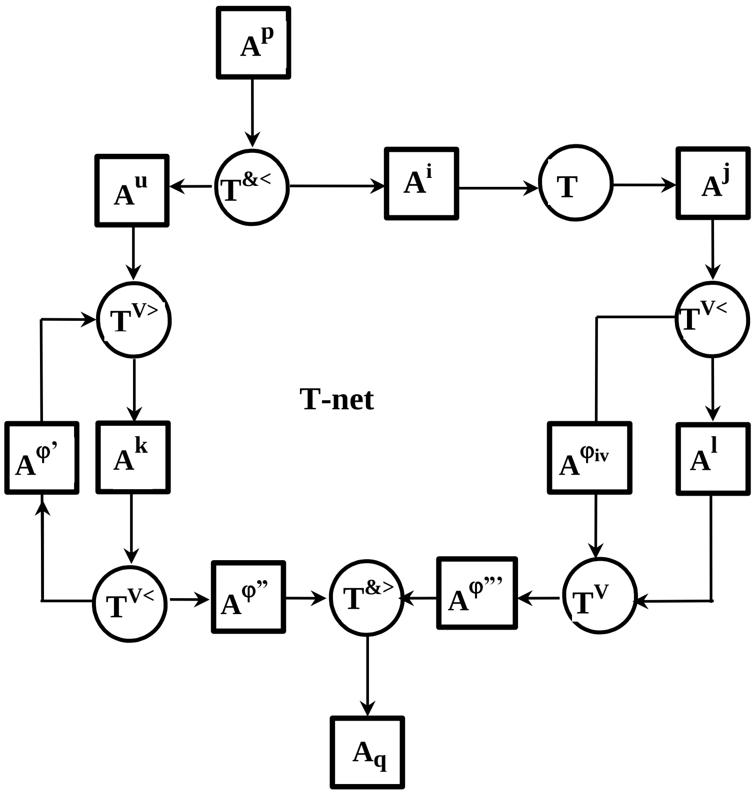

Figure 5b. T-net corresponding to task net (see Figure 5a) *(source: self study)*

Net presented in the Figure 5a does not "show" the method (technology) of task realization, there is no possibility to model task realization of X_P, $X_{P'}$, $X_{P''}$, X_i, $X_{i'}$, $X_{i''}$, X_j, $X_{j'}$, $X_{j''}$, ... X_Q, $X_{Q'}$, $X_{Q''}$ stream.

It is necessary to prepare, for every task in the net, at least one accumulator, which can store its markers, in order to allow it. At the same time transformers for task nets, which will perform operations assigned to parallel and alternative connections in the task nets, need to be determined. Many different variants of a given task can be realized (performed) or set for realization (planned), as a part of particular task type, in a T-net accumulator. Therefore construction of multitask net needs to be predicated with the determination of task types that will be realized by given net. Suitable number of accumulators, with a capacity that will assure a harmonious task realization, needs to be selected for every defined task type.

T-net with one input and output accumulator realizing task net from Figure 5a is presented in the Figure 5b.

Due to the constraints present in T-nets (see Figure 5b) it is necessary to introduce additional elements (accumulators), which would divide the neighboring transformers, substituting for elements from the original net. Such accumulators gather tasks present before and after the transformation.

Constructed T-net can serve many tasks in parallel (all of its transformers can be active simultaneously) and their markers are stored in accumulators. Accumulators can also realize the "policy" of task (marker) arrangement according to set priority system, what takes place in task realization planning and control system e.g. in real production systems.

Determination of T- net tasks is conditioned by its four transformers and realized transforming tasks functions $T^{\&>int}$, $T^{\&<int}$, $T^{V>int}$ and $T^{V<int}$ (see point 2).

6 Transforming net modeling

Transforming net (T-net) can be modeled with the use of techniques used in case of Petri nets (e.g. reachability graph) or through regular expressions used in event nets [11, 14].

Essential practical aspect of every network structure is its openness understood as the possibility to attach new or close down (eliminate) existing elements. In case of T-nets it usually means connecting or eliminating accumulators and transformers.

The most basic T-net (see Figure 2i) consists of two accumulators and a connecting transformer. Such net realizes operations based on tasks (or its markers) described with a T transforming function.

Development of the net presented in the Figure 2i can be realized through:

- adding accumulators:
  - any amount of input accumulators with a simultaneous declaration of transformer type (alternative or parallel gathering transformer); see Figure 6a,
  - or any amount of output accumulators with a simultaneous declaration of transformer type (alternative or parallel dispersing transformer); see Figure 6b,
- adding transformers:
  - adding one alternative transformer or parallel gathering from the side of input accumulator; see Figure 6c,
  - adding one alternative transformer or parallel dispersing from the side of output accumulator; see Figure 6c,
- transformer decomposition:
  - into a pair of alternative transformers connecting any number of accumulators; see Figure 6d,
  - into a pair of gathering transformers connecting any number of accumulators; see Figure 6d.

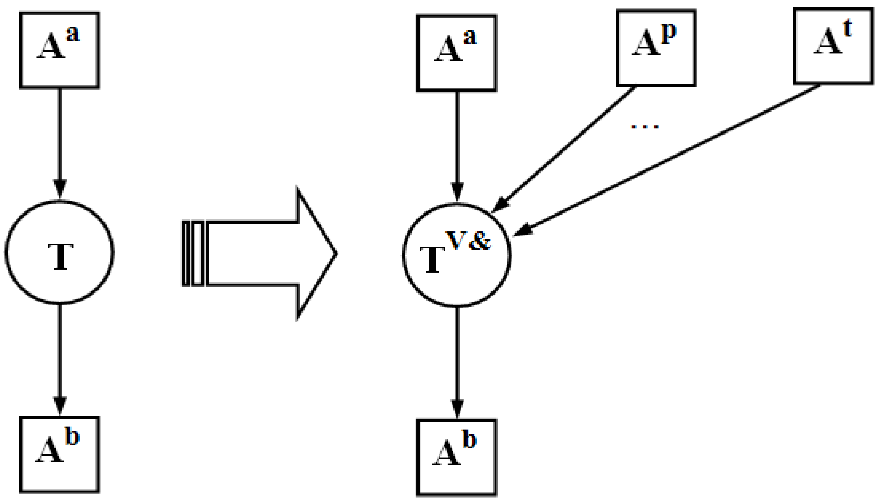

Figure 6a. Adding input accumulators
(source: self study)

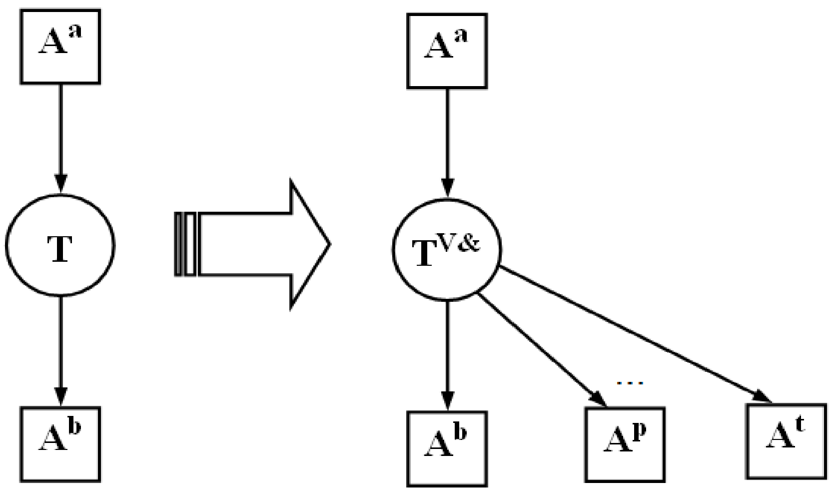

Figure 6b. Adding output accumulators
(source: self study)

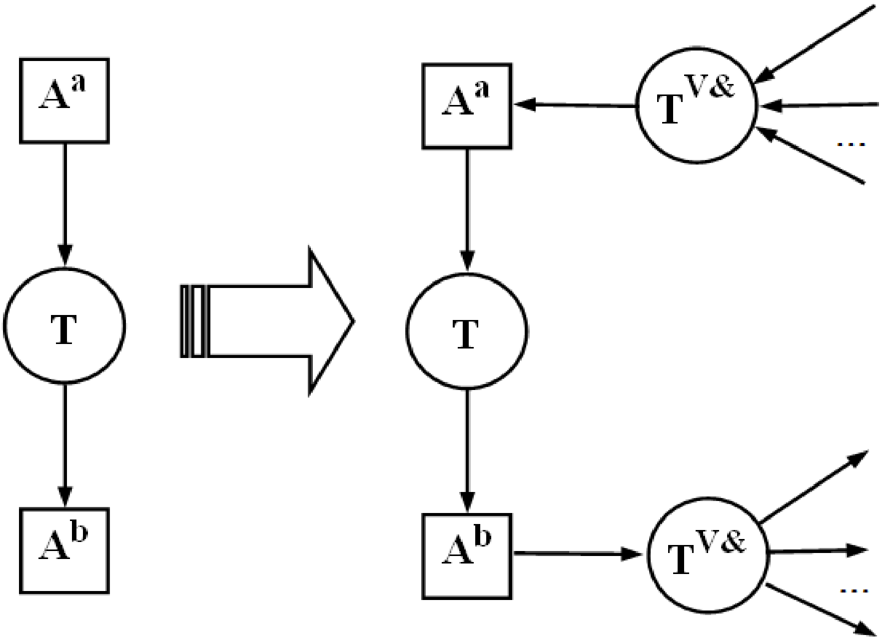

Figure 6c. Adding transformers *(source: self study)*

Presented examples of T-net development do not exploit all network development possibilities. This is especially significant for T-nets with periodically connected accumulators and transformers (see Figure 5c).

It is necessary to emphasize that adding a new transformer into a T-net requires a simultaneous addicting of at least two accumulators (one from input and one from output side).

It is crucial to ask about the possibility to stimulate the activities of a T-net in a situation when it realizes the processing of task flows randomly appearing at its input accumulators. Such network should assure realization of incoming tasks within the set time and cost limitations.

If one assumes that T-net accumulators have limited capacity of stored task markers and that transformers simultaneously realize a limited number of allowable alternative transforming functions in a limited time, these constraints condition the limited of T-net states - where a T-net state is understood as a current placement of markers in all accumulators with simultaneously realized collection of transforming functions.

It is easy to notice that even in case of relatively small T-nets the number of its allowable states grows exponentially in relation to the number of accumulators, its capacity, time characteristics and transformer functions. For example a T-net shown in the Figure 3c, with an assumption that every transformer can have no more than two markers, can have the estimated number of states at the level of 16 thousand without the inclusion of the transformer function realization time.

The important aim of construction and modeling of different T-net variants is the analysis of its correctness according to set system of correctness axioms. These axioms should be determined a priori – before the modeling starts.

Axiom defined net functioning correctness is the first step to prove the correctness of any defined network if one can prove that the net fulfills correctness axioms – it is correct according to the axioms. Axiom correctness proof cannot, however, be a result of tests. It is necessary use the theory of system characterization, formulated by V.A. Gorbatow and confirmed in many elaborations on characterization theory [1-3 and 13].

Network correctness axiom definition needs to refer to its structure features, especially for alternative and parallel transformers, which structure features (number if inputs and outputs) should be in accordance with its technological formulas. In such case a local correctness, for every transformer in relation to connected accumulators, can be defined.

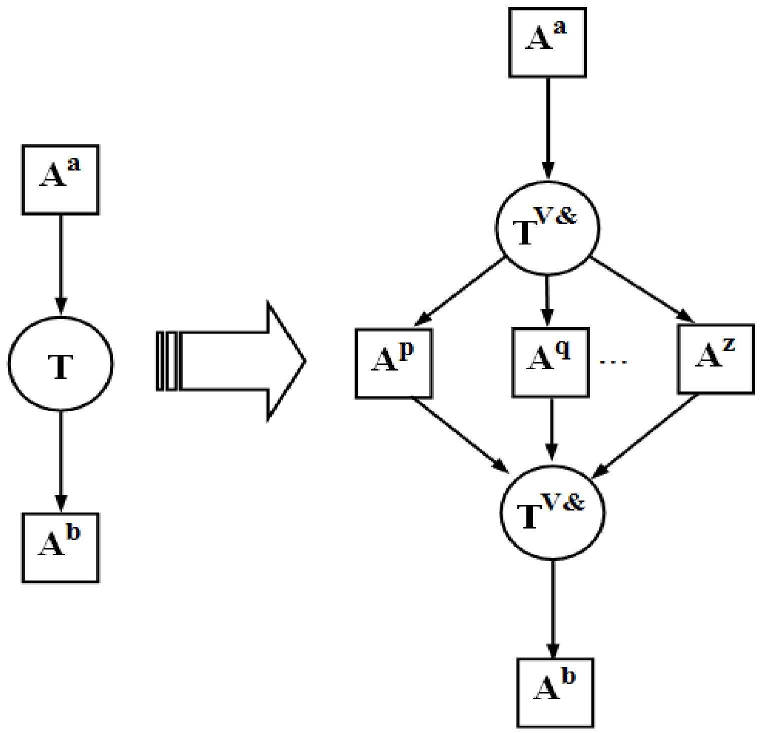

Figure 6d. Transformer decomposition into pair of alternative transformers or pair of parallel transformer *(source: self study)*

It is essential to bear in mind that local correctness is a necessary condition for the functioning of the whole network (global correctness), which is not equal to the sum of local correctness and must be defined in a way that suits the constraints of starting and finishing accumulators in the network (see Figure 2d).

In every case the main task of the T-net task modeling and simulation is the construction of a priori flawless structures or the search the search of errors in existing nets through attempts to prove its correctness.

In case of T-nets a calculation effective solution can be assuming the constructive procedure of correctness assurance or the approach based on the characterization theory.

7 Transforming network design

T-net design should lead to the accomplishment of network that fulfills functional requirements – realizes specific class of tasks in a correct manner (according to given constraints). Therefore the first step is to determine task class for the network to realize. Despite of the obviousness of this statement it is not that simple to fulfill it.

Usually the definition of a product structure in manufacturing activities is not directly connected with the manufacturing technology. Similar situation can be found in service processes, which can be realized in many different manners.

One of the practical issues in effective production and service task realization is the determination of activities necessary for task decomposition into more basic units and the other way around – synthesis of basic tasks results into the final task (or the primary task that was the subject of decomposition).

Task decomposition and task result synthesis is performed in a continuous manner. The main reason for a single task decomposition is to bring it from the planning to operational level (more detailed), which will gather all necessary components that will be later merged (composed) and will provide a result suitable for the final task.

During the procedure of transforming network design one needs to assume that every formulated task will have one corresponding resource with two distinguished states:

- R_z resource distinguished state proceeding the task formulation,
- R'z distinguished state corresponding to the standby task realization.

Task realization can have different results and in boundary cases can lead to partial realization or even cancellation. Every resource participating in task realization, stored in a particular type of T-net accumulator, has its own set of features and its values. Set collection of features determines the class of the resource.

Set collection of resource features values for given class distinguishes resource type of certain class. T-net transformers task is to:

- decomposition of a complex resource from given class and type into partials form other classes till the class and type of elementary resources, which are not subjected to further decomposition; in special cases of the decomposition process there can be only one partial resource – in such case both resources will belong from different classes and different resource types,
- partial resources synthesis, from different classes and types, to a complex resource with a simultaneous determination of resource feature value (setting the type of the complex resource); in special cases the synthesis process, when the feature list is changed, from one partial resource only one complex resource can be created – in this case (similarly to the decomposition process) both resources will belong to different classes and different types of resources,
- change of given class resource type into a new and desired resource of the same class as a result of given type output resource feature values transformation.

T-net design process should be started from the design of type trajectory for the resources of all classes. Type trajectories are the illustration of changes of given resource in technological processes. Properly designed T-net connects decomposition, synthesis and change resource transformers.

8 Summary

The material presents verified concept of T-nets [4]. Verification was based in the classic functionality analysis of Parallel Block Schemes (PBS) [1, 3], colored Petri nets and first models of transforming nets constructed on the basis of PBS schematics [8, 9, 11, 13 and 14].

T-net is build in a manner that connects the technological resource processing aspects with the logical requirements for the order, time and cost of realization of technological operations. T-net structure allows parallel realization of many tasks simultaneously with the consideration of priorities resulting from T-net state monitoring.

Correctness of networks is defined with properly determined axioms, which can be "weakened" or detailed in relation to current T-net state. In each case local and global T-net task realization must be assured.

T-net plays the role of virtual model of real task realization processes. The existence of such model allows to monitor and asses the progress of realized tasks as well as calculations and simulation of task realization strategy.

Proposed T-net theory elements allow the verification of proper functioning axioms without the necessity of testing of network and its elements configuration.

Many of described issues and solutions still have conceptual character and is subjected to verification and change.

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BARRIERS FOR EMPOWERMENT IN ORGANISATIONS ON THE BASIS OF SURVEYS

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Abstract: The objective of the paper is to present the results of investigation regarding barriers for empowerment in the context of organisational problems of companies, their application in the search for solutions, and adequate implementation in order to increase the efficiency of the processes of decision-making.

Key words: organization, organizational structure, manager, personnel, superior, empowerment, delegating power.

1 Introduction

One of the concepts of personnel management in organisations which lead to strength and independence of employees is empowerment – which is particularly controversial among practitioners and theoreticians of management. The notion of empowerment is often reduced to a simple delegation of power, and it is this kind of simplifications which imply numerous misunderstandings and objections to the effect that this is an "old formula in a new disguise " [4, p. 684-695].

Empowerment is nevertheless a far more complex and multidimensional idea – it comprises virtually all the aspects of functioning of an organisation. It links the organisational level (organisational empowerment) with the psychological, individual plane of each employee, and this is precisely what implies its power [5, p. 1]. The organisational empowerment may be construed as a body of deliberate managerial actions and practices, which give the subordinates power, control and authority. The purpose of those actions is empowering of employees – namely their strength and independence through an organisational context which gives rise to the state of empowerment, i.e. empowerment at the individual and psychological plane. The psychological empowerment is perception of being empowered. R.M. Kanter, who defines the organisational empowerment as delegating of power to employees, considers a continuum of power – from absolute powerlessness to the state of being empowered [2, p. 358-370].

Since the modern capitalism is a recent phenomenon in our country, it seems important to present the situation of the Polish companies and their properties which are relevant from the point of view of implementation of empowerment. This is precisely the subject of the paper.

2 Scope of investigation

The subject of the analysis are the results of the surveys realised in June 2009 in state and private companies of different sizes in the province of Mazowsze. The analysis was realised in 50 randomly selected companies. 500 questionnaires were handed out, and 218 of them were filled out and returned. The questionnaire was anonymous and realised without participation of third parties.

The presented data are a part of a wider project which includes more specific and detailed problems. This paper presents a concise summary of the most important properties of the companies in Mazowsze and their employees, as regards the perspective of implementation of empowerment. The other results and conclusion implied by the study, which relate to more specific issues will be published in two other papers.

3 Analysis and interpretation of empirical studies

Analyzing the obtained data regarding the level of education of respondents, it may be noted that the most numerous groups are those with post-secondary and secondary education. The former includes 63 people (29,1% of all the respondents), while the latter includes 50 people (23,1% of all the respondents). The group with an M.A. includes 46 people (21,3% of all the respondents), while the group with a B.A. or an engineering degree includes 39 people (18,1% of all the respondents). Among all the respondents may also be distinguished a group of those who have a postgraduate studies and solely vocational studies. Among all the respondents there were 14 people (6,5% of all the respondents) with post-graduate studies and solely 4 people (1,9% of all the respondents) with vocational education.

While evaluating the level of education of the aforementioned groups of respondents, it must be noted that most managers and middle-level directors have an engineering degree (Table 1). 5 managers have an engineering degree (25% of all the managers) as well as 9 middle-level directors (37,5% of all the directors in this group). Most commonly the low-level managers have post-secondary education (6 directors, which means 50% of this group of respondents), while independent specialists have an M.A. degree (12 independent specialists, which means 41,4% of this group of respondents).

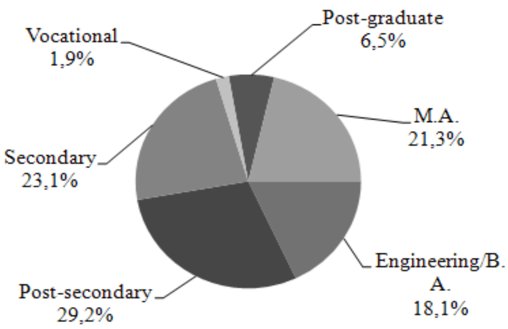

Figure 1. Level of education of the respondents *(source: [3])*

Most commonly specialists have post-secondary education (12 of them, which means 30% of this group of respondents), line employees have a secondary education (6 of them, which means 25% of this group of respondents), and assistants have a post-secondary education (5 of them, which means 41,7% of this group of respondents).

It must be emphasized that only 3 managers have a post-graduate education (15% of this group of respondents), which is the case of two middle-level directors (8,3% of this group of directors) and 5 independent specialists (17,3% of this group of specialists). Such a high level of education is also the case for one specialist (2,5% of this group of respondents) and one line employee (6,3% of this group of respondents).

The data obtained in regard to the functions the respondents have in the companies where they are employed indicate that the majority were specialists and senior specialists. Specialists formed a group of 40 people (18,5% of all the respondents), while independent specialists formed a group of 29 people (13,4% of all the respondents). What is important is that the study included also middle- and low-level directors and managers. The former group of those respondents was formed by 24 people (11,1% of all the respondents). The group of managers was slightly less numerous and it included 20 people (9,3% of all the respondents), while the group of low-level directors included 12 respondents (5,6% of all the respondents). Among the respondents there were also line employees and assistants. The former group included 16 people (7,4% of all the respondents), while the latter included 12 people (5,6% of all the respondents). Apart from the aforementioned groups of respondents, there was another group of respondents specified as „others".

Table 1. Level of education for specific groups of respondents *(source: [3])*

Position	Education					
	Post-graduate	M.A.	Engineering/B.A.	Post-secondary	Secondary	Vocational
manager	3	4	5	3	5	
middle-level director	2	4	9	5	4	
low-level director		1	1	6	4	
independent specialist	5	12	7	2	3	
specialist	1	9	7	12	11	
line employee	1	2	2	4	6	1
assistant			2	5	4	1
others	2	14	6	26	13	2

This most numerous group which included 63 people (29,2% of all the respondents) was formed by respondents employed at positions which are different to those specified above. Since this group included people employed at various positions, which require distinct qualifications, and who have different levels of education (e.g. human resources clerk, security personnel and caretaker), in spite of a relatively elevated number of people in this group, the discussion omit the indications of this group of respondents.

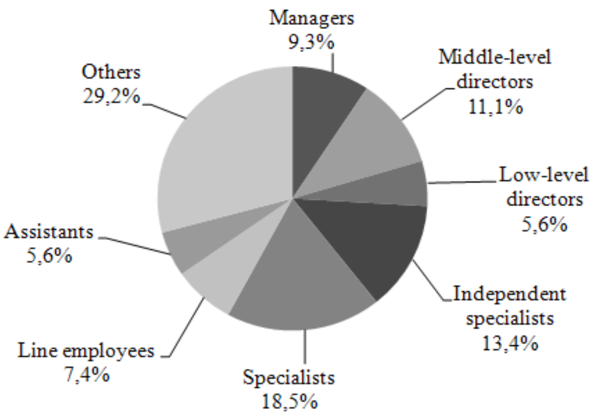

Figure 2. Positions occupied by the respondents
(source: [3])

Analyzing the relevant data regarding the seniority of the respondents, it may be noted that the seniority of 1/3 of the respondents is shorter than two years, and the seniority of a similar group exceeds ten years. The seniority of slightly more than 20% of the respondents amounts to 2-5 years, and the seniority of the remaining 15% is 6-10 years.

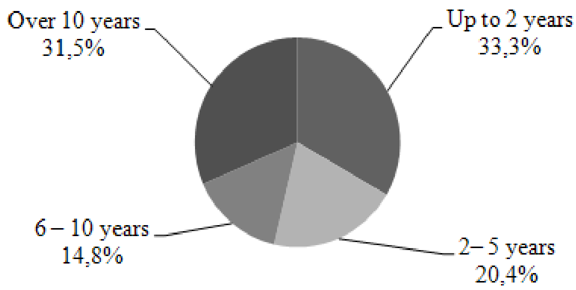

Figure 3. Seniority of the respondents
(source: [3])

What is interesting is the data regarding seniority in relation to the positions of the groups of respondents.

The data presented in Table 2 indicate that the seniority of managers and directors is relatively long. The seniority of 70% of the total number of managers amounts to at least six years, while six among the managers (30% of this group of respondents) have been on their positions for more than ten years. The seniority of as many as 14 middle-level directors (58,4% of this group of respondents) and eight low-level directors exceeds 10 years. The situation in both the groups of specialists is different, since the seniority of the majority of them does not exceed five years. Furthermore, 17 independent specialists (58,6% of this group of respondents) and 22 specialists (55% of this group of respondents) have been on their positions for not more than five years. In case of line employees, the seniority of six among them (37,5% of this group of respondents) exceeds ten years, while over 66% assistants have been on their positions for not more than two years.

Table 2. Seniority of specific groups of respondents
(source: [3])

Position	up to 2 years	2-5 years	6-10 years	over 10 years
manager	1	5	8	6
middle-level director	1	6	3	14
low-level director		2	2	8
independent specialist	9	8	6	6
specialist	14	8	5	13
line employee	4	5	1	6
assistant	8	1		3
others	36	8	7	12

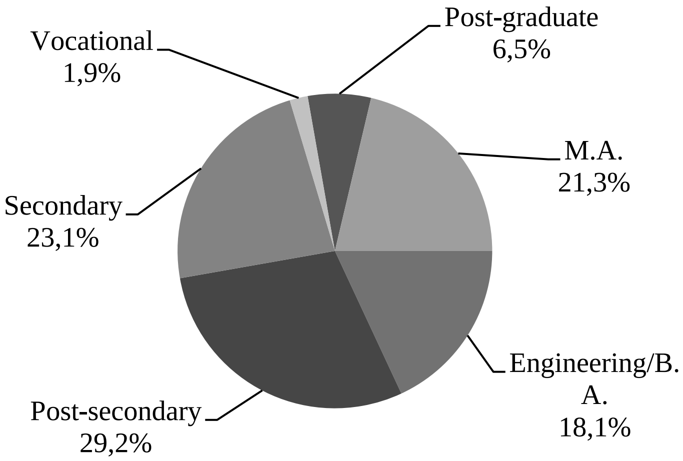

Figure 4. Properties of the respondents' companies
(source: [3])

Having classified the respondents regarding the form of ownership of their companies, as well as the number of employees in those companies, it was determined that the most numerous group of respondents amounting to 60 people (27,8% of all the respondents) is employed in state companies which employ at least 151 employees. Slightly fewer, namely 47 respondents (21,8% of all the respondents) are employed in private companies which also employ at least 151 employees. The fewest respondents work in state companies which employ 51-150 people.

It must be also noted that most managers, i.e. eight of them (40% of this group of respondents) are employed in the smallest private companies, which employ between 3 and 50 employees. Most directors are employed in state companies which employ more than 150 employees, since in such companies are employed as many as nine middle-level directors (45% of this group of respondents) and seven low-level directors (58,3% of this group of respondents). In the same group of companies there are most respondents who are employed at a position of specialist and independent specialist. In case of specialists, there are as many as 20 people (50% of this group of respondents), while in case of independent specialists the group amounts to eight people (27,6%). It must be emphasized that the same percentage of respondents who are employed as independent specialists work in private companies which employ more than 150 employees.

Analyzing the structure of employment of respondents employed as assistants and line employees, it may be noted that most assistants, i.e. three of them (25% of this group of respondents) work in state companies which employ between 51 and 150 employees, and the same number in private companies which employ more than 150 employees, while most, namely eight line employees (50% of this group of respondents) work in state companies which employ more than 150 employees. The aforementioned distribution of employment indicates that the conclusions from the analysis of indications of the respondents may not reflect adequately the analysed aspects of empowerment in state companies which employ up to 50 employees.

Coming to a conclusion of the analysis of the studied population, we must draw attention to the education of the respondents in relation to the „properties" of their companies, since assuming that during selection of respondents their education was not an important factor, the distribution of education in accordance with the form of ownership and the size of the companies, taking into account the percentage of the respondents employed in the specified groups of companies, permits to determine general tendencies in the employment policy in these groups of companies.

Table 3. Number of respondents employed in companies of distinct forms of ownership and size, in accordance with their education *(source: [3])*

Education	Total	State company Number of employees			Private company Number of employees		
		3-50	51-150	> 150	3-50	51-150	> 150
post-graduate	14	4	2	6	1	1	
M.A.	46	9	3	16	4	3	11
engineering	39	3	5	9	9	8	5
post-secondary	63	4	3	13	16	7	20
secondary	50	7	6	14	7	5	11
vocational	4			2	2		
others							
state companies							
3 – 50 employees	27	27					
51 – 150 employees	19		19				
>150 employees	60			60			
private companies							
3 – 50 employees	39				39		
51 – 150 employees	24					24	
>150 employees	47						47

Analysing the data in Table 3, it may be noted that as many as 12 people with post-graduate education (85,7% in this group of respondents) and 28 people with an M.A. (60,9% of this group of respondents) are employed in state companies of different sizes, although those companies employ only 49,1% of all the respondents. Such disproportions in the proclivity to people post-graduate education or an M.A. in state and private companies (the rate is at least 6:4) may constitute a basis for the hypothesis that the intention of private companies, in opposition to state companies, is primarily to employ people with a specific specialization, who in extreme cases are „human automata" for the employers. The high probability of this thesis may be illustrated by the fact that as many as 43 respondents with a post-secondary education (68,3% of all the respondents) are employed in private companies, in which work 50,1% of all the respondents. The aforementioned statements are also confirmed by the requirements for candidates and the policy of recruitment for new plants, as was the case in the Opel plant in Gliwice.

Analysing the responses given by the respondents regarding specific actions and attitudes, which are characteristic for the respondent's superior, if they delegate a part of their authority. The respondents might indicate that the superior: tightens the control and supervision, reduces the control and supervision, rewards commitment and initiative, facilitates access to information, questions skills and qualifications of the employees, and demonstrates a lack of confidence towards the employees.

The respondents gave altogether 338 responses; since 217 responses related to version 2-4, and solely 121 responses related to version 1 as well as 5 and 6, it may justify a thesis that the respondents believe the attitudes of their superiors once they have delegated power to the subordinates are more often correct than not (the relation is 217:121).

Altogether 39,4% of all the respondents indicated that the superior, once he has delegated power to the subordinate, increases the control and supervision of such a person, while solely 16,2% of the respondents indicated that the superiors in such situations do precisely the opposite, namely limit the control and supervision.

A significant part of the respondents, namely as many as 43,9%, indicated that after delegation of power the superior rewards commitment and initiative of the subordinates, and 40,3% of the respondents indicated that in such situations superiors provide a better access to information for the subordinates. A relatively small group, namely 7,4% of the respondents indicated that in such situations the superior questions the skills and qualifications of the employees, and 9,3% indicated that the superior demonstrates a lack of confidence towards the employees.

Analysing the distribution of responses given by the respondents (from the groups of respondents specified in relation to their positions) regarding control and supervision exercised by the superiors after delegation of power to the subordinates, it may be noted that the respondents in all the groups more often indicate that the superiors in such situations increase supervision and control of the subordinates rather than reduce them. The highest percentage of the people who indicate an increase of supervision is in the group of assistants (58,3%) and managers, middle- and low-level directors (50% each), and the lowest in the group of specialists (25%). The highest percentage of the people who indicate a decrease of control in such situations is in the group of low-level directors (33,3%) and managers (30%), while the lowest is in the group of line employees (6,3%).

As regards the level of those percentage values, it might be said that generally the higher position occupied by the respondents, the higher the percentage of those who indicate that after delegation of power, the superior limits supervision and control.

Analysing the responses given by the respondents regarding (taking into account their education), it may be said that they believe that after delegation of power, the superiors rather increase than limit the control. The highest percentage of the people who indicate an increase of supervision is in the group with an engineering education (46,1%), post-secondary education (44,4%) and post-graduate education (42,8%), and the lowest in the group of people with an M.A. (30,4%). The highest percentage of the people who indicate a decrease of control in such situations is in the group of people with an M.A. (30,4%), while the lowest is in the group of people with an engineering education (7,7%).

It must be also emphasized that the longer the seniority, the lower the percentage of the respondents who say that the superiors intensify the control (from 43% in the group of respondents whose seniority is shorter than two years to 36,8% in the group of respondents whose seniority is longer than ten years). The responses also indicate that the longer the seniority, the higher the percentage of those who believe that the superiors reduce control (from 11,1% in the group of the respondents whose seniority is shorter than two years to 20,6% in the group of the respondents whose seniority is longer than ten years). Coming to a conclusion of the analysis of responses regarding control, it must also be indicated that who indicated an increase of control in such situations were the respondents employed in private companies. Do the managers of such company believe that „the master's eye makes the horse fat"? The reason for a relatively low number of responses indicating intensification of supervision and control of people employed in state companies is probably the fact that the directors in such companies do not care much about their job.

As regards the 95 responses (43,9% of all the respondents) related to the superiors rewarding commitment and initiative in a situation of delegation of power, it must be emphasized that the superiors of the other group of respondents (56,1% of all the respondents) probably do not perceive or do not want to perceive the motivational function of rewarding. Without dwelling however upon the subject of motivation and its absence, it should be noted that the highest percentage of people who claim that their superiors in the indicated situations reward commitment and initiative is in the group of managers (55%) and assistants (50%), and the lowest in the group of line employees (37,5%) and low-level directors (25%). The highest percentage of the respondents, who claim that such rewarding takes place, is in the group of people with an M.A. (50%), and the lowest in the group of people with a post-graduate education.

However who indicates such rewarding of the employees most commonly are the respondents whose seniority amounts to 6-10 years (62,5% of the total number of people in this group of respondents), and where such a response is least common is among those whose seniority is the longest (32,4% of the total number of people in this group of respondents), but there is no evident correlation between the seniority and the frequency of such responses. It should also be emphasized that such rewarding is more frequently indicated by the respondents working in companies which employ up to 50 employees.

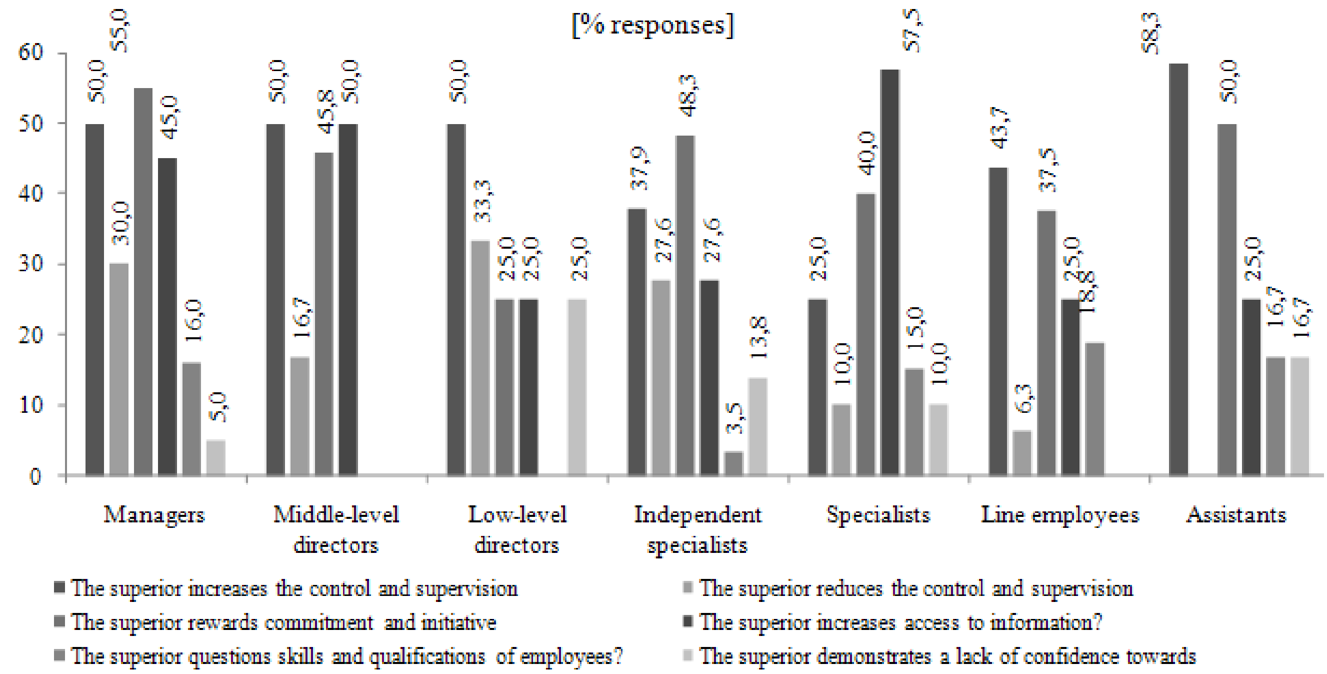

Figure 5. Respondents' responses to the question which among the specified actions and attitudes are characteristic for their superior, if he delegates a part of his authority
(source: [3])

Taking into account the 87 responses (40,3% of all the respondents) regarding an increasing access to information after delegation of power, it must be emphasized that almost 60% of the respondents' superiors do not consider the fact that apart from the crucial information in the decision-making process, the access to the information which might not be indispensable within the given scope of responsibilities has also a major motivational importance. The highest percentage of the respondents who indicated that in the specified situations their superiors increase the access to information is in the group of specialists (57,5%) and middle-level directors (50%), while the lowest is among the low-level directors, line employees and assistants (25% each). The distribution of the percentage of responses in accordance with the education is approximately equal (from 36% to 46%), except for the employees with a post-graduate education (21,4%), who probably before had a wide access to different kinds of information regarding the company.

Relatively infrequently the respondents responded that after delegation of power the superiors demonstrate doubts about skills and qualifications of the employees (16 responses – 7,4% of all the respondents), as well as a lack of confidence towards the employees (20 responses – 9,3% of all the respondents). Taking into account the number of responses indicating a higher level of control, it may be assumed that the two specified reasons do not exhaust the list of the most important reasons for an increase of supervision. Due to this situation and to the relatively small number of responses, they will be not analysed any further.

The distribution of responses of people (from groups of respondents defined in accordance with the position they occupy) to the question which of the specified barriers may exist in the case of the person delegating power is presented in Figure 6.

The analysis of the presented data implies that the most common barrier for the person who delegates power to the subordinates indicated by the respondents is the desire to know all the details (33,3% of all the respondents), the erroneous conviction that „I can do that better" (23,2 % of all the respondents), no confidence towards the subordinates and reluctance towards promotion of the subordinates (in each case 18,9% responses of all the respondents); the least common barrier indicated by the respondents is the inability to organise the control of the delegated activities (6,5% responses). It must also be noted that approximately 10% of the respondents stated that they are not able to identify such barriers, and the same percentage of the respondents said they have no specific opinion about the subject.

The analysis of the distribution of responses of the people (from groups of respondents defined in accordance with the position they occupy) to the question which of the specified barriers may exist in the case of those who delegate power, implies that the highest percentage of managers (60%), middle-level directors (37,5%) and low-level directors (33,3%), as well as line employees indicated that such a barrier is a desire to now all the details. It must also be noted that with equal frequency the low level directors indicated a sense of threat felt by the person delegating power, a lack of acceptance of the possibility of committing an error by the subordinate and a lack of confidence towards the subordinate. The independent specialists most commonly indicated a lack of confidence towards the subordinate (27,6%), while the specialists and assistants indicated an erroneous conviction of the superiors that they can do the tasks better (30% and 33,3%, respectively).

The analysis of the distribution of responses of the people (from groups of respondents defined in accordance with their education) to the question which of the specified barriers may exist in the case of those who delegate power, implies that the respondents from all the specified groups most commonly perceived the barrier to spring from the desire to now all the details. This value amounted in the case of people with a post-graduate education to 42,8%, in the case of those with an M.A. to 32,6%, in the case of those with an engineering education to 41%, in the case of those with a post-secondary education to 25,4%, in the case of those with a secondary education to 36%, and in the case of those with a vocational education to 25%. It must also be emphasized that the majority of the respondents in virtually all the groups defined in accordance with the form of ownership and size of the company (except for the respondents working in state companies which employ more than 150 employees) perceived the barrier to spring from the desire to now all the details.

The percentage was contained in the range between 21% and 45%. In the case of the respondents working in state companies which employ more than 150 employees, the majority perceived the barrier to be the erroneous conviction of the superiors that they can do the tasks better (25%). Most people whose seniority is shorter than two years and longer than ten years perceived the barrier to be related to be overburdened with work; the people whose seniority is 2-5 years pointed out to bad organisation of work; and the people whose seniority is longer than two years, but does not exceed five years, indicated the fear of responsibility.

Due to the aforementioned factors as the most important barriers, it must be assumed that the desire to know all the details, the erroneous conviction that “I can do that better”, sense of threat, a lack of acceptance of the possibility of an error committed by a subordinate, and a lack of confidence towards the subordinates.

The analysis of the responses given by the respondents implies that the most common barrier indicated by the respondents as regards those who power is delegated to is being overburdened with work (33,3% of all the respondents), a lack of experience (20,2 % of all the respondents), fear of responsibility, independence and an increase of the difficulty of work (18,5% each), as well as an escape from responsibility and bad organisation of work (18,1% each). It must also be noted that approximately 15% of the respondents stated that they are not able to indicate such barriers, and approximately 10% of the respondents declared they have no specific opinion on the subject.

The distribution of responses of people (from groups of respondents defined in accordance with the position they occupy) to the question which among the specified barriers may exist in the case of the people power is delegated to, implies that the highest percentage of managers (45%) indicated the escape from responsibility, the middle-level directors indicated the fear of responsibility and independence, as well as being overburdened with work (25% each). The latter was also mentioned by most independent specialists (41,4%), specialists (35%) and line employees (18,8%).

It must also be noted that the identical percentage of line employees perceived the barriers that may exist in the case of the people power is delegated to, apart from being overburdened with work, to relate to a bad organisation of work and excessive subordination to the superiors. In the other groups of respondents most low level directors (33,3%) and assistants (25%) indicated fear of responsibility and independence.

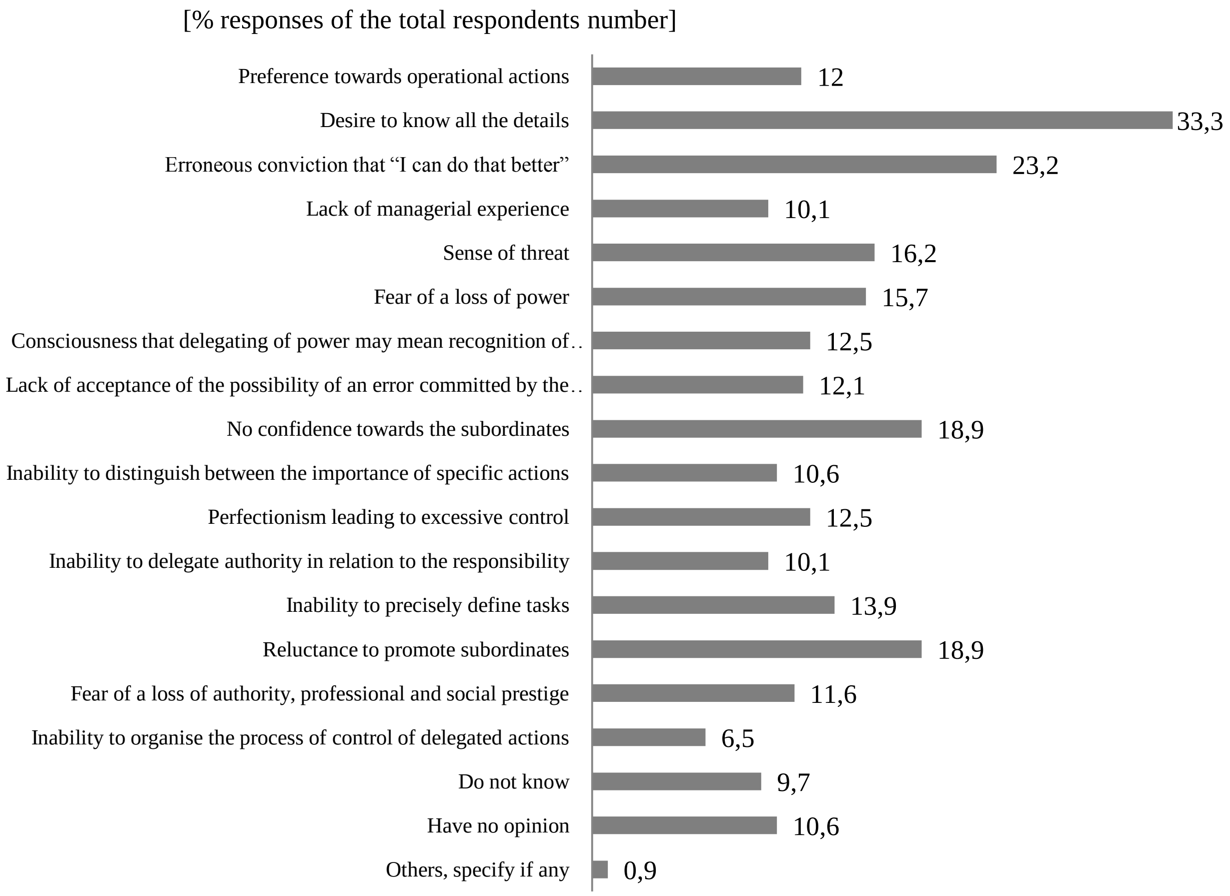

Figure 6. Barriers of those who delegate power
(source: [3])

The distribution of responses of people (from groups of respondents defined in accordance with their education) to the question which among the specified barriers may exist in the case of the people who delegate power implies that most people with a post-graduate education fear of responsibility and independence, as well as fear of changes (50% each), most people with an M.A. (58,7%), a post-secondary (33,3%) and secondary education (28%) indicated an escape from responsibility, and most people with an engineering education (33,3%) indicated a bad organisation of work. Since at the same time the respondents regardless of the form of ownership of their company and its size (identified with the number of employed persons) most commonly perceived the most serious barriers to be bad organisation of work, fear of responsibility and independence, and being overburdened with work, then the most important barriers that might exist in the case of people power is delegated to may be considered to be escape from responsibility, fear of responsibility and independence and being overburdened with work, bad organisation of work and excessive subordination to the superiors.

The distribution of responses of people (from groups of respondents defined in accordance with the position they occupy) to the question which among the specified barriers may exist in the case of the people power is delegated to, implies that the highest percentage of managers (45%) indicated an escape from responsibility, middle-level directors indicated a fear of responsibility and independence and being overburdened with work (25% each). The latter was also indicated by most independent specialists (41,4%), specialists (35%) and line employees (18,8%). It must also be pointed out that the identical percentage of line employees perceived the barriers that may exist in the case of the people power is delegated to, to relate also to a bad organisation of work and excessive subordination to the superiors. In the other groups of respondents most low level directors (33,3%) and assistants (25%) indicated fear of responsibility and independence.

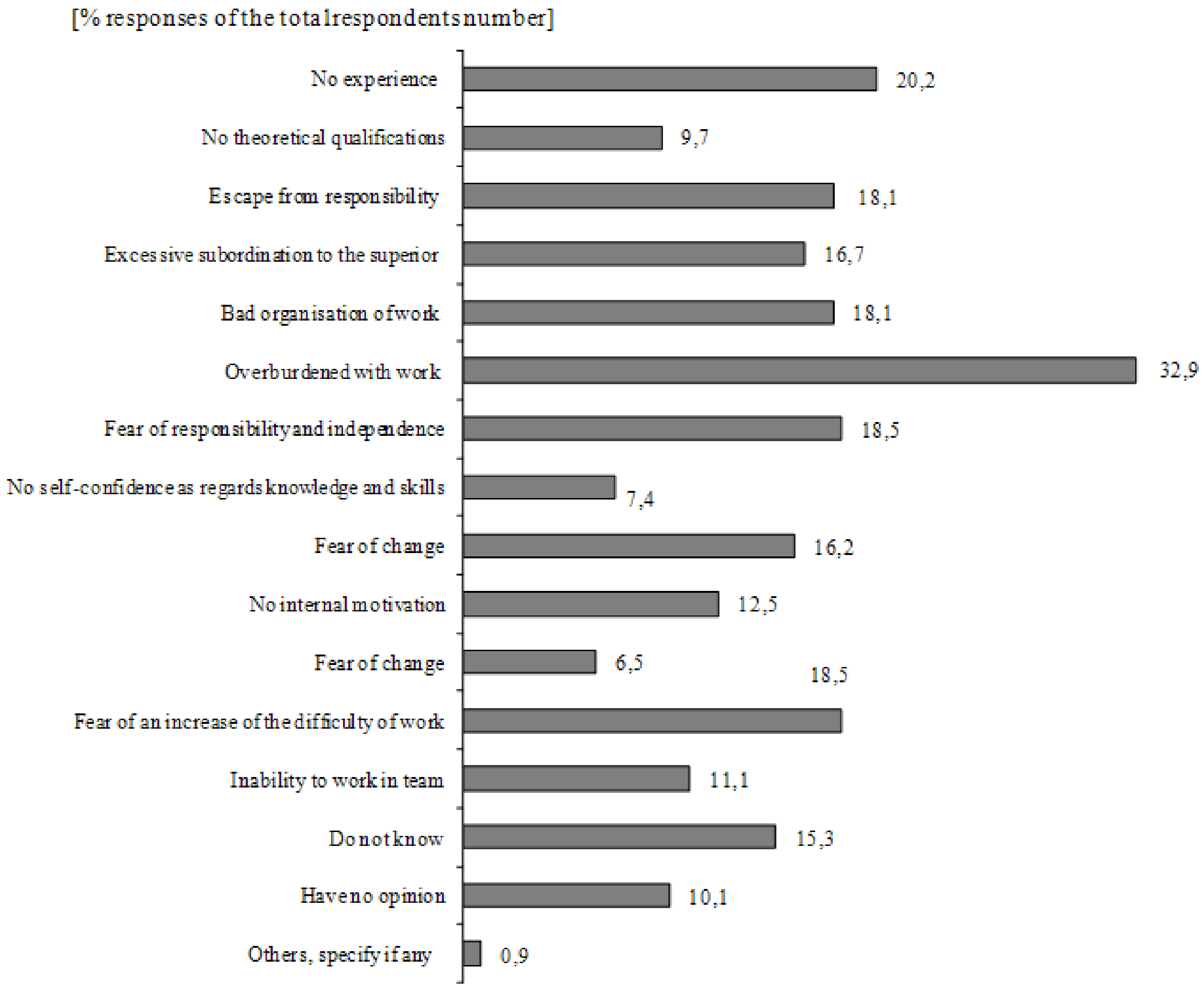

Figure 7. Barriers which exist in case of employees power is delegated to
(source: [3])

The distribution of responses of people (from groups of respondents defined in accordance with their education) to the question which among the specified barriers may exist in the case of the people who delegate power implies that most people with a post-graduate education fear of responsibility and independence, as well as fear of changes (50% each), most people with an M.A. (58,7%), a post-secondary (33,3%) and secondary education (28%) indicated an escape from responsibility, and most people with an engineering education (33,3%) indicated a bad organisation of work. Since at the same time the respondents regardless of the form of ownership of their company and its size (identified with the number of employed persons) most commonly perceived the most serious barriers to be bad organisation of work, fear of responsibility and independence and being overburdened with work, the most important barriers that may exist in the case of people power is delegated to include an escape from responsibility, fear of responsibility and independence and being overburdened with work, a bad organisation of work and excessive subordination to the superiors.

An analysis of the data presented in Figure 8 implies that the external barrier which precludes delegation of power, which is most commonly indicated by the respondents is the single-person management tradition (24,5% of all the respondents), a lack of qualified personnel (24,1% of all the respondents) and misunderstandings regarding the scope of power and responsibility (22,7% of all the respondents). It must also be noted that approximately 10% of the respondents stated that they are not able to identify such barriers or have no specific opinion on the subject.

The distribution of responses of people (from groups of respondents defined in accordance with the position they occupy) to the question which among the specified external barriers preclude delegation of power implies that the highest percentage of managers (40%) and middle-level directors (33,4%) indicated the single-person management tradition. Most low level directors (25%), independent specialists (37,9%) and specialists (32,5%) perceive the most important barrier in a lack of qualified personnel, while line employees (25%) and assistants (41,7%) indicate the necessity to make quick decision while there is no time to explain the principles of delegation of power. It must also be pointed out that the low level directors apart the lack of qualified personnel frequently indicated (25% people in this group of respondents) a lack of employees willing to participate, while the line employees perceived an additional barrier in the misunderstandings regarding the scope of power and responsibility (25% of the people in this group of respondents).

The distribution of responses of people (from groups of respondents defined in accordance with their education) to the question which among the specified external barriers preclude delegation of power implies that most of the people with a post-graduate education (35,7% of this group of respondents) perceives the barrier in a vertical and downward flow of information, while the people with an M.A.

(34,8%) and an engineering education (28,2%) believe the barrier is a lack of qualified personnel. The people with a post-secondary education most commonly indicated (23,8%) a lack of financial resources; while the people with a secondary education indicated the tradition of single-person management (32%). The people with a vocational education were not able to identify any barriers. It must also be pointed out that the people with an M.A. perceived such a barrier with an equal frequency (34,5%) as in the case of a lack of qualified personnel in misunderstandings regarding the scope of power and responsibility.

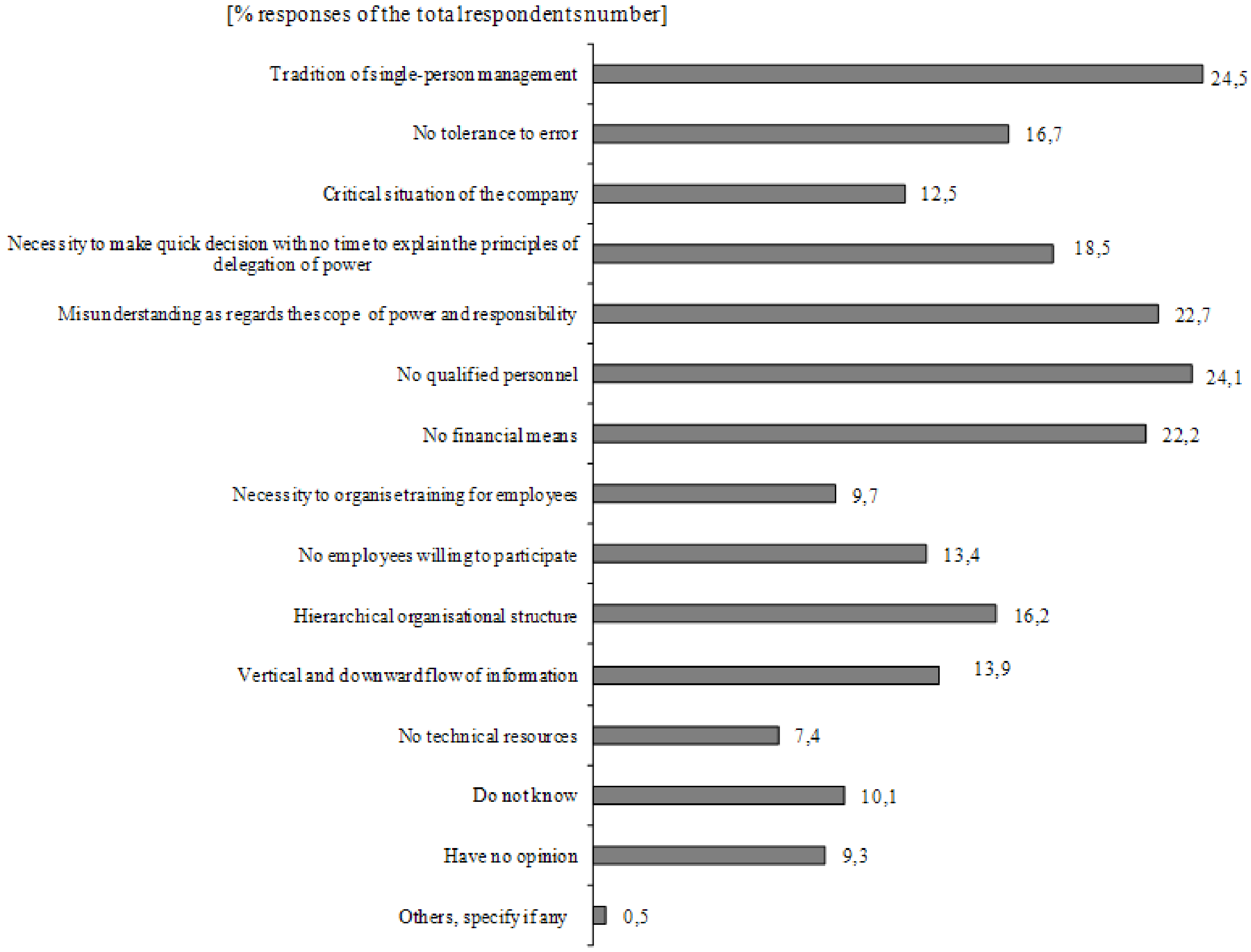

Figure 8. External barriers precluding delegation of power

(source: [3])

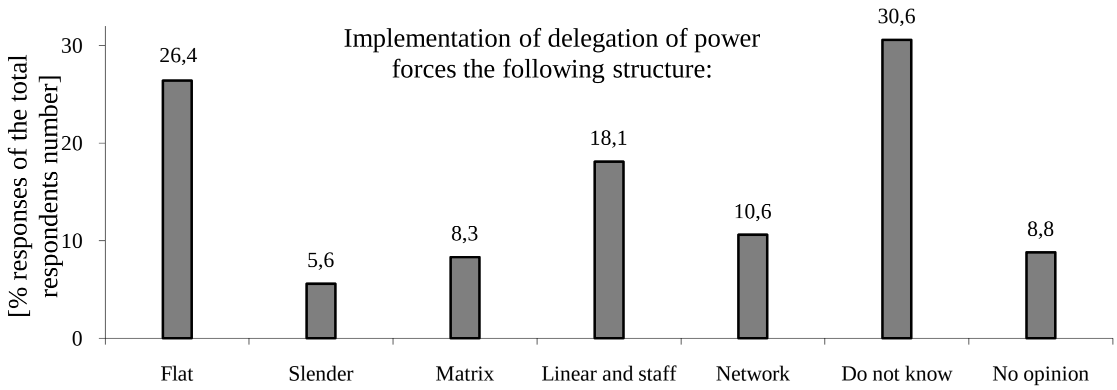

Figure 9. Organisational structure forced by delegation of power *(source: [3])*

The distribution of responses of people (from groups of respondents defined in accordance with the seniority of the groups of respondents) implies that solely those whose seniority did not exceed two years most frequently perceived the barrier to be the tradition of single-person management, while those whose seniority amounted to more than two years most frequently perceived the barrier to consist in misunderstandings regarding the scope of power and responsibility and a lack of qualified personnel. Considering the distribution of the responses (from groups defined in accordance with the form of ownership of the company and the number of the employees) we come to a conclusion that the respondents employed in state companies most frequently perceived the barriers in a lack of financial resources, the tradition of single-person management, a lack of qualified personnel and a hierarchical organisational structure.

The conclusions which spring from the realised analyses of the distribution of responses given by the respondents imply that among the specified barriers which preclude delegation of power, the most important ones are the tradition of single-person management, misunderstandings regarding the scope of power and responsibility, a lack of qualified personnel and al lack of adequate financial means. Sometimes delegation of power is precluded by a hierarchical organisational structure and a vertical, downward flow of information.

During the following part of the study the respondents were expected to indicate the type of the organisational structure which is forced by delegation of power. The total number of 216 respondents gave 235 responses, while most respondents (26,4%) indicated that delegation of power forces a plane structure, and slightly fewer indicated that it forces a linear-staff structure (18,1%) and a network structure (10,6%). The fewest respondents indicated that delegation of power forces a matrix structure (8,3%) and a slender structure (5,6%). One of the respondents stated that delegation of power causes another type of organisational structure, but gave no details. It must also be pointed out that 8,8% of the respondents have no specific opinion, while as many as 30,6% of the respondents said they did not know what kind of organisational structure is related to the empowerment in their company. The last remark relates first of all to the people with a vocational education, since all the respondents in this group declared they were not able to give any answer to this question.

The distribution of responses of people (from groups of respondents defined in accordance with the position they occupy) implies that the highest percentage of managers (60%), independent specialists (37,9%) and specialists (17,5%) indicated that delegation of power forces a plane organisational structure. It must be pointed out that the same percentage of specialists believe that empowerment forces a linear and staff structure. A similar opinion was expressed by the highest percentage of middle-level directors (37,5%) and low-level directors (25%), assistants (25%) and line employees (18,8%), while the same percentage of people in the last group of respondents believe that delegation of power contributes to formation of a slender organisational structure. A response to this question was most difficult for the people in the group of assistants (58,3%), specialists (35%), line employees (31,2%) and independent specialists (27,6%).

In relation to the percentage values, it might be concluded that generally the higher the position occupied by the respondents, the higher percentage of people stating that delegation of power contributes to forming of a plane organisational structure.

The distribution of responses of people (from groups of respondents defined in accordance with their education) to the question implies that the highest percentage of the respondents of all the specified groups are convinced that delegation of power forces a plane organisational structure. This view was expressed by 21,4% of the people with a post-graduate education, 36,9% of the people with an M.A., 30,8% of the people with an engineering education, 20,6% of the people with a post-secondary education and 24% of the people with secondary education. Such views are also shared by most respondents in all the groups defined on the basis of seniority and most of those who work in private companies distinguished on the basis of the number of employees. Only in the case of state companies which employ more than 150 employees, most employees do not share this view and indicate that empowerment forces a linear and staff structure.

It may be concluded that most respondents believe that implementation of empowerment leads to flattening of the organisational structure, although at the same time a significant part of the people indicated that the modifications in management contribute to forming a linear and staff structure. Taking into account the characteristic features of these types of structures, it must be pointed out that delegation of power generally contributes to streamlining of management.

It should also be pointed out that the fundamental advantage of the linear and staff structure is the fact that such a structure combines the advantages of the linear structure and a functional structure, while the disadvantage of such a structure is the possibility of its gradual evolution („shifting”) towards the functional structure.

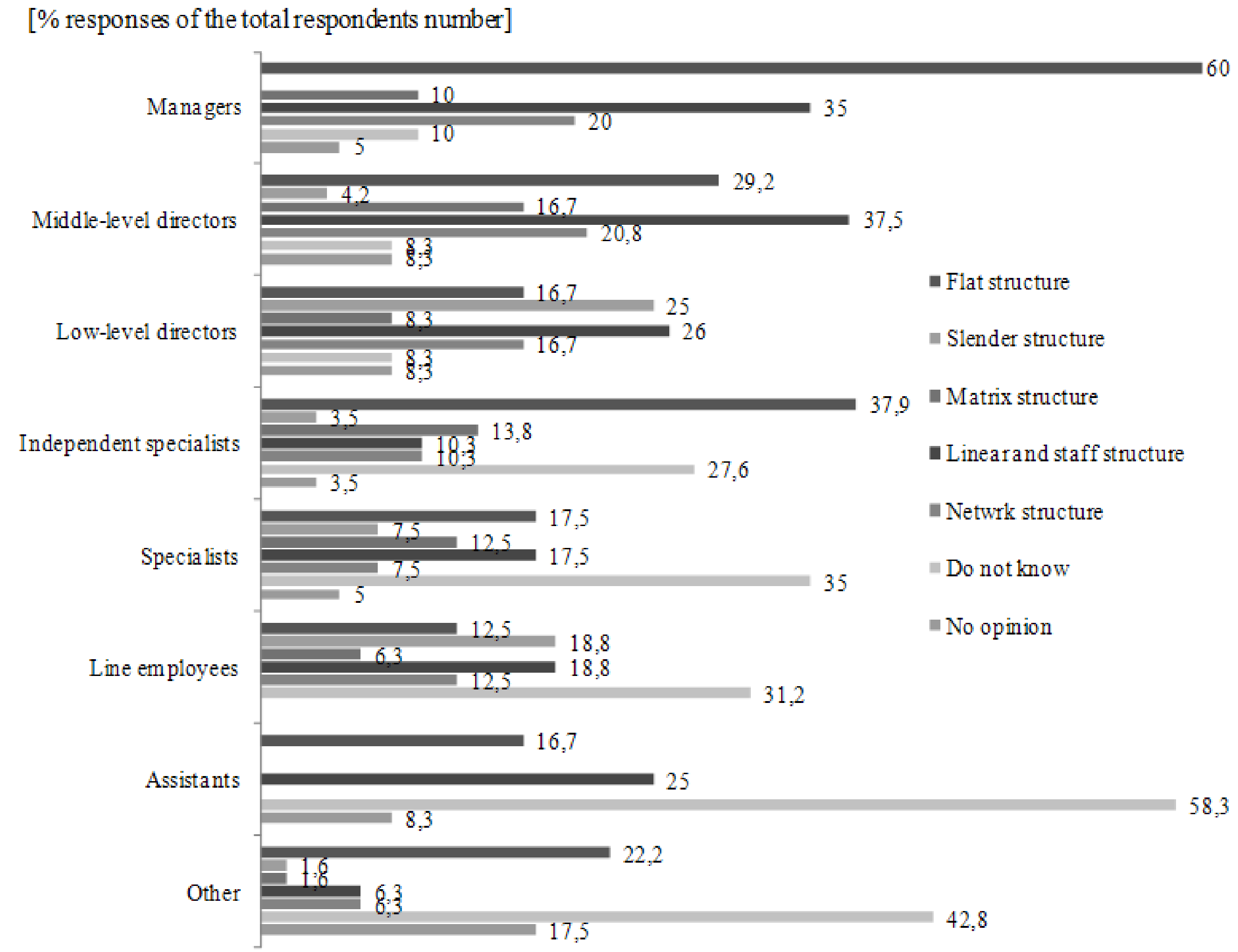

Figure 10. Indications given by the respondents regarding organisational structure forced by delegation of power *(source: [3])*

The effect of such a transformation of the organisational structure may be an excessive development of functional relations between specific levels and their transformation into parallel official relations [1, page 143]. The fundamental advantages of the linear structure are the clear-cut nature and exactitude of the distribution of tasks, authority and responsibility, as well as a full implementation of the principle of unity of management. The basic disadvantages of the structure are a reduction of the role of specialists and the requirement of universalism (versatility) regarding the directors. It must also be emphasized that if in a stable environment and in case of simple technologies the requirement is possible to meet, then in a turbulent environment with complex technologies, there is no practical possibility to fulfil the requirement in question.

4 Summary

Directors, while performing their duties, must draw inspiration from new tendencies regarding performance of such roles in organisations, which have been successful. It applies both to the forming of the structures of such organisations and management. It is suggested to continuously adapt the organisational structure adequately to the requirements of the environment, and build it up around processes including all the stages, from development of a new product to sales and after-sales service. As far as management is concerned, and taking into account the advantage of the organisation, apart from a collective decision-making process, directors should consider implementation of empowerment and subsidiarity, as well as delegation of a part of their duties and authority to the subordinates. Moreover, they should apply broadly interpreted ethics and skilfully manage the „contracts” between the organisation and its members, while moulding their attitudes, they should base upon the knowledge of the characteristic personality traits and prevent cognitive dissonance.

The analysis of the presented data implies that the major barriers in delegation of power are the following: the superior’s desire to know all the details, an erroneous conviction of the management: „I can do that better”, a sense of threat and a lack of acceptance of the possibility of an error committed by the subordinate, and a lack of confidence towards the subordinates. The external barrier precluding delegation of power which was most frequently indicated by the respondents was the tradition of single-person management (24,5% of all the respondents) and a lack of qualified personnel (24,1% of all the respondents) and misunderstandings regarding the scope of power and responsibility (22,7% of all the respondents). As far as the employees power is delegated to are concerned, the principal barriers are being overburdened with work (32,9% of the responses), a lack of experience (20,2% of the responses), fear of responsibility and independence (18,5% of the responses) and an escape from responsibility (18,1% of the responses). In order to implement empowerment in Polish companies the aforementioned barriers must be overcome.

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THE EXPERT KNOWLEDGE COLLECTION METHODOLOGY IN THE DECISION SUPPORT SYSTEM

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Abstract: The purpose of this article is to present and analyse issues connected with the expert knowledge collection methodology in the decision support systems (DSS). The considerations concentrate on a conception of building an information system, based on an application of case-based reasoning method and reasoning based on approximate knowledge. The expert's knowledge is systematically collected in a case base. A mechanism of classical CBR and a logic model of the case base were described. It was assumed that the cases compared with regard to similarity are elements of tolerance space what considerably accelerates the retrieval of satisfying solutions. A local and global measure of case similarity is developed. The method can be used in complex tasks of image identification.

Keywords: Expert system, case-based reasoning (CBR), approximate knowledge, object-attribute-value, tolerance space, CBR mechanism, expert inference, case, case base, similarity of phenomena, matrix of similarity, CBR cycle.

1 Introduction

The expert knowledge – is the experts' knowledge (hence the term: "expert system"). This knowledge requires a continual verification within the scope of its correctness and effectiveness. Hence there is a need of quality evaluation and its social usefulness.

The experts' knowledge working with DSS is an example of an immeasurable factor whose value becomes a real value in a situation when the expert gives up the job – hence there is a necessity to collect (codify) the experts' knowledge in a special DSS knowledge base, whose element is a case base. The case base collects the experience in the form of cases, understood as problems and their solutions, without instructions related to the rules on the basis of which these decisions were made. The experience is a specific knowledge developed when solving the problems, connected with a concrete problem situation, easy to observe and describe, gained through actions and participation in the events. Requiring the experience of the expert, it is expected that the current problems shall be solved basing on the cases that occurred in the past. It is expected that starting to solve a current problem the expert shall try to recall what solutions were applied in a similar situation in the past. If they lead to the success, surely the expert shall try to act in the same or similar way in a given situation as well. If they came to fail earlier and undertaken actions were ineffective, this time surely the expert shall take advantage of the experience and not reuse applied methods, but replace them with other actions. A presented mechanism of using the experience corresponds with reasoning by analogy whose essence lies in the fact that a reasoning person, in the course of solving a problem, goes back in his mind to the past, recalls problems known to him, presents them and models himself upon them. The use of earlier collected experience requires not only to store it in a convenient form but to introduce automated mechanisms of using it as well. A case-based reasoning method (CBR method) – reasoning by analogy – is an artificial intelligence method which imitates a mechanism of experience use.[1]

The purpose of this article is to present and analyse selected issues connected with the expert knowledge collection methodology in the decision support systems. The considerations concentrate mainly on presenting a conception of building an information system with a case base, based on a case-based reasoning method and assumption of making use of approximate knowl-

[1] A CBR conception was presented in the study by Riesbeck C., Schank R., *Inside Case-Based Reasoning*, Lawrence Erlbaum, 1989, later developed by Kolodner J., *Case-Based Reasoning*, Morgan Kaufman Publishers Inc., San Francisco 1993. The information based on Maher M., Balachandran M., Zhang D., *Case-based reasoning in design*, Lawrence Erlbaum Associates, 1995, p. 2 [on:] http://books.google.com (15.01.2010).

edge by a reasoning person[2]. A representation conception of the expert's knowledge in the form of case base is presented in the article. A mechanism of classical CBR and an exemplary logic model of the case base were discussed. Then it was assumed that the cases compared with regard to similarity are elements of tolerance space what allows to realize an introduced assumption. The tolerance spaces as a special type of approximation space were described among other in the study [5]. The elements of these spaces can be compared with each other with regard to similarity. It is assumed that apart from a set of objects (elements), the additional knowledge about similarity within the framework of their features (properties) is possessed as well, however, it is assumed that the similarity occurred in complex structures is based on the similarity occurred in simpler, elementary sets of values. The assumption that the cases are elements of tolerance space affects the CBR mechanism what is presented in a chapter describing an information system model. There is a presentation of expert inference as an example of system operation of a given model in the article as well. A summary concludes the article.

2 The expert's knowledge recorded in the case base

A CBR method or method of the system with a case base is used in making prognostic decisions based on the experience recorded in the case base. It found an application for solving many issues, such as: diagnosing, classification, forecasting, evaluation, interpretation, planning, designing, teaching, knowledge, and experience management [2]. It can be use among other to diagnose events or schedule operations. An application area of the systems with a case base includes these domains which meet the criteria such as: regularity (i.e. phenomena are predictable, execution of the same action for a subsequent time, in the same or similar situations it leads to the same or similar results), regularity, i.e. repeatability, similarity of phenomena, continuity of modelled reality (that is little changes in a modelled domain result in little changes in a way of solving old problems).

The CBR method is based on observation of the expert's reasoning who goes back in his mind to the past, recalls problems known to him, presents them and models himself upon their solutions in the course of problem solving process. Therefore CBR takes advantage of specific knowledge included in situations, experienced in the past, called cases. According to this approach, to put it most generally, a case is a pair: <problem, solution>[3]. A problem as well as a solution posses features (attributes) which can be described by the data of various types of values: e.g. by numbers, symbols, text, sets of values, multimedia, etc. The cases are independent, they are not rules, they are a record of real events. Therefore the case base collects experience in the form of cases, understood as problems and their solutions, without instructions related to the rules on the basis of which the decisions were made. This property distinguishes a system with the case base from an expert system where the knowledge is expressed by means of the rules.

In the systems based on rule-based reasoning, the knowledge is represented by means of facts and rules of if-then type. Reasoning is of cause-effect character. The creation of rule-based expert system requires the knowledge "how" to solve a problem. Therefore the purpose of the construction of the rules is generalization and structurization of the expert's knowledge. The drawbacks of rule-based representation appear in the case when the domain expert is not able to express every possible situation then the built knowledge base can include: gaps (they are constituted by unforeseen situations), discrepancies (they can be removed but it is not easy) and effects of personal opinions of the experts (lack of objectivity). The CBR method is an alternative to rule-based reasoning because – as Riesbeck and Schank state [12]: people-experts are not systems of rules but libraries of experiences.

The knowledge representation by means of cases is the most natural form because it is easier for the domain expert to express his opinion on individual cases (examples), on each severally. It is explained by the fact that the expert gains experiences through the contact and handling of concrete situation in practice, he is engaged in solving concrete problems. It should be noticed that the experts as well as all people use analo-

[2] For the needs of the study it is assumed based on [5], that approximate knowledge is the knowledge arisen on the basis of approximate data encumbered with an error.

[3] Bergmann R., Kolodner J., Plaza E. – *Representation in case-based reasoning*, The Knowledge Engineering Review. Vol. 00:0, 1-4, Cambridge University Press, UK 2005. [on] http://www.iiia.csic.es/People/enric/papers/Representation_in_CBR.pdf , p. 1 (18.11.2009). In the references [2, 13] it is also mentioned the third element of the case – outcome which as an optional one was omitted in the study.

gies, comparing a new, unknown case with the known cases, held in memory, with which they managed already earlier. Just as all people in everyday life, the experts make use of approximate knowledge, arisen on the basis of approximate data encumbered with an error. However it is necessary to be prepared for the fact that evaluations expressed in this way shall include some degree of uncertainty.

3 The CBR mechanism

The solution of current problem through adaptation of solutions used in the past is the essence of CBR. Therefore an idea of the method boils down to an assumption that similar problems have similar solutions. The below figure presents a graphic interpretation of the essence of CBR (see Figure 1).

The CBR mechanism is realized in the 4-phase cycle:

- retrieving a case (or cases) the most similar to the one under consideration in a case base,
- reusing a way of solution of this case (these cases) to solve a current problem,
- revising an old solution (solutions) with the object of its adjustment to the problem under consideration; possible adaptation, modification of solution,
- retaining the problem under consideration together with the used solution as a new case, experience in order to use it later during solving new problems in the future.

Wanting to build an information system using a CBR method it is necessary to challenge many problems into which there should be included [1, 3]: definition of case within the framework of domain, selection of case representation, determination of a way of similarity measurement, selection of retrieval techniques of similar cases and solution adaptation methods.

A next problem related to the CBR is to determine a way of retrieval of cases similar to a given one. In practice, two retrieval techniques dominate [1, 7]: nearest-neighbour retrieval method which consists in reviewing a base, case by case, in order to find the most similar case and inductive retrieval method which creates a decision tree enabling to classify the cases with regard to a decision. The analysis of the references [1, 2 and 13] allows to state that in most CBR applications a nearest-neighbour retrieval method is selected.

A basic problem related to the CBR is to measure similarity between cases; the measurement depends on a way of case representation. The measurement of similarity between cases is based on the following idea: similarity of cases results from similarity occurring within the framework of their features (properties) describing a problem.

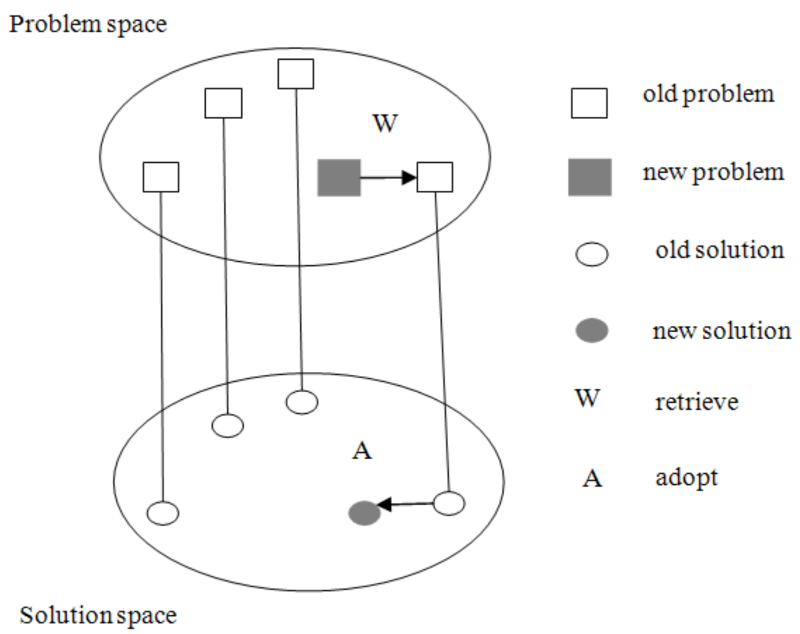

Figure 1. The CBR acc. to Leake
(source: [3])

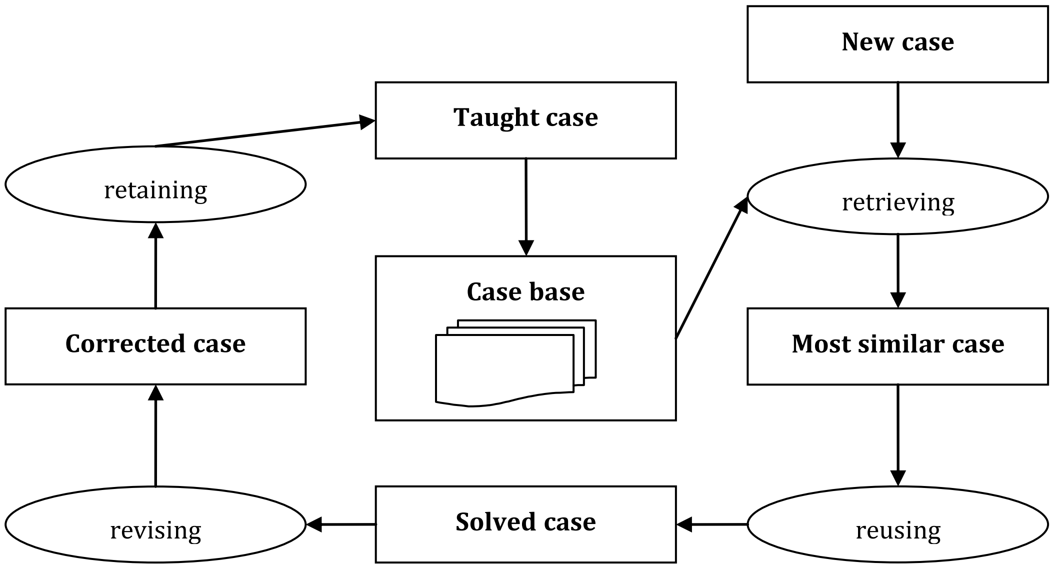

Figure 2. The CBR cycle acc. to Aamodt & Plaza, 1994
(source: self study on the basis of [2])

Additionally it is assumed that a measure of similarity of cases is a reflexive function (every case is similar to itself) and symmetric function (the following property occurs: if a case c is similar to a case c', than c' is similar to c). A way of realization of the afore-mentioned idea of similarity measure is a structure of so called global measure, determined for the problem as a combination of so called local measures, determined for the features describing the problem, however, distinction of "power" of their impact on similarity of the case through the introduction of weights is admitted.

A next problem connected with the realization of CBR cycle is to modify, adapt a solution. As the references show, an adaptation of the solution can take place: interactively, with participation of the user who proposes the solution, or automatically, on the basis of implemented method. The simplest automatic method is to download (copy) a solution applied to similar problems, i.e. to accept the solution without its modification. A more advanced approach is to transform retrieved solutions by means of common rules or expressions.

The CBR method has many advantages but it is not deprived of drawbacks and limitations. These features which distinguish it from other techniques of automatic solving of the tasks can be included into the advantages of CBR. First of all, it does not require a good understanding of a domain from which the data come. The knowledge about the domain has not to be known, it can be incomplete, it can be gained during going through and reading the content of cases, therefore this method allows for learning on the basis of successes and errors.

When building a CBR system, a way of "how" to solve a problem has not to be known, it is sufficient to give a solution without pointing to the rules on the basis of which it arose. This feature significantly distinguishes the CBR from the systems based on the rules. Teaching the system based on the CBR, consisting in adding the cases to the base, is automatic to some degree. Such systems process the data of any types, any complex structures, and they always give a possibility of reading on the basis of what premises a final outcome is received. The other advantages of CBR mentioned in the reference [4] include a reduction of knowledge acquisition costs, decrease of efforts made to solve a new problem, easiness of implementation of the method, relatively small maintenance cost, use of existing data, quick proposal of problem solutions, easiness of method application, simple learning through memorizing, and first of all, high acceptability by the final users.

It results from the analysis of the references [2, 13] that a very little attention is paid to the drawbacks of CBR method. In the authors' opinion it can be assumed that in the first place the CBR drawbacks result from drawbacks and limitations of applied techniques in each of phases of CBR cycle and they can be considered as inconveniences. In the first place such inconveniences of CBR, mentioned in the reference [1] - in the authors' opinion – can include the fact that the limitations are put on properties of the domain in which it can be used (regularity, repeatability, similarity of phenomena, continuity of modelled domain). The fact that it is necessary to select the problem features (attributes) in relation to which reasoning is carried out can be considered as a next drawback. It requires an additional knowledge of the user who carries out the reasoning. The fact that the case base requires a lot of memory can be considered as an additional difficulty as well. It can be explained in such a way that a presented classical mechanism of CBR always finds a solution therefore the fact whether a found case is more or less similar to the case under consideration depends on the size and quality of the case base. The bigger case base, the better approximation of cases. The next difficulty is a necessity of preparation, indication of similarity function adjusted to the representation of cases what can be an additional problem for the User. The classical CBR does not take making use of approximate knowledge into consideration as well what - in the authors' opinion - can be a drawback of the method.

4 The exemplary logic model of the case base

The information system created using a method of artificial intelligence, including the CBR, belongs to so called systems with a knowledge base. Three permanent elements can be distinguished in the systems of such a class [10, 11]: knowledge base, reasoning mechanism and the user's interface. In the case of CBR method application, the knowledge base is constituted by a case base and an additional knowledge about a domain, i.e. a dictionary which describes a definition of the case and its representation, similarity measures and solution adaptation rules.

The case base includes a description of various problems from the past along with the description of their solving without instructions related to the rules on the basis of which the decisions were made. It results from this determination that the case base is, in the sense of logic model of relational data base, simply a data base.

Assuming that in most CBR applications a representation based on a vector of features ("flat" model) which employs a form of structure: Object-Attribute-Value [3, 13] is selected, the case base can be defined as follows:

$$\mathrm{CB} = < U,\ \mathrm{A},\ \mathrm{D} > \tag{1}$$

where:

U - finite set of cases,

A - non-empty, finite set of attributes (features, properties) describing a problem and for every attribute $a \in A$ we have $a\colon U \rightarrow U_a$, where U_a is a set of values of attribute $a \in A$,

D - non-empty, finite set of attributes describing a problem solution and for every $d \in D$ we have $d\colon U \rightarrow U_d$, where U_d is a set of values of attribute d.

The nearest-neighbour retrieval method as a retrieval technique of similar cases is used the most often when a representation of the case is determined in such a way. Then the measurement of similarity between two cases $c, c' \in U$ is calculated according to the formula:

$$\mathrm{sim}(c, c') = \frac{\sum_{a \in A} w_a \mathrm{sim}_a(a(c), a(c'))}{\sum_{a \in A} w_a} \tag{2}$$

where

A - set of attributes describing a problem and for $a \in A$ we have $a\colon U \rightarrow U_a$,

$\mathrm{sim}_a\colon U_a \times U_a \rightarrow [0, 1]$ - local measure of similarity determined for every attribute $a \in A$,

U_a - set of values assumed for every $a \in A$,

$w_a \geq 0$- weight of attribute $a \in A$.

It should be noticed that in the formula (2) the measures of local similarity sim_a are dependent on a type of values assumed within the framework of feature. Additionally, it is assumed that a measure of similarity of cases is a reflexive function and symmetric function, however, the weights allow to express the validity of attribute, impact of feature on similarity of cases. It is assumed that local similarities as well as weights of attributes must be known and given by the user of the system or calculated using machine training techniques. The analysis of the references [2, 13] allows to conclude that the cases of heterogeneous, mixed features – both quantitative and qualitative ones – using real, non-transformed data, can be compared with each other in this way with respect to similarity.

The executed empirical researches [9, 14] point to the problems of the users of the system with a numerical determination of local similarity. Sometimes it is significantly easier to determine a fact of similarity between the values of a given attribute then to express it numerically through giving a precise value or function (measure) according to which these value is calculated. It can be grounded by the fact that a man, in everyday life, in a natural, intuitive way, does not calculate but he estimates, i.e. he makes use of approximate knowledge. Additionally, it can be assumed that the values of some attributes can come from a measure, therefore it is necessary to take a device error tolerance into account. The achieved results point to the demand for the extension of classical measure of similarity by measures which take making use of approximate knowledge into account. An assumption that the cases are elements of tolerance space is the attempt to solve this problem.

5 The role of tolerance space in processing the expert's knowledge

The tolerance spaces (TS) and their properties were described by Doherty, Łukaszewicz and Szałas in the article [5]. The tolerance spaces as a special kind of approximation spaces allow, in a convenient way for the user, to compare objects, whose features assume the values of various types, with each other with regard to similarity. It is assumed that apart from a set of objects, an additional knowledge about similarity within the framework of their features (properties, attributes) is known as well, however, it is assumed that the similarity occurred in complex structures is based on the similarity occurred in simpler sets of values on the basis of which they arose. It means that the tolerance spaces determined for the elementary sets (e.g. values of features) induce, determine a tolerance space for complex structures for the construction of which they were used [5]. The property is very essential because in the CBR method, the similarity of cases results from the similarity of their problems and it results from the similarity within the framework of compared features describing the problem.

Let U be a set of some objects. The similarity between the objects of the set U can be measured, i.e. it can be expressed as a value of some function, so called measure of similarity sim: $U \times U \rightarrow [0, 1]$ such one that for every $u, u' \in U$ it occurs:

- sim(u, u') = 1, i.e. every object is similar to each other,
- sim(u, u') = 0, when u and u' are not similar to each other,
- sim(u, u') expresses a similarity degree of the object u' to u.

The measure of similarity increases in conjunction with the increase of similarity between objects of the set U. The objects for which a similarity degree is above a certain threshold value can be considered as indistinguishable objects.

A concept of tolerance space (TS) is understood as a tuple TS = <U, sim, p>, where U is a non-empty set of objects, sim: $U \times U \rightarrow [0, 1]$ is a measure of tolerance, p is a threshold value, however, $p \in [0, 1]$.

The measure of similarity is a tolerance measure when it is a reflexive and symmetric function, i.e. for every object $u, u' \in U$ a condition sim(u, u') = 1 is fulfilled and sim(u, u') = sim(u, u').

A set of indistinguishable objects with the object $u \in U$, i.e. similar ones to a degree of at least p constitutes its surroundings (or neighbourhood) understood as:

$$I(u) = \{u' \in U; sim(u, u') \geq p\} \tag{3}$$

As it is given earlier, an important property of TS is the fact that the similarity of objects of complex structures results from the similarity occurring in the sets of values used for the purposes of their construction.

Let a set of objects under consideration be defined as an information table.

A concept of information table is understood as a pair IT = <U, A>, where U is a non-empty, finite set of objects, A is a finite set of attributes (features, properties) and for the attribute $a \in A$ we have $a: U \rightarrow U_a$, where U_a is a set of values of attribute $a \in A$.

In the TS theory it is assumed that apart form the information table IT = <U, A> an additional knowledge about similarity occurring in the sets of values of attributes (in so called elementary sets) is possessed as well. The knowledge is expressed by means of tolerance space TS_a = <U_a, sim_a, p_a> for every attribute $a \in A$, where U_a is a set of values of attribute $a \in A$ (treated as an elementary set), sim_a means a tolerance measure determined for the elements U_a, however, p_a means a threshold value determining the surroundings. The similarity occurring in the elementary sets is subsequently transferred to the similarity of objects of information table. Then a tolerance space TS_{IS} = <U, sim, p> for the information table IT is defined through constructing a tolerance measure sim (so called global measure) on the basis of tolerance measures sim_a (so called local measures) and giving a threshold value p, e.g. by the expert or using machine training techniques.

The measures of similarity, including tolerance measures, can be defined in several ways [8, 9]. The exemplary local sim_a and global sim tolerance measures, together with a short characteristic, are presented in the further part of the study.

It should be noticed that in the CBR a retrieval of similar case in the case base boils down to comparing the problems with respect to similarity, therefore a subset CB, which with the assumed representation CB = <U, A, D> is the information table IT = <U, A>, is taken into account in the phase of retrieval. Taking this fact into consideration it can be acknowledged that the tolerance measures for the information table can be measures of similarity for the cases from CB.

6 The exemplary local tolerance measures sim_a

The similarity (tolerance) of objects, being elements of elementary set (e.g. numbers, symbols, logic values) can be presented in various ways, e.g. as a matrix of similarity, affinity to surroundings and as functions of measure [8, 9]. Finally, the expert decides a way of expression of the knowledge about similarity.

- The matrix of similarity

If the similarity between objects under consideration is known and expressed by means of numerical values then these values can be stored in a so called matrix of similarity:

$$\begin{aligned} &\mathrm{MatrixSim}_a = [s_{uu'}], \text{where } u, u' \in U_a \\ &\text{and} \quad s_{uu'} = sim_a(u, u') \text{ for } a \in A \end{aligned} \qquad \text{(m1)}$$

- The measures based on a distance function

If on the set of values of attribute U_a a distance function d: U_a x $U_a \rightarrow [0, \infty]$, such one that for every u, u'$\in U_a$ it occurs d(u, u) = 0 and d(u, u') = d(u', u) (weaker then metrics, without triangle condition) is determined, then the similarity between objects results from their proper "proximity". The smaller distance between the objects the bigger similarity between them. A selection of distance function d can depend on a kind of values of the set U_a (interval, symbolic, binary ones). Let u, u'$\in U_a$, then the measure of similarity sim_a can be expressed by the distance function according to the definition (m2):

$$sim_a(u, u') = 1 - d(u, u') / \max\{d(x, y) : x, y \in U_a\} \qquad \text{(m2)}$$

A measure (m2) can be applied to these sets of values for which a calculation of maximal distance of objects is possible.

$$sim_a(u, u') = \begin{cases} 1 & \text{for } d(u, u') \le \varepsilon; \varepsilon > 0 \\ 0 & \text{otherwise} \end{cases} \qquad \text{(m3)}$$

A measure (m3) is applicable to the numerical sets when an approximation error $\pm\varepsilon$ is known. In particular, it receives the following form (m4)

$$sim_a(u, u') = \begin{cases} 1 & \text{for } u = u' \\ 0 & \text{for } u \ne u' \end{cases} \qquad \text{(m4)}$$

Other exemplary tolerance measures based on the distance function are described by the formulas (m5) and (m6)

$$sim_a(u, u') = 1/(1 + d(u, u')) \qquad \text{(m5)}$$

$$sim_a(u, u') = e^{-d(u,u')} \qquad \text{(m6)}$$

The presented measures are applicable when a distance function d is known, adjusted to such a type of data. For example, for the numerical data, the distance can be calculated according to the formula d(u, u') = |u-u'| (Euclid distance), for logic (symbolic) values, e.g. $d(u, u') = \{1 \text{ for } u = u'; 0 \text{ for } u \ne u'\}$.

- The affinity to the surroundings

If a numerical value of similarity degree is not known or a measure function is not known, or it is a problem to give its definition, then the fact of similarity between the objects can be expressed through the affinity to the object's surroundings. The knowledge can be expressed as follows.

Let

$$I_a(u) = \{u' \in U_a; sim_a(u, u') \ge p_a\}$$

mean the neighbourhood of element u$\in U_a$, then for u, u'$\in U_a$ we have:

$$sim_a(u, u') = \begin{cases} 1 & \text{for } u' \in I_a(u) \\ 0 & \text{for } u' \notin I_a(u) \end{cases} \qquad \text{(m7)}$$

All presented measures sim_a are tolerance measures, i.e. they are reflexive and symmetric functions.

7 The exemplary global tolerance measures sim

The similarity (tolerance) of objects, being elements of information table (what with the assumed case representation it boils down to similarity between cases from the case base) can be presented in various ways, e.g. as a matrix of similarity, affinity to surroundings and as functions of measure based on the similarity occurring in the sets of features (elementary sets) [8, 9]. Finally, the expert decides a way of expression of the knowledge about similarity between the objects.

- The matrix of similarity

If the similarity between objects u, u'$\in$U is known in the form of numerical values then these values can be stored in a so called matrix of similarity:

$$MatrixSim = \lfloor s_{u,u'} \rfloor, \text{where } u, u' \in U \text{ and } s_{uu'} = sim(u, u') \quad (M1)$$

- The measures based on a similarity degree within the framework of features

We assume that the similarity between the objects is not known but we have an additional knowledge about a set of values of every attribute a$\in$A expressed by tolerance spaces TS_a = <U_a, sim_a, p_a> which induce a tolerance space TS_{IS} = <U, sim, p> for the information table. Then the function sim: U x U$\rightarrow$[0,1] can be defined by means of tolerance measures sim_a of elementary sets and a threshold value p can be given by the expert or determined by means of machine training techniques. A construction of global tolerance measure on the basis of local tolerance measure can be as follows:

$$sim(u,u') = \sum_{a\in A} w_a sim_a(a(u), a(u')) \Big/ \sum_{a\in A} w_a, \text{ where } w_a \in [0,1] \quad (M2)$$

The similarity between the objects in (M2) is decided by the weight of attributes w_a and similarity degree within the framework of features (attributes), i.e. the value sim_a. This measure is a classical measure used in CBR (formula 2):

$$sim(u,u') = \left(\prod_{a\in A} sim_a(a(u), a(u'))\right)^{1/|A|} \quad (M3)$$

The similarity between the objects in (M3) is decided not only by the similarity occurring within the framework of all a$\in$A, but by their accordingly big degree expressed by sim_a.

$$sim(u,u') = \max_{a\in A}(sim_a(a(u), a(u'))) \quad (M4)$$

The similarity between the objects in (M4) is decided by the biggest similarity degree sim_a for a$\in$A. It means that the similarity of the objects is determined on the basis of one feature, not always the same one.

$$sim(u,u') = \min_{a\in A}(sim_a(a(u), a(u'))) \quad (M5)$$

The similarity between the objects in (M5) is decided by the smallest similarity degree sim_a for a$\in$A, i.e. all features impact on the similarity.

$$sim(u,u') = \sum_{a\in A} sim_a(a(u), a(u')) \Big/ |A| \quad (M6)$$

The similarity between the objects in (M6) is decided by an arithmetic mean of the similarities in the set of values of attributes a$\in$A. This measure is a special case of measure (M2), assuming that the weights w_a for a$\in$A are equal for every attribute and they receive the value $w_a = 1/|A|$.

- The measure based on the affinity to the surrounddings within the framework of features

If a value of similarity degree within the framework of features is not known but the fact of “being indistinguishable” is stated, i.e. the affinity to the object’s surroundings for every feature is known, then the measure of similarity for the object can be expressed as follows.

Let sim_a mean a tolerance measure in a set of values U_a of attribute a$\in$A, p_a a threshold value, I_a: $U_a \rightarrow 2^{Ua}$ surroundings (neighbourhood) of element of this set, i.e. for u$\in$U we have $I_a(u)$ = (u'$\in$ U_a; sim_z(u, u') $\geq$ p_a) and let S_a: U x U$\rightarrow$ [0, 1] be a function verifying an affinity to the object y to the object’s surroundings x, where x, y$\in U_a$ for a$\in$A described by the formula:

$$S_a(x,y) = \begin{cases} 1 & \text{for } y \in I_a(x) \\ 0 & \text{for } y \notin I_a(x) \end{cases} \quad (M7)$$

then for u, u'$\in$U we have

$$sim(u,u') = \sum_{a\in A} w_a S_a(a(u), a(u')) / \sum w_a, \text{ where } w_a \in [0, 1] \text{ is a weight of } a \in A \quad (M8)$$

Selecting a weight of attribute w_a for a$\in$A in (M8), the “power” of similarity within the framework of a given feature on the similarity between the objects can be expressed. The similarity between the objects is decided not only by the number of attributes for which the similarity of features occurs but also by their “quality” expressed by the weight. Selecting a threshold value p_a properly, it can be determined which attributes (features) have the biggest impact on the similarity. Assuming $w_a = 1/|A|$ for every a$\in$A, i.e. determining that the similarity within the framework of every feature is equally important, the similarity between the objects shall be decided by a number of attributes for which the indistinguishability occurs within the framework of the features.

- The affinity to the surroundings

If a numerical value of similarity degree is not known or a measure function is not known (e.g. it is a problem to give its definition, then the fact of similarity between the objects (to be more precisely: being indistinguishable) can be expressed through the affinity to the surroundings (neighbourhood). The knowledge can be expressed as follows.

Let $u \in U$ and $I(u) = \{u' \in U; sim(u,u') \geq p\}$ mean the surroundings (neighbourhood) of element u, then for u, u' $\in$U we have (M9):

$$sim(u,u') = \begin{cases} 1 & \text{for } u' \in I(u) \\ 0 & \text{for } u' \notin I(u) \end{cases} \quad \text{(M9)}$$

All presented measures are tolerance measures, i.e. they are reflexive and symmetric functions. Finally, their usefulness or purposefulness of use is decided by the expert who carries out the reasoning.

The threshold values p_a and necessary weights w_a for $a \in A$ must be determined. They are given by the user who carries out the reasoning. When the user has no knowledge on this issue, default values (threshold values equal to 1) shall be accepted or they shall be calculated automatically using machine training techniques.

The presented definitions of measures assume that for every object $u \in U$ all values for every attribute $a \in A$ are known, i.e. a problem of missing data is not taken into consideration in a proposed approach.

8 The model of information system with the case base

As it is already described, wanting to build an information system using a CBR method it is necessary to challenge many problems. The basic problems include: definition of case, selection of case representation and measurement of similarity between cases. The purpose of the article is to present a conception of the system in a generalized form, therefore a definition of the case [4] is omitted in the presented model, it is only assumed that the case representation is based on a vector of features.

We assume that apart from the case base, an additional knowledge about occurring similarity within the framework of features of the problem under consideration, expressed by means of tolerance spaces, is known. Then this similarity is transferred to the similarity of problems and consequently to the similarity of cases. Such an assumption is a system model assumption which can be presented as follows.

The system assumptions. We have a case base CB = <U, A, D> defined according to the formula (1) and we possess an additional knowledge about similarity occurring within the framework of features of the problem expressed by tolerance spaces $TS_a = <U_a, sim_a, p_a>$ for every $a \in A$, then this similarity is transferred to the similarity of cases, i.e. the tolerance spaces TS_a determine a tolerance space above the case base TS_{CB} = <U, sim, p>.

The introduction of the afore-mentioned assumption to the system allows to make use of surroundings I_a (formula (3)) determined for the values of features of the problem in order to determine a similarity between the cases, what can be described by means of the below-mentioned formula (formula (4), on the basis of M7 and M8):

$$sim(c,c') = \frac{\sum_{a \in A} w_a S_a(a(c), a(c'))}{\sum_{a \in A} w_a} \quad (4)$$

where:

$$S_a(x,y) = \begin{cases} 1 & \text{for } y \in I_a(x) \\ 0 & \text{for } y \notin I_a(x) \end{cases} \quad \text{for} \quad x, y \in U_a,\ a \in A,$$

w_a - weight of attribute $a \in A$ and $w_a \in [0, 1]$.

$S_a : U_a \times U_a \rightarrow [0, 1]$ - determines the affinity to the surroundings I_a of the values of attribute $a \in A$, allows to make use of the fact of "being indistinguishable" within the framework of a given feature.

It should be noticed that a classical measure of similarity for the CBR determined by the formula (2) is also a tolerance measure (it is reflexive and symmetric), therefore it can be applied to the proposed approach. The presented definition of local and global tolerance measures constitute additionally an element extending a classical approach to the measurement of similarity between the cases.

The CBR_{TS} reasoning cycle. Assuming that cases from a case base CB are elements of tolerance space allows to make use of cases indistinguishable from the one under consideration, what impacts on a reasoning cycle, what we mark as CBR_{TS} (Tolerance-Based Case-Based Reasoning). In this situation, every case collected in the base determines its surroundings (neighbourhood), i.e. a set of cases indistinguishable from it, i.e. such ones whose similarity degree exceeds a certain threshold value.

Taking into account conditions which must be met by domains from a field of CBR application and the essence of CBR method in the form of statement: similar problems have similar solutions, it can be concluded that after the application of tolerance space to the CBR, the essence of CBR_{TS} method would extend the essence of CBR by the statement: indistinguishable problems

[4] A concept of definition of case is understood as giving a number of attributes, their names, sets of assumed values.

have indistinguishable solutions, what is illustrated by Figure 3.

An additional advantage of such an approach is a possibility of quick statement of a precedent (a precedent in the meaning of untypical case, not appearing earlier, which can happen many times in the future). If a case the most similar to a new one does not belong to its surroundings, it means that the new case is a precedent. Such information – in the authors' opinion – would help the reasoning person to solve a problem because he would know that he deals with a new unknown situation, naturally, in the context of collected cases.

As it is said earlier, assuming that the cases from the CB are elements of tolerance space impacts not only on a similarity measure but also on a classical CBR cycle. It is obtained a four-phase CBR_{TS} (so called Tolerance-Based Case-Based Reasoning) cycle whose first phase of retrieving $_{TS}$ is extended in relation to the classical phase of retrieving by a possibility of retrieving cases indistinguishable from the one under consideration (i.e. its surroundings-neighbourhood). In order In order to retrieve the surroundings (neighbourhood) of new problem, it is proposed to use a neighbourhood-retrieval algorithm whose essence would consist in reviewing

a case base, case by case, in order to find all indistinguishable from the one under consideration, i.e. for which a property compliant with the formula (3) occurs. In relation to other CBR_{TS} phases it is assumed that they are compliant with 2, 3, 4 phases of classical CBR cycle. Taking the CBR_{TS} into account, it is a four-phase cycle including the following phases:

- retrieving a case the most similar to the one under consideration or cases indistinguishable from the one under consideration (i.e. its surroundings),
- reusing a way of solution of retrieved case (cases) to solve a new problem,
- revising an old solution (solutions) with the object of its adjustment to the problem under consideration; possible adaptation, modification of solution,
- retaining the problem under consideration together with the used solution as a new case.

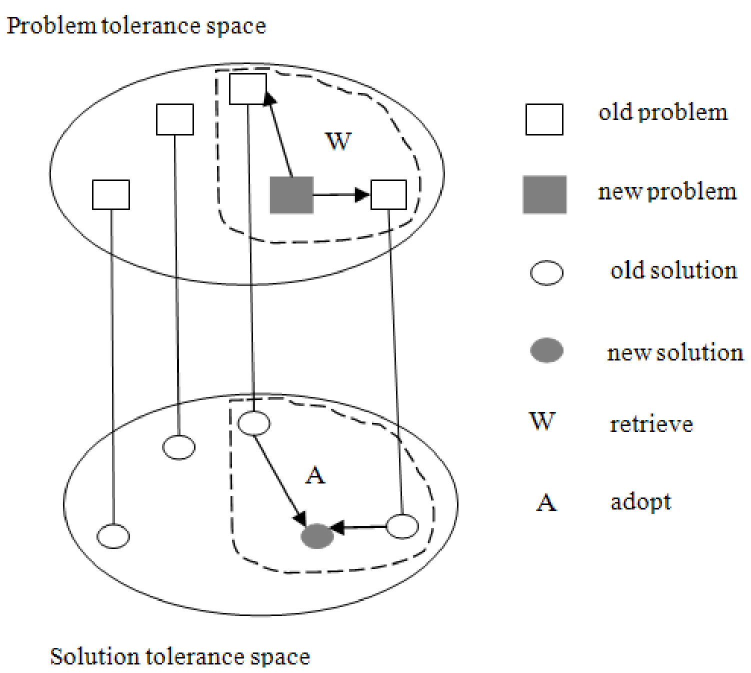

Figure 3. The essence of CBR_{TS}.
(source: self research on the basis of the CBR acc. to Leake [3])

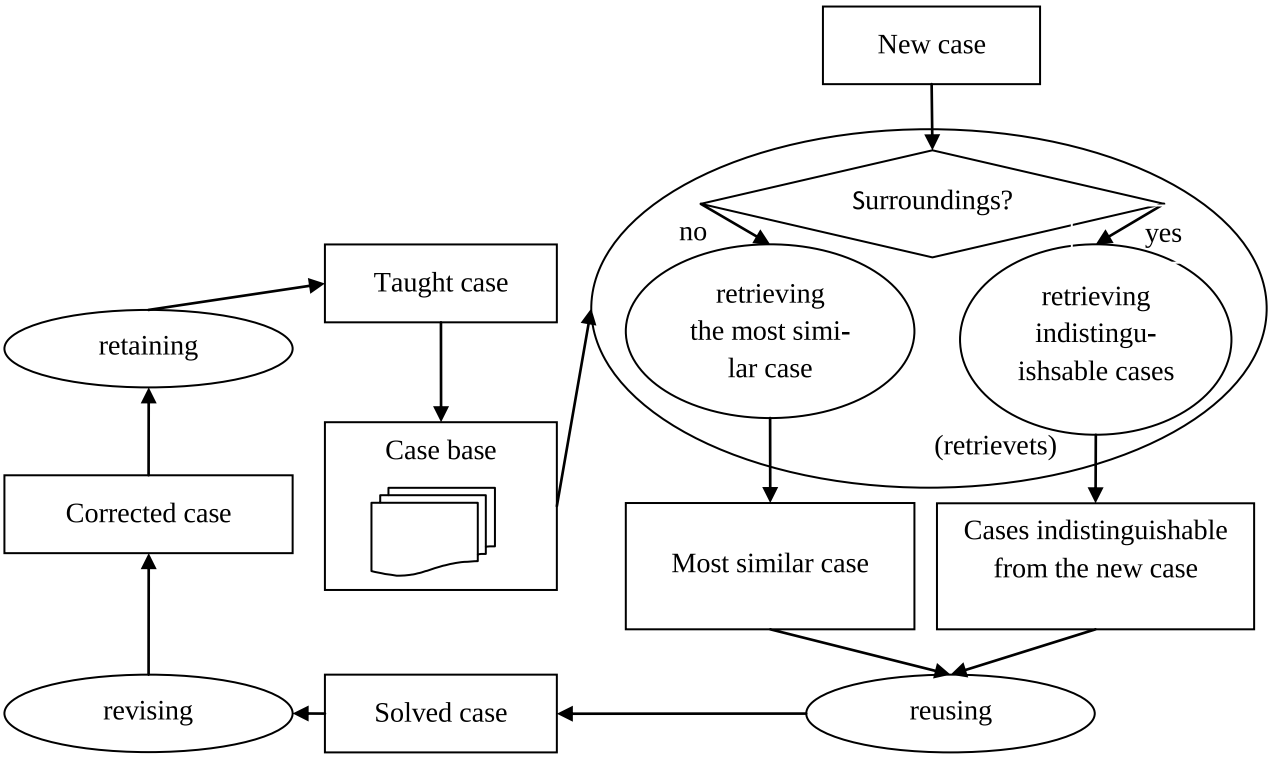

Figure 4. The CBR_{TS} cycle.
(source: self study)

Figure 4 presents the essence of CBR_{TS} cycle. The prepared CBR_{TS} mechanism has all advantages as a classical CBR and additionally it:

- enables to make use of approximate knowledge thanks to that the user can operate with surroundings – colloquially: "a fact of being indistinguishable" without determination of similarity degree or measure,
- gives a possibility of quick statement of appearance of a precedent,
- enables to solve a new problem through adapting many solutions which were applied to the problems indistinguishable from the one under consideration,
- thanks to introduced parameterisation (use of similarity threshold) dissemination of knowledge, its repeated usage, sharing, training takes place.

A necessity of giving the thresholds p determining the surroundings can be considered as a CBR_{TS} drawback, all drawbacks of classical CBR, if a variant of retrieval of the most similar case is selected. According to this approach, a case the most similar to the new one is always retrieved, naturally, on the assumption that the case base is not empty. If the case base does not include a large number of cases, what is natural in an initial phase of making use of CBR system, then a returned case of too small similarity degree, so that a solution connected with it is useful in a new situation, can be a result of retrieval. A possibility of return of empty surroundings as a result of retrieval which informs the user of appearance of unknown situation (precedent) can be considered as an advantage.

The system model. An information system created with using artificial intelligence tools belongs to so called systems with a knowledge base. Three permanent elements can be distinguished in the systems of this class: knowledge base, mechanism of reasoning and interface. Making assumptions about the system allows to define the information system based on a CBR method taking into account a possibility of making use of approximate knowledge in the form compliant with the formula (5):

$$system = < CB, \{TS_a : a \in A\}, TS_{CB}, CBR_{TS}, I > \tag{5}$$

where:

CB, TS_a, TS_{CB} - create a knowledge base and are compliant with made assumptions about the system,

CBR_{TS} - constitutes a mechanism of reasoning,

I - the user's interface.

An exemplary operation of the system is presented in the next chapter.

A prepared model of the system presents a conception of system in the generalized form. The introduced parameterisation of the model is a tool enabling to adjust a knowledge base of the system to the user's requirements, therefore, tracking an operation of the system based on the prepared model requires:

- to design a case within the framework of domain, i.e. to give features describing the case and their characteristic in the form of assumed values U_a and U_d,
- to organize a case base CB = <U, A, D>, where U constitutes a finite set of cases, A non-empty, finite set of attributes describing a problem and for every attribute $a \in A$ we have $a:U \rightarrow U_a$, where U_a is a set of values of attribute $a \in A$ and D is a non-empty, finite set of attributes describing a solution of the problem and for every $d \in D$ of decision description we have $d:U \rightarrow U_d$, where U_d is a set of values of decision-making attribute d,
- to give an additional knowledge about similarity within the framework of features of the problem and to express it in the form of tolerance space $TS_a = \langle U_a, sim_a, p_a \rangle$ (i.e. to determine the sets of values U_a, to point to a tolerance measure sim_a and indistinguishable threshold p_a for every feature $a \in A$),
- to give an additional knowledge about similarity of cases and to express it in a tolerance space $TS_{CB} = \langle U, sim, p \rangle$ (i.e. to determine a set of cases U, to point to a global tolerance measure sim and indistinguishable threshold p),
- to formulate a new problem,
- to select features of the problem creating an index (i.e. taking part in we reasoning) and to determine their weight w_a,
- to execute a CBR_{TS} mechanism.

With regard to the accepted scope of the article, a model of the system (5) is presented in the basic form possible to be extended further. According to the authors' intention, the introduction of tolerance space to the CBR constitutes a starting point for the further considerations on an application of theory of approximate set. Such a determined theme shall constitute a subject-matter of further researches.

9 The formulation of enquiries – the presentation of the expert inference

We have CB = <U, A, D> a case base, where U = {c0, c1, c2, c3} constitutes a set of cases, A = {a0, a1} is a set of attributes describing a problem, D = {d0} is a set of attributes describing a decision and we possess an additional knowledge about similarity occurring in the sets of elementary attributes as in the below Table 1.

Let

- $TS_{a0} = \langle U_{a0}, sim_{a0}, p_{a0} \rangle$ be a tolerance space for the attribute a0, where:
  $U_{a0} = [50, 60]$,
  $sim_{a0}(u, u') =^{def} 1\text{-}d(u, u')/\max\{d(x, y): x, y \in U_{a0}\}$,
  $p_{a0} = 0{,}88$ (calculated on the basis of ε),
- $TS_{a1} = \langle U_{a1}, sim_{a1}, p_{a1} \rangle$ shall be a tolerance space for the attribute a1, where:
  $U_{a1} = \{0, 1, 2\}$,
  $sim_{a1}(u, u') =^{def} \{1 \text{ for } u' \in I(u); 0 \text{ otherwise}\}$,
  $p_{a1} = 1$ (assumed).

Then

$TS_{CB} = \langle U, sim, p \rangle$ shall be a tolerance space above the CB, where:

U = {c0, c1, c2, c3},

sim – variants:

- when selecting retrieval of indistinguishable ones (making use of surroundings),

$$sim(u, u') =^{def} \sum_{a \in A} w_a S_a(a(u), a(u')) \quad (6)$$

where $S_a(x, y) = \{1 \text{ for } y \in I_a(x); 0 \text{ otherwise}\}$

- when selecting retrieval of the most similar one (classical approach),

$$sim(u, u') = \sum_{a \in A} w_a sim_a(a(u), a(u')) / \sum_{a \in A} w_a \quad (7)$$

$w_{a0} = w_{a1} = 0{,}5$,

p = 1 (assumed).

Table 1. The case base CB and additional knowledge about similarity
(source: self study)

Case base CB

case	a0	a1	d0
c0	50,5	0	d_{00}
c1	51,1	1	d_{01}
c2	52,0	2	d_{02}
c3	53,2	1	d_{03}

Additional knowledge about similarity
attribute a0:
set of values U_{a0} = [50, 60],
similar values when $d(x, y) \leq \varepsilon = 1,2$
attribute a1:
set of values U_{a1} = {0, 1, 2},
I(0) = {0, 1}; I(1) = {0, 1, 2}; I(2) = {1, 2}
equal weight of attributes

Table 2. A degree of local and global similarity when retrieving indistinguishable cases, example 1, variant 1
(source: self study)

feature a	a0	a1	sim(n, ci), i = 0..3
sim_a(n, c0)	0	1	0,5
sim_a(n,c 1)	0	1	0,5
sim_a(n, c2)	1	1	1,0
sim_a(n, c3)	1	1	1,0

The results of operation of the system described by the formula (4).

Example 1
Let n = <52, 5, 1, ?> be a new case. The CBR_{TS} mechanism:

- Variant 1
  - Phase 1. Retrieving TS – retrieval of indistinguishable ones is selected.

Index: all features of the problem, i.e. a0, a1.

Result of the phase: surroundings of new case I(n) = {c2, c3}.

Substantiation: A degree of local and global similarity between a new case and the cases from the case base is calculated on the basis of additional knowledge about similarity between problems expressed by tolerance spaces TS_a and TS_{CB} (similarity measure based on the surroundings, formula (5)). The similarity degree is represented in the below table (Table 2).

The surroundings of a new case n include the cases which are similar at least to the degree p = 1 (acc. to def. TS_{CB}), therefore this condition is met by the cases c2 and c3.

  - Phase 2. Reusing

A decision d_{04} can be made interactively (with participation of the reasoning person) with using the solutions d_{02}, d_{03} of cases c2, c3.

Result of the phase: $d_{04.}$

  - Phase 3. Revising

In real conditions, this decision d_{04} is subject to revising and possible adapting and modification. It becomes a solution of new problem after the acceptance and application.

Result of the phase: new case n = <52,5, 1, d_{04}>.

  - Phase 4. Retaining

The new case n being a result of the phase 3 is added to the case base as a new case c4 = n. The reorganization of the case base through updating a set of cases U by a new case c4 = n is a result of the phase.

Result of the phase: U = {c0, c1, c2, c3, c4}, where c4 = n = <52,5, 1, d_{04}>.

- Variant 2
  - Phase 1. Retrieving TS – retrieval of the most similar one is selected.

Index: all features of the problem, i.e. a0, a1.

Result of the phase: the most similar case c2.

Substantiation: A degree of local and global similarity between a new case and the cases from the case base is calculated on the basis of additional knowledge about similarity between problems expressed by tolerance spaces TS_a and TS_{CB} (classical measure of similarity, formula (7)). The similarity degree is represented in the Table 3.

The new case n is the most similar to the case c2.

Table 3. A degree of local and global similarity when retrieving indistinguishable cases,example 1, variant 2
(source: self study)

feature a	a0	a1	sim(n, ci), i = 0..3
$sim_a(n, c0)$	0	1	0,9
$sim_a(n, c1)$	0	1	0,93
$sim_a(n, c2)$	1	1	0,975
$sim_a(n, c3)$	1	1	0,965

Table 4. A degree of local and global similarity when retrieving indistinguishable cases, example 2, variant 1
(source: self study)

feature a	a0	a1	sim(n, ci), i = 0..3
$sim_a(n, c0)$	0	1	0,5
$sim_a(n, c1)$	0	1	0,5
$sim_a(n, c2)$	0	0	0,0
$sim_a(n, c3)$	0	1	0,5

- Phase 2. Reusing

A decision d_{04} can be made interactively (with participation of the reasoning person) with using the solution d_{02} of case c2.

Result of the phase: $d_{04} = d_{02}$.

- Phase 3. Revising

In real conditions, this decision d_{04} is subject to revising and possible adapting and modification. It becomes a solution of new problem after the acceptance and application.

Result of the phase: new case n = <52,5, 1, d_{04}>.

- Phase 4. Retaining

The new case n being a result of the phase 3 is added to the case base as a new case c4 = n. The reorganization of the case base through updating a set of cases U by a new case c4 = n is a result of the phase.

Result of the phase: U = {c0, c1, c2, c3, c4}, where c4 = n = <52,5, 1, d_{04}>.

Example 2

Let n = <55,0, 0, ?> be a new case. The CBR_{TS} mechanism.

- Variant 1
  - Phase 1. Retrieving TS – retrieval of indistinguishable ones is selected.

Index: all features of the problem, i.e. a0, a1.

Result of the phase: surroundings of new case I(n) = { } (empty).

Substantiation: A degree of local and global similarity between a new case and the cases from the case base is calculated on the basis of additional knowledge about similarity between problems expressed by tolerance spaces TS_a and TS_{CB} (measure of similarity based on the surroundings, formula (5)). The similarity degree is represented in the Table 4.

The surroundings of a new case n include the cases which are similar at least to the degree p = 1 (acc. to def. TS_{CB}), therefore this condition is not met by any case.

- Phase 2. Reusing

The surroundings of the new case n are an empty set, i.e. there are no cases indistinguishable from the one under consideration in the case base, therefore there is a precedent in the sense of collected cases. A decision d_{04} must be made by the reasoning person.

Result of the phase: d_{04}.

- Phase 3. Revising

In real conditions, this decision d_{04} is subject to revising. It is applied without changes or it is subject to possible adapting and modification. It becomes a solution of new problem after the acceptance and application.

Result of the phase: new case n = <55, 0, 0, d_{04}>.

Table 5. A degree of local and global similarity when retrieving indistinguishable cases, example 2, variant 2 *(source: self study)*

feature a	a0	a1	sim(n, ci), i = 0..3
sim_a(n, c0)	0	1	0,775
sim_a(n, c1)	0	1	0,805
sim_a(n, c2)	1	1	0,35
sim_a(n, c3)	1	1	0,91

- Phase 4. Retaining

The new case n being a result of the phase 3 is added to the case base as a new case c4 = n. The reorganization of the case base through updating a set of cases U by a new case c4 = n is a result of the phase.

Result of the phase: U = {c0, c1, c2, c3, c4}, where c4 = n = <55,0, 0, d_{04}>

- Variant 2
    - Phase 1. Retrieving TS – retrieval of the most similar one is selected.

Index: all features of the problem, i.e. a0, a1.

Result of the phase: the most similar case c3.

Substantiation: A degree of local and global similarity between a new case and the cases from the case base is calculated on the basis of additional knowledge about similarity between problems expressed by tolerance spaces TS_a and TS_{CB} (classical measure of similarity, formula (6)). The similarity degree is represented in the Table 5.

The new case n is the most similar to the case c3.

- Phase 2. Reusing

A decision d_{04} can be made interactively (with participation of the reasoning person) with using the solution d_{03} of case c3.

Result of the phase: $d_{04} = d_{03.}$

- Phase 3. Revising

In real conditions, this decision d_{04} is subject to revising and possible adapting and modification. It becomes a solution of new problem after the acceptance and application.

Result of the phase: new case n = <55,0, 0, d_{04}>.

- Phase 4. Retaining

The new case n being a result of the phase 3 is added to the case base as a new case c4 = n. The reorganization of the case base through updating a set of cases U by a new case c4 = n is a result of the phase.

Result of the phase: U = {c0, c1, c2, c3, c4}, where c4 = n = <55,0, 0, d_{04}>.

10 Summary

The purpose of this article was to present and analyse issues connected with the expert knowledge collection methodology in the decision support systems. The considerations concentrated mainly on the presentation of a conception of building an information system with a case base, based on a case-based reasoning method and on an assumption of making use of approximate knowledge by the reasoning person.

It was assumed that the cases are elements of tolerance space what allowed to operate with the surroundings, i.e. the cases indistinguishable from the one under consideration. It was shown that the introduction of this assumption impacted on a classical reasoning mechanism. It is received a four-phase CBR_{TS} (tolerance-based case-based reasoning) cycle being an extension of CBR method.

The case-based reasoning method and areas of its application belong to a group of subjects taken up by many researchers. Various solutions for the purpose of this method and domains, in which it can be applied successfully are still being searched. In the authors' opinion, the issues raised in the study cover this stream of researches.

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MODELING OF POLISH ENTERPRISES INSOLVENCY PROCESSES WITH THE USE OF GORBATOV CHARACTERIZATION PRINCIPLE – RESEARCH RESULTS

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Abstract: Economical activities of enterprises should be based on such managerial decisions that assure quick and effective adjustment of the company to the changes that appear in the market. Enterprises, which are not able to use their opportunities and avoid threats, are bound to face the thread of insolvency. Effects of the insolvency are felt not only by the enterprise, but also by its creditors. Therefore, it is necessary to elaborate a warning system that will beforehand allow diagnosing the condition of the enterprise and setting necessary directions for the company to avoid insolvency. The article presents research results on the use of characterization theory in the creation of insolvency threat evaluation model based on Polish enterprises.

Key words: characterization theory, corporate bankruptcy, bankruptcy prediction, corporate crisis management, model of bankruptcy prediction.

1 Introduction

Enterprise, which has lost its ability to survive, stands in the face of crisis. It is a common phenomenon in modern economical environment and it affects enterprises on different levels. In case of temporary difficulties, which are overcome, the company will be able to survive and develop its activities. This situation is more dangerous when the management does not see the threat and manage the company towards intensification of the crisis. This results in the thread of insolvency that can lead to bankruptcy.

Results of insolvency (especially the financial problems) are felt not only by the enterprise itself, but also by [1, 11]:

- contractors (suppliers, customers) – insolvency directly influences the financial problems and results in bankruptcy of co-operating companies (especially in case of high dependence of subjects on delivered components or sales of finished products),
- creditors (financial institutions, partners) – bankruptcy results in problems with execution of debt.
- state – bankruptcy of a major economic subject (with considerable market share) can destabilize the functioning of the sector or even the whole economy (e.g. state receives additional cost connected with the increase of unemployment, such as social cost of unemployment, social benefits etc.),
- employees – incoming job reductions can lead to insufficient means of livelihood.

Threat of bankruptcy is also connected with direct and indirect cost of insolvency. Direct cost includes employee and company representative wages, as well as cost of time of managers who manage the company during the bankruptcy process. Indirect cost includes cost of lost sales, revenue and loosing the possibility to receive loans. In terms of direct and indirect insolvency cost one can distinguish [17]:

- administrative costs (direct) – resulting from the necessity to perform restructuring process, which is a cost generating mechanism requiring engagement of employees, banks and company representatives,
- cost of lost investment opportunities (indirect) – enterprise with financial trouble can have problems with obtaining the capital for new ventures (even more profitable than its basic activities),
- cost of creditor/shareholder conflict (indirect) – in the moment of financial crisis creditors are afraid that the company will loose its solvency and invested capital will be lost. On the other hand the shareholders are interested in the increase of market value of the enterprise. That is why managers may be forced to making short-term decisions that please the creditors but ignore the shareholders.

Analysis of the financial and economical condition of the enterprise can be a basis for the model of insolvency threat evaluation. The main objective of such model is to provide an early enough (e.g. allowing taking necessary preventive measures) diagnosis of potential threats (dangers) that can lead to the bankruptcy of the enterprise.

Customers of the insolvency threat evaluation model are the following [8, 11]:

- management board - responsible for the constant supervision and evaluation of the financial condition of the enterprise,
- auditors, responsible for e.g. evaluation of financial reports and determination of potential threats for the functioning of the business unit,
- banks, which can evaluate the insolvency threat in the process of granting the loan to the enterprise,
- rating institutions, such as Standard & Poor, Moody's, which can use the models to build enterprise ratings,
- bank guarantee funds, in order to select the banks endangered with insolvency,
- customers or suppliers, to check the financial credibility of the contractors,
- potential investors investing money in stock market or bonds,
- nations and local authorities, to select potential bankruptcies in the national sector,
- judges dealing with insolvency and bankruptcy (increase of correctness of sentences),
- other units e.g. debt selling companies, insurance companies, debt collectors.

2 Enterprise insolvency processes – stages

2.1 Main causes enterprises bankruptcy

Bankruptcy is not a sudden event that appears overnight – it is the end stage of a process defined as enterprise crisis.

Crisis starts when there is a major difference (endangering the functioning of the company) between the changes in the economical environment and the strategy of market activities as well as the organization of management processes of the enterprise. Such viewpoint is presented in the works of P. Drucker [4], D. Sull [13], E. Urbanowska-Sojkin [15] that determine the "difference" as:

- outdated organization business theory [4],
- active inertia pitfall [13],
- lack of balance between the goals and resources of the enterprise [15].

P. Drucker emphasized that the premises of the crisis situation arise when the business theory in the organization is out of date. According to Drucker the theory of organization consists of three parts [4]:

- assumptions on the organizational external environment: society and its structure, the market, the customers and technology,
- assumptions on the organization's mission, purpose and raison d'etere,
- assumptions on the core competences, the skills and abilities required to accomplish the mission of the organization.

„ (...) Assumptions about the external environment determine the source of the organization's benefits. Assumptions about the mission determine the favorable outcome for the organization: in other words, they indicate how it perceives its role in changing the society and economy. Finally, assumptions on the core competences determine the directions necessary to be perfected by the organization, in order to maintain the position of the market leader (...)" [4, p. 34]. When a difference between the goals and the current situation of the enterprise emerges, it usually leads to the crisis in the enterprise.

Similar viewpoint can be found in the works of E. Urbanowska-Sojkin [15], which states that lack of balance between the goals and the resources in the enterprise leads to a crisis. Erroneous perception of the environment and one's position in it results in disturbances of goal formulation and external ability to reach them as well as resources necessary to realize the goals.

Works of D. Sull [13] present the concept of active inertia pitfall (see Figure 1), which describe the situation where once defined success formula is repeated continuously, despite the changing environmental conditions. What is interesting is the fact that in such circumstances the managing board usually intensifies the activities that lead to the success in the past. What is more, managers lack the perspective that would allow a synonymous and neutral evaluation of the success formula.

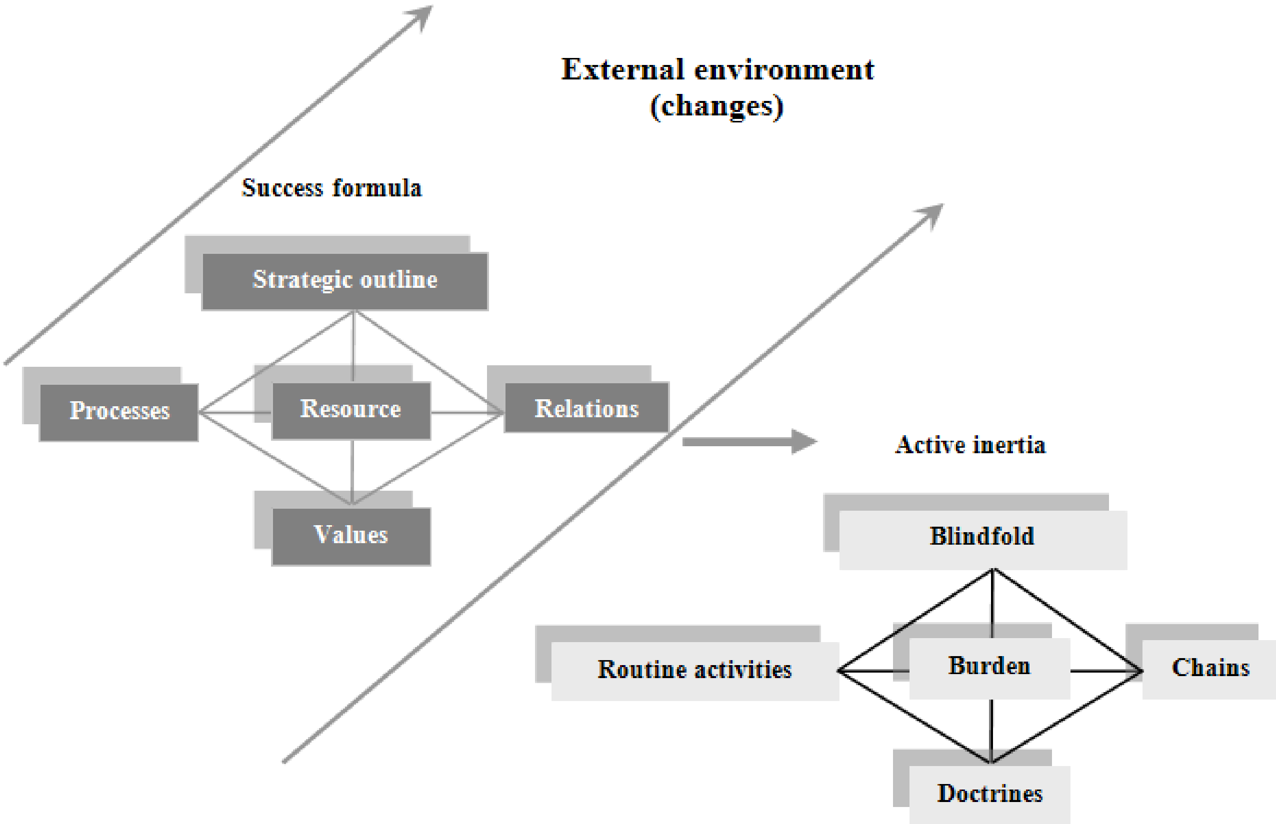

Figure 1. Pitfall of active inertia
(*source: [13, p. 94]*)

Usually the set strategic outline, resources, processes and values of the enterprise are assumed as obvious and the need for change is not noticed. Success formula is understood as the activities that allow the enterprise to come into being and gain a significant market position.

It also is the „ (...) unique set of strategic outline (perception of the competitive environment), resources (necessary to gain competitive advantage) processes (ways of operating), relations (permanent relations with external stakeholders and contacts between functional departments), values (inspiring factors, synonymous and modeling the identity of the organization)" [13, p. 90].

Initial success draws customers, investors, imitators. It also assures the managing board that selected strategy is successful and should be reinforced. Such attitude "puts the enterprise managers off their guard" and reassures that current success formula is correct. „ (...) Individual elements of the success formula become less flexible: strategic outline changes into a blindfold, resources become a burden, processes are driven by routine, relations change into chains and values into numb doctrines (...)" [13, p. 93].

Changing environment enforces changes in the enterprise. Managing board sees the changes and takes actions. However, the non-flexible structure directs them to the same old tracks. The greater the difference between the environment and the success formula, the more intense actions are undertaken – unfortunately they do not bring expected results. This can lead to the crisis in the enterprise and end in its bankruptcy.

2.2 Stages of insolvency process

Threat of insolvency is a consequence of prolonging crisis within the company. Organization faces bankruptcy when all undertaken actions, to deal with the crisis, have failed. Literature presents a four-stage concept of the crisis [10, 18 and 19]:

- Stage 1

Usually concerns situations where the first symptoms of the crisis, generated by internal and external sources, are visible. They are, however, ignored by the management. This results in gradual preservation of the functional inefficiency of the organization.

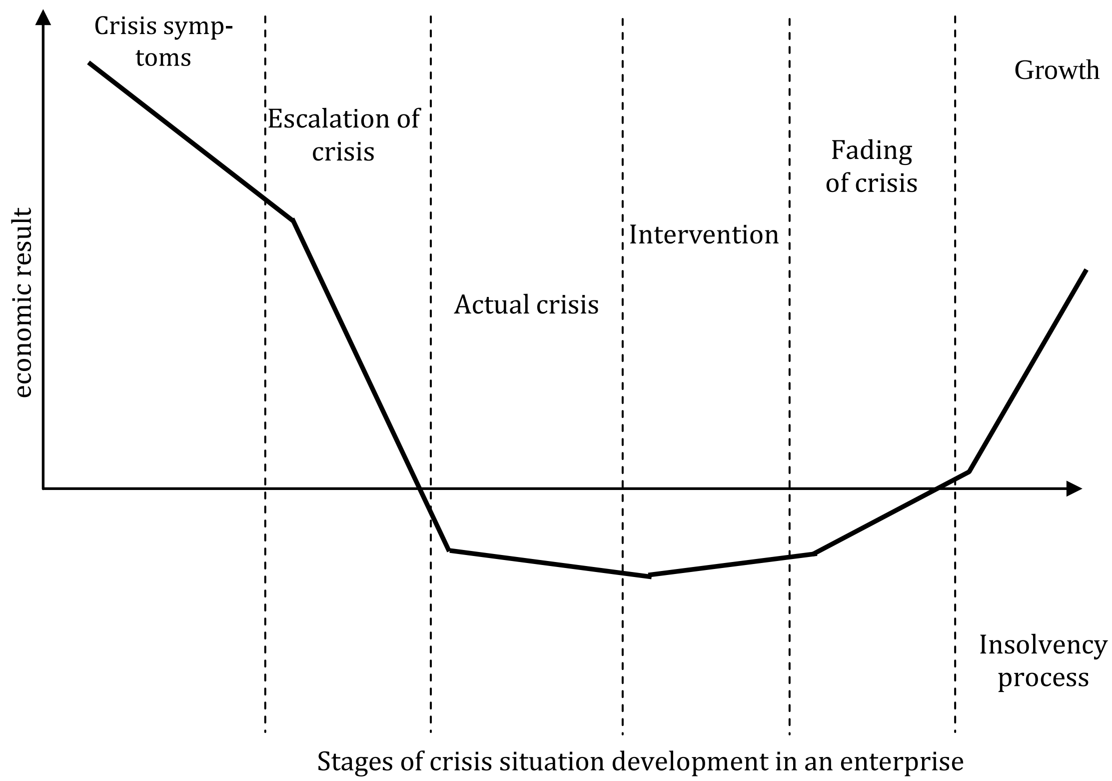

Figure 2. Developed, multiphase model of the course of crisis situation in an enterprise
(source: [18, p. 44])

- Stage 2

Mistakes within the enterprise lead to better threat symptoms visibility than in stage one. Despite this fact management still ignores the threat or takes ineffective /erroneous actions. This results in even more serious functional inefficiency of the organization, which leads to even more serious mistakes and increase of irregularities. This way the enterprise enters stage three, in which significant activity disturbances are revealed.

- Stage 3

This is the culmination of the crisis situation development. This moment requires introduction of radical changes, due to symptoms that transformed into the state that threatens future existence of the enterprise. The symptoms are e.g. loss of market position, financial insolvency, dangerous level of loan, significant increase in fixed cost etc. Introduction of changes is based mainly of curative actions.

- Stage 4

Final stage that ends with bankruptcy and liquidation of the enterprise.

Works of A. Zelek [18, p. 44] present the concept of developed, multiphase model of the course of crisis situation in an enterprise (see Figure 2). According to A. Zelek, efficient actions taken in the "intervention" stage can save the enterprise form bankruptcy.

On the other hand D. Czajka [3, p. 506] distinguishes three stages of enterprise crisis, where the third stage leads to bankruptcy:

- Initial stage: distribution and production dynamics problem occurs, receivables execution slows down, contradictory decisions accumulate or there is a total lack of decisions. Stock increases or maintains a high level together with decrease or stoppage of sales. Liabilities increase and current assets decrease, first symptoms of financial insolvency occur.
- Intermediate stage: production problems occur with higher frequency, material shortage due to lack of financial resources starts, production process stops to be profitable, quality of products decreases. Receivables are not paid in time and current bank loans limits are used in full. Liabilities are not paid in time and the interest level rises. Some suppliers require to be paid up-front or increased level of prepayments. Receiving a loan is more difficult due to the opinion that the enterprise is not reliable. Wages payment is not regular, highly qualified em-

ployees start to leave the company and go to the competition.

- Final stage: production is stopped, receivables payment slows down, and material assets are being sold out. Enterprise stops paying its liabilities, there are no more financial resources. Creditors apply for the company to receive the bankrupt status.

3 Characterization principle – use of insolvency threat level evaluation in the construction of the model

3.1 Theoretical basis for the characterization principle

„ (...) V.A. Gorbatov characterization principle is a part of modern methodology for the systems theory. Main gnoseologic postulates of the characterization principle are:

- characteristics of the solutions rather than the solutions themselves should be sought,
- solution characteristics should relate do the created class representatives (invariants) of equivalent solutions,
- equivalent solutions class is created as a result of input data interpretation of the solved task group of the problem area in the representative solution characteristics categories (...)". [7, p. 190].

„(...) Usually there is less equivalent class solutions than the solutions themselves and the analysis of solution characteristics can be performed without their direct (objective) generation. Characterization theory consists of formal elaboration and methodological verification in the selected characterization theory objective area, main idea of which is based on the mutual interpretability of functioning model of certain object with the model of its structure. Mutual interpretability of models is reached through:

- selection of universal rules of "proper" functioning (expressed in the model of functioning),
- structural (technical) interpretation of the functioning model [7, p. 191].

Universal rules of „proper functioning" are expressed with graph figures determined as [5, 7 and 9]:

- obligatory graph figures – abstract constructions, which, as homeomorphisms, should occur in the model - otherwise it can be incorrect,
- forbidden graph figures – easily identifiable objects, which isolation or dispersion (in the functioning model) assures the functional correctness of the object,
- neutral – used for functioning model simplification transformations, which do not result in forbidden and obligatory figures.

„(...) Object (resource) will function properly only if a mutually synonymous interpretation between its functioning rules (described with the Ψ_a functioning model) and the structure that realizes it (described with Ψ_b structure model) is determined and proven (...)" [7, p. 142]. In order to determine and prove synonymous interpretation of these two models the following assumptions are taken:

- resource functions adequately to its structure,
- resource structure is adequate to its desired way of functioning.

„(...) Basic model of the characterization theory can be described as:

$$< \Psi_a, \Psi_b, P_0(\Psi_a, \Psi_b) > \quad (1)$$

where:

Ψ_a - functioning model,

Ψ_b - structure model,

$P_0(\Psi_a, \Psi_b)$ – atomic predicate characterizing the interpretation possibility of Ψ_a functioning model in the categories of Ψ_b structure model (...)" [9, p.142].

„(...) Practical application of characterization principle to solving the determined group of tasks (problems) requires the elaboration of adequate theory that expresses in detailed determination of Ψ_a, Ψ_b models and P_0 predicate (...)" [9, p. 142].

3.2 Characterization principle application methodology in research practice

Search of optimal solution for formulated research problem can be performed on the basis of the Gorbatov characterization principle [5], as part of the stages presented in the Figure 3.

Stage 1 is based on a precise determination of the objective area (research reality) and formulation of the research problem.

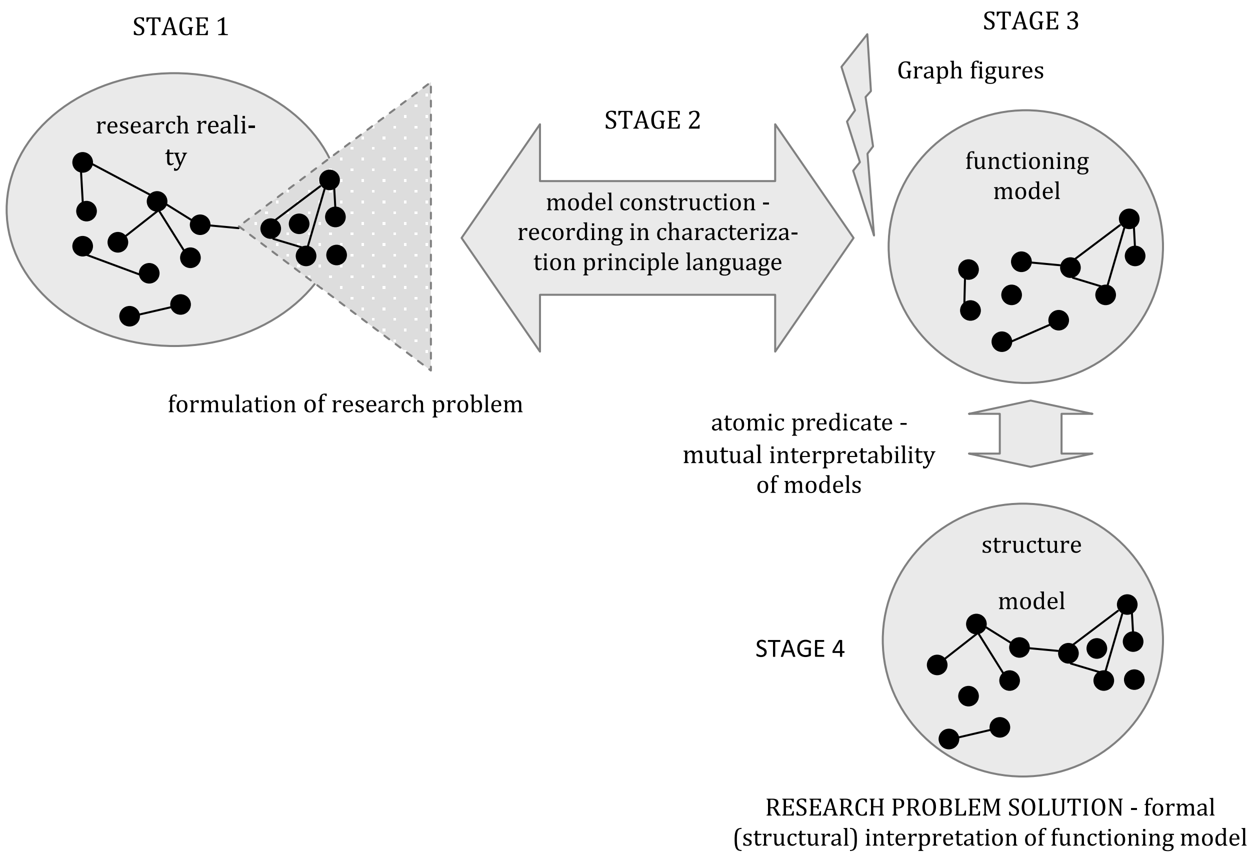

Figure 3. Characterization principle application methodology in research practice *(source: self study)*

As part of stage 2 the following are defined:

- logical predicate (formal recording of the researched problem),
- universal rules of proper functioning in the form of figures: forbidden, obligatory, neutral (usually in the form of graphs).

During stage 3 the defined logical predicate has its functioning model Ψ_a (resource, object) elaborated, for which its structural interpretation, in the form of structure model Ψ_b (stage 4), is sought.

Structure model Ψ_b is a solution for the formulated research problem. The basic condition is to create adequate characterization theory, in the form of basic model of this theory, for the selected subjective area.

3.3 Research problem, assumptions, hypothesis, research goal

The following research problem was formulated: two groups of companies are presented: enterprises, which went bankrupt and enterprises, which held their position in the market. Each enterprise makes or made financial statements and reports (balance sheet, cash flow statement). Research method that fulfills the following requirements is sought:

- on the basis of evaluation and comparison of two groups of enterprises will allow to determine the characteristics (described with indicators) of the financial and economical condition of the companies that bankrupted and that held their position in the market,
- on the basis of the financial and economical characteristics of bankrupt enterprises will allow to diagnose the insolvency threat level of any other enterprise,
- on the basis of insolvency threat level diagnosis and comparison with characteristics of enterprises that survived the crisis will allow to determine preventive activities for this process.

The following assumptions were made for such formulated research problem:

- financial reports (balance sheet, cash flow statement, income statement) are a synthetic record of the enterprise’s activities,

- results of decisions and mistakes made during management processes are reflected in the financial statements,
- financial indicators, based on financial statements, describe the economical and financial condition of the enterprise,
- insolvency is a process that can be diagnosed on the basis of economical and financial condition changes.

With relation to the research problem and selected assumptions the following research hypotheses were formulated:

- H_1: set of functional and structural models, describing changes in the economical and financial condition of bankrupt and survivor companies, can be determined with the use of characterization principle,
- H_2: comparative analysis, which aims at identification of differences in the functioning of two enterprise groups, can be performed on the basis of set of functional and structural models, describing changes in the economical and financial condition of bankrupt and survivor companies,
- H_3: set of functional and structural models, describing changes in the economical and financial condition of bankrupt and survivor companies, can be used to evaluate the insolvency threat level for any enterprise. Insolvency threat level can be determined on the basis of evaluation of comparison of any enterprise with the set of functional and structural models of selected group of enterprises.

In context of research problem, set assumptions and formulated hypotheses, the following research goal was determined: elaboration of observation models set and insolvency symptoms analysis, described in the form of Gorbatov characterization principle.

3.4 Characterization principle application methodology in the solving of the research problem

Characterization principle application methodology in the solving of the research problem formed above (see point 3.3) is based on the elaboration of the theory that, form the economical and financial viewpoint, determines the following:

- functioning models (Ψ_a) of survivor and bankrupt enterprises,
- structure models (Ψ_b) of survivor and bankrupt enterprises,
- atomic predicate $P_0(\Psi_a, \Psi_b)$, that determines the possibility of functionality model interpretation in the categories of structure model.

Scientific experiments were performed on the basis of financial and economical condition evaluation of survivor and bankrupt enterprises, precisely the changes of financial and economical condition of enterprises over the period of three years. Economical and financial condition of the enterprises was described with a set of indicators used in financial reports analysis.

Figure 4 presents the four main stages of performed research as well as expected results.

Changes of financial and economical condition of enterprises were recorder in the following form:

- Set of logic predicates (stage 1), expected result of which were 3 logic predicates for each enterprise group. One logic predicate corresponded to one financial year. Functions record the changes in the economical and financial status over the researched period (increases and decreases of selected economical and financial indicators). According to the formal recording of the research problem (see Appendix A) the following cases of companies in logic predicate were formulated in the form of disjunction.
- Set of logic predicates graph models (stage 2), expected result of which were 3 logic predicates graph models for each enterprise group. Every logic predicate had one corresponding graph model. Forbidden figures were eliminated from the logic predicate graph models what resulted in functioning graph models.
- Set of functioning graph models (stage 3), expected result of which were 3 functioning graph models for each enterprise group (they represent the common characteristics of the enterprises from the economical and financial viewpoint). Every functioning graph model had one corresponding functioning model.

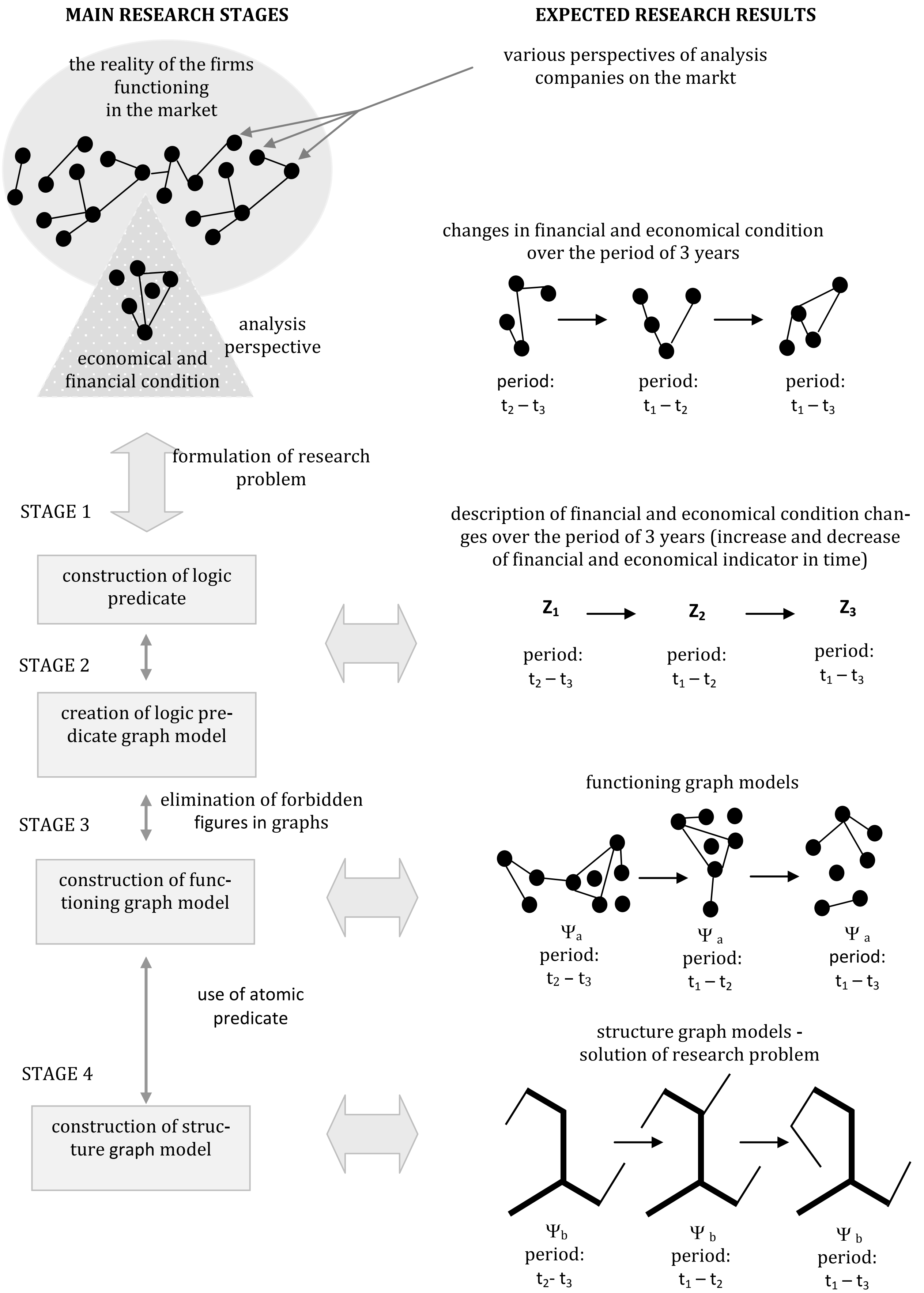

Figure 4. Main stages and results of performed research
(*source: self study*)

- Set of structure graph models (stage 4), expected result of which were 3 structure graph models for each enterprise group (these models are the sought solution of set research problem). Every structure graph model had one corresponding structure model.

Graph match index, which allows to determine in what part any enterprise matches the graph functioning (or structure) model of bankrupt enterprises and graph functioning (or structure) model of survivor enterprises, was elaborated. Evaluation of insolvency threat or survival level for the enterprise in upcoming period of 3 years was possible on the basis of comparison of the reached graph match index.

4 Research experiments results

4.1 Research sample

Financial records of 52 manufacturing enterprises that bankrupted in the period of 2000-2004 and 52 enterprises that survived in the period of 2000-2004 were collected for the conduction of this research experiment. The selection of bankrupt and survivor enterprises was selected with the following criteria:

- branch of operation of bankrupt enterprise,
- period (financial year) of the financial statement.

For example if the financial records of a bankrupt clothing company, for the years 2000, 2001, 2002, were gathered than records of a survivor company form the same industry and from the same period of time were gathered. Such selection of the research sample is to eliminate differences between particular company groups (bankrupt, survivor) that can occur due to:

- character of the branch that given company operates in,
- character of the time period (external conditions of the economical environment) that given company operated in.

Elimination of these differences leads to the possibility to compare the experiment results of particular enterprises:

- between enterprises within the same economic branch (bankrupt, survivor),
- between enterprises in different economic branches (bankrupt, survivor).

Research sample was divided in the following manner:

- „learning sample” (42 bankrupt enterprises, 42 survivor enterprises) – on its basis the following were constructed for particular company groups: sets of logic predicates, sets of logic predicates graph models, sets of functioning graph models, sets of structure graph models,
- „test sample” (10 bankrupt enterprises, 10 survivor enterprises) – on its basis tests of functioning and structure graph model sets were tested with relation to their “usefulness” in the insolvency threat situation evaluation; the assumption for the measure of functioning and structure graph model sets “usefulness” in the insolvency threat situation evaluation is their “ability” to classify the enterprise as “bankrupt” or “survivor” with the number of erroneous classification not exceeding 40% of the cases (it was assumed that in the test sample in every group for 10 cases up to 4 cases can be wrongly classified).

For every enterprise financial indicators, which indicate changes in the economical and financial condition of the bankrupt and survivor enterprises were calculated on the basis of collected financial statements.

4.2 Variables of logic predicate - indicators describing changes in the economical and financial condition

Changes in the economical and financial condition of two enterprises’ groups are described with 17 indicators. Indicator set was elaborated on the basis of related literature [2, 6, 12, 14 and 16]. Preparation of economical and financial condition evaluation was possible, on the basis of the indicators, in the aspect of:

- profitability ratios (indicators: return on assets, return on net assets, net profit margin, return on equity),
- efficiency ratios (indicators: fixed assets value, reversed fixed assets turnover ratio, asset turnover ratio, receivables turnover ratio, stock turnover ratio),
- liquidity ratios connected with evaluation of working capital (indicators: current ratio, quick ratio, working capital to sales ratio, working capital in financing of movable assets),
- debt ratios and ability to cover liabilities (indicators: debt ratio, debt to equity ratio, reversed current liquidity ratio, ability to cover debt form cash flow).

Due to the fact that:

- profitability indicators: return on assets, net assets, return on net sales, return on equity,
- working capital indicators: in sales revenues, in financing of moving assets,
- ability to cover debt form cash flow indicator could have positive or negative values – finally (including all remaining indicators) 24 logic predicate variables (F_1, ... F_{24}) were elaborated.

In other words, apart from the change of the indicator in time, selected indicators were analyzed whether their value is positive or negative. For example negative value of working capital indicators means serious problems with financing of current activities (lack of working capital). What is more, if its value decreased in time it corresponded to increase of problems in the enterprise. Additionally if the enterprise had losses and lost its ability to cover debt form cash flow (negative value), it meant that its presence in the market is seriously threatened. Final set of indicators, describing financial and economical condition, and corresponding predicate variables were collected in the Table 1a and Table 1b.

Table 1a. Financial indicators and corresponding predicate variables used in the research (*source: own elaboration)*

Description	Indicator Wsk_i	Predicate F_i	Value of the logic predicate F_i
return on assets (positive, negative value)	Wsk_1	F_1	$F_1 = 1$ (positive indicator value Wsk_1) $F_1 = 0$ (negative indicator value Wsk_1) variable signature $–F_1$
return on assets (decrease, increase of value in time)	Wsk_1	F_2	$F_2 = 1$ (increase of indicator value Wsk_1) $F_2 = 0$ (decrease of indicator value Wsk_1) variable signature $–F_2$
return on net assets (positive, negative value)	Wsk_2	F_3	$F_3 = 1$ (positive indicator value Wsk_2) $F_3 = 0$ (negative indicator value Wsk_2) variable signature $–F_3$
return on net assets (decrease, increase of value in time)	Wsk_2	F_4	$F_4 = 1$ (increase of indicator value Wsk_2) $F_4 = 0$ (decrease of indicator value Wsk_2) variable signature $–F_4$
net profit margin (positive, negative value)	Wsk_3	F_5	$F_5 = 1$ (positive indicator value Wsk_3) $F_5 = 0$ (negative indicator value Wsk_3) variable signature $–F_5$
net profit margin (decrease, increase of value in time)	Wsk_3	F_6	$F_6 = 1$ (increase of indicator value Wsk_3) $F_6 = 0$ (decrease of indicator value Wsk_3) variable signature $–F_6$
return on equity (positive, negative value)	Wsk_4	F_7	$F_7 = 1$ (positive indicator value Wsk_4) $F_7 = 0$ (negative indicator value Wsk_4) variable signature $–F_7$
return on equity (positive, negative value)	Wsk_4	F_8	$F_8 = 1$ (increase of indicator value Wsk_4) $F_8 = 0$ (decrease of indicator value Wsk_4) variable signature $–F_8$
fixed assets value (decrease, increase of value in time)	Wsk_5	F_9	$F_9 = 1$ (increase of indicator value Wsk_5) $F_9 = 0$ (decrease of indicator value Wsk_5) variable signature $–F_9$
reversed fixed assets turnover ratio (decrease, increase of value in time)	Wsk_6	F_{10}	$F_{10} = 1$ (increase of indicator value Wsk_6) $F_{10} = 0$ (decrease of indicator value Wsk_6) variable signature $–F_{10}$
			Continued in table 1b→

Table 1b. Financial indicators and corresponding predicate variables used in the research (cont.)
(*source: self study)*

Description	Indicator Wsk_i	Predicate F_i	Value of the logic predicate F_i
asset turnover ratio (decrease, increase of value in time)	Wsk_7	F_{11}	$F_{11} = 1$ (increase of indicator value Wsk_5) $F_{11} = 0$ (decrease of indicator value Wsk_7, variable signature $–F_{11}$
current liquidity ratio (decrease, increase of value in time)	Wsk_8	F_{12}	$F_{12} = 1$ (increase of indicator value Wsk_8) $F_{12} = 0$ (decrease of indicator value Wsk_8, variable signature $–F_{12}$
quick liquidity ratio (decrease, increase of value in time)	Wsk_9	F_{13}	$F_{13} = 1$ (increase of indicator value Wsk_9) $F_{13} = 0$ (decrease of indicator value Wsk_9) variable signature $–F_{13}$
working capital to sales ratio (positive, negative value)	Wsk_{10}	F_{14}	$F_{14} = 1$ (positive indicator value Wsk_{10}) $F_{14} = 0$ (negative indicator value Wsk_{10}) variable signature $–F_{14}$
working capital to sales ratio (decrease, increase of value in time)	Wsk_{10}	F_{15}	$F_{15} = 1$ (increase of indicator value Wsk_{10}) $F_{15} = 0$ (decrease of indicator value Wsk_{10}) variable signature $–F_{15}$
working capital in financing of movable assets (positive, negative value)	Wsk_{11}	F_{16}	$F_{16} = 1$ (positive indicator value Wsk_{11}) $F_{16} = 0$ (negative indicator value Wsk_{11}) variable signature $–F_{16}$
working capital in financing of movable assets (decrease, increase of value in time)	Wsk_{11}	F_{17}	$F_{17} = 1$ (increase of indicator value Wsk_{11}) $F_{17} = 0$ (decrease of indicator value Wsk_{11}) variable signature $–F_{17}$
stock turnover ratio (decrease, increase of value in time)	Wsk_{12}	F_{18}	$F_{18} = 1$ (increase of indicator value Wsk_{12}) $F_{18} = 0$ (decrease of indicator value Wsk_{12}) variable signature $–F_{18}$
receivables turnover ratio (decrease, increase of value in time)	Wsk_{13}	F_{19}	$F_{19} = 1$ (increase of indicator value Wsk_{13}) $F_{19} = 0$ (decrease of indicator value Wsk_{13}), variable signature $–F_{19}$
debt ratio (decrease, increase of value in time)	Wsk_{14}	F_{20}	$F_{20} = 1$ (increase of indicator value Wsk_{13}) $F_{20} = 0$ (decrease of indicator value Wsk_{14}), variable signature $–F_{20}$
debt to equity ratio (decrease, increase of value in time)	Wsk_{15}	F_{21}	$F_{21} = 1$ (increase of indicator value Wsk_{15}) $F_{21} = 0$ (decrease of indicator value Wsk_{15}) variable signature $–F_{21}$
reversed current liquidity ratio (decrease, increase of value in time)	Wsk_{16}	F_{22}	$F_{22} = 1$ (increase of indicator value Wsk_{16}) $F_{22} = 0$ (decrease of indicator value Wsk_{16}) variable signature $–F_{22}$
ability to cover debt form cash flow (positive, negative value)	Wsk_{17}	F_{23}	$F_{23} = 1$ (positive indicator value Wsk_{17}) $F_{23} = 0$ (negative indicator value Wsk_{17}) variable signature $–F_{23}$
ability to cover debt form cash flow (decrease, increase of value in time)	Wsk_{17}	F_{24}	$F_{24} = 1$ (increase of indicator value Wsk_{17}) $F_{24} = 0$ (decrease of indicator value Wsk_{17}) variable signature $–F_{24}$

Evaluation of changes in the economical and financial condition was performed on the basis of the change direction of Wsk_1, ...Wsk_{17} indicators (decrease, increase – regardless of the value of the change) or their score categorized: positive, negative.

Analysis was performed for every enterprise (1 ÷ 42) in every group (bankrupt, survivor) according to the following rules:

- value of the (t_2) indicator in the second financial year (e.g. 2001) was compared with the value of the (t_3) indicator in the third financial year (e.g. 2000):
  - if the value of the indicator in the second year was higher than in the third year the evaluation was that its value increased in time,
  - if the value of the indicator in the second year was lower than in the third year the evaluation was that its value decreased in time,
  - if the value of the indicator in the second year was the same as in the third year the evaluation was that the value did not change,
- in case of Wsk_1, Wsk_2, Wsk_3, Wsk_4, Wsk_{10}, Wsk_{11}, Wsk_{17} indicators additional evaluation was made in the third year and the indicator value was checked whether it is positive or negative (named indicators can be negative if the company in the third financial year: made a loss - Wsk_1, Wsk_2, Wsk_3, Wsk_4; had a deficiency of working capital - Wsk_{10}, Wsk_{11}; net loss was higher than the depreciation charge - Wsk_{17}),
- value of the indicator in the first financial year (t_1) (e.g. 2002) was compared with the value of the indicator in the second financial year (t_2) (e.g. 2001):
  - if the value of the indicator in the first year was higher than in the second year the evaluation was that its value increased in time,
  - if the value of the indicator in the first year was lower than in the second year the evaluation was that its value decreased in time,
  - if the value of the indicator in the first year was the same as in the second year the evaluation was that the value did not change,
- in case of Wsk_1, Wsk_2, Wsk_3, Wsk_4, Wsk_{10}, Wsk_{11}, Wsk_{17} indicators additional evaluation was made in the second year and the indicator value was checked whether it is positive or negative (named indicators can be negative if the company in the second financial year: made a loss - Wsk_1, Wsk_2, Wsk_3, Wsk_4; had a deficiency of working capital - Wsk_{10}, Wsk_{11}; net loss was higher than the depreciation charge - Wsk_{17}),
- value of the indicator in the first financial year (t_1) (e.g. 2002) was compared with the value of the indicator in the third financial year (t_3) (e.g. 2002):
  - if the value of the indicator in the first year was higher than in the third year the evaluation was that its value increased in time,
  - if the value of the indicator in the first year was lower than in the third year the evaluation was that its value decreased in time,
  - if the value of the indicator in the first year was the same as in the third year the evaluation was that the value did not change,
- in case of Wsk_1, Wsk_2, Wsk_3, Wsk_4, Wsk_{10}, Wsk_{11}, Wsk_{17} indicators additional evaluation was made in the first year and the indicator value was checked whether it is positive or negative (named indicators can be negative if the company in the first financial year: made a loss - Wsk_1, Wsk_2, Wsk_3, Wsk_4; had a deficiency of working capital - Wsk_{10}, Wsk_{11}; net loss was higher than the depreciation charge - Wsk_{17}).

Therefore the value of a single indicator can have increasing, decreasing or constant (no change) direction. During the analysis an observation was made that the value of particular indicators, in every enterprise (regardless form the group) and in every analyzed time period, was strictly increasing or decreasing. There was no case of a constant indicator in time, that is why the number of logic predicates could be limited to 24 (additional 17 variables would be necessary if the case of constant variable was included).

4.3 Construction, interpretation and analysis of logic predicates sets

Logic predicate values table was elaborated on the basis of the analysis described in point 4.2, performed for every enterprise in particular enterprise groups (bankrupt, survivor).

On the basis of the formal research problem solving (see Attachment A) recording, the following was elaborated:

- set of 3 logic predicates describing the group of 42 bankrupt enterprises:
  - $ZB_{t_2-t_3}$ - describes changes in the economical and financial condition of enterprises in the time period t_2 in comparison with t_3,

- $ZB_{t_1-t_2}$ - describes changes in the economical and financial condition of enterprises in the time period t_1 in comparison with t_2,
- $ZB_{t_1-t_3}$ - describes changes in the economical and financial condition of enterprises in the time period t_1 in comparison with t_3,

- set of 3 logic predicates describing the group of 42 survivor enterprises:
  - $ZP_{t_2-t_3}$ - describes changes in the economical and financial condition of enterprises in the time period t_2 in comparison with t_3,
  - $ZP_{t_1-t_2}$ - describes changes in the economical and financial condition of enterprises in the time period t_1 in comparison with t_2,
  - $ZP_{t_1-t_3}$ - describes changes in the economical and financial condition of enterprises in the time period t_1 in comparison with t_3.

Elaborated sets of logic predicates assured full projection of the changes in economical and financial state that occurred in the group of bankrupt and survivor enterprises over the period of 3 years. Successive cases of enterprises were recorded in the form of disjunction.

Exemplary (fragment) logic predicates table was presented in the table 2. Rows include information about successive cases of enterprises columns collect the predicates.

Table 2. Exemplary variable logic values for predicates of bankrupt enterprises in the $t_2 - t_3$ period *(source: self study)*

Bankrupt enterprises	F_1	F_2	F_3	...	F_{24}
1	0	0	0	...	0
2	1	0	1		0
3	0	1	0	...	1
...					
42	1	0	1		0

Exemplary form of logic predicate (the part related to data collected in table 2) was presented below.

$$Z_{t_2-t_3}(F_1,-F_1,F_2,-F_2,F_3,-F_3,...,F_{24},-F_{24}) =$$
$$= -F_1 \wedge -F_2 \wedge -F_3 \wedge ... \wedge -F_{24} \vee$$
$$\vee F_1 \wedge -F_2 \wedge F_3 \wedge ... \wedge -F_{24} \vee$$
$$\vee -F_1 \wedge F_2 \wedge -F_3 \wedge ... \wedge F_{24} \vee ... \vee$$
$$\vee F_1 \wedge -F_2 \wedge F_3 \wedge ... \wedge -F_{24}$$

Set of logic predicates should be interpreted in the following way – changes in the economical and financial condition for any enterprise in any selected period indicate that the enterprise:

- no. 1 indicator value was (predicate F_1) positive (negative) „I”,
- no. 1 indicator value (predicate F_2) decreased (increased) „I”,
- no. 2 indicator value was (predicate F_3) positive (negative) „I”,
- no. 2 indicator value (predicate F_4) decreased (increased) „I”,
- ... no. 24 indicator value (predicate F_{24}) decreased (increased).

In detail, the set of logic predicates indicates that in given enterprise group:

- in 2nd year in comparison with 3rd year there were changes in the economical and financial condition such as in case of enterprise no 1 (first part of the logic predicate), OR in case of enterprise no 2 (second part of the logic predicate), OR ..., OR in case of enterprise no 42 (forty-second part of the logic predicate),
- in 1st year in comparison with 2nd year there were changes in the economical and financial condition such as in case of enterprise no 1 (first part of the logic predicate), OR in case of enterprise no 2 (second part of the logic predicate), OR ..., OR in case of enterprise no 42 (forty-second part of the logic predicate),
- in 1st year in comparison with 3rd year there were changes in the economical and financial condition such as in case of enterprise no 1 (first part of the logic predicate), OR in case of enterprise no 2 (second part of the logic predicate), OR ..., OR in case of enterprise no 42 (forty-second part of the logic predicate).

Analysis of the elaborated set of logic predicates for the groups of bankrupt and survivor enterprises allowed the formulation of the following conclusions:

- despite of the differences in the functioning of bankrupt and survivor enterprises, in the same period and over the period of 3rd years (parts of the logic predicate vary when it comes to the value of the logic predicate), one can observe some “common characteristics” (e.g. in the group of bankrupt enterprises the logical value of F_1 was usually equal to 0 – recording „- F_1” indicated that the value of the return on assets ratio was negative what corresponds to financial losses),

- despite of the differences in the functioning of bankrupt and survivor enterprises, one can observe that in the same period of time some cases (parts of the logic predicate) of survivor (bankrupt) enterprises are similar to the bankrupt (survivor) enterprises; this means that there are minor differences in the logic values of predicates in particular parts of the logic predicate; this fact can lead to the following conclusions:
  - survivor (bankrupt) enterprises underwent similar changes in the economical and financial condition – same as in case of bankrupt (survivor) enterprises,
  - totality of economical conditions in macro and micro-environmental scale for the enterprises were similar; however, other factors decided about the final “success” (survival) or “failure” (bankruptcy) of the enterprise,
- one can assume that the “common characteristics” of bankrupt (survivor) enterprises described with logic predicates will be reflected in the structure graph model,
- set of logic predicates is a form of knowledge recording about the changes in the economical and financial condition that occurred in a group of bankrupt and survivor enterprises.

4.4 Construction, analysis and interpretation of functioning graph model sets

Corresponding functioning graph model, with eliminated forbidden figures, was elaborated for all logic predicates. This resulted in the creation of:

- set of 3 functioning graph models that represented (described) the manner of functioning (from the viewpoint of changes in the economical and financial condition) of the group of 42 bankrupt enterprises,
- set of 3 functioning graph models that represented (described) the manner of functioning (from the viewpoint of changes in the economical and financial condition) of the group of 42 survivor enterprises.

Functioning graph models fully realized the set logic predicate. This means that particular paths in every graph corresponded to the successive parts of the logic predicate. Figure 5 presents an example of functioning graph model of survivor enterprises elaborated on the basis of corresponding logic predicate.

Analysis of functioning graph model sets allowed to draw the following conclusions:

- each graph (tree-shaped) has as many levels as the number of predicate variables, that is 24 levels corresponding to successive predicate variables (F_1, ... F_{24}), which had various logical values in particular paths of the graph,
- every path in a graph has the same length, which means that it connects all 24 vertexes; this corresponds to a single part of ea logic predicate and is compliant with the set economical and financial condition, which is analyzed on the basis of constructed set of indicators,
- every path in a graph corresponds to a single enterprise case; this allows observation and evaluation of differences (characteristics expressed with economical and financial indicators) that occurred between particular enterprises; such differences can indicate “individual” reasons that led to survival or bankruptcy of a company,
- it can be expected that the common characteristics of enterprises will be “connected” in the structure graph models (these characteristics will differ in various enterprises’ groups).

Functioning graph model fully corresponds to the logic predicate. That is why the interpretation of particular paths in successive functioning graph model sets should be performed similarly to the one in case of particular parts in the set of logic predicates.

Evaluation of the most frequently used path in the graph (the one taken by the majority of enterprises) was made as part of the functioning graph models analysis. Table 3 collects the most frequent paths in the functioning graph models of bankrupt enterprises.

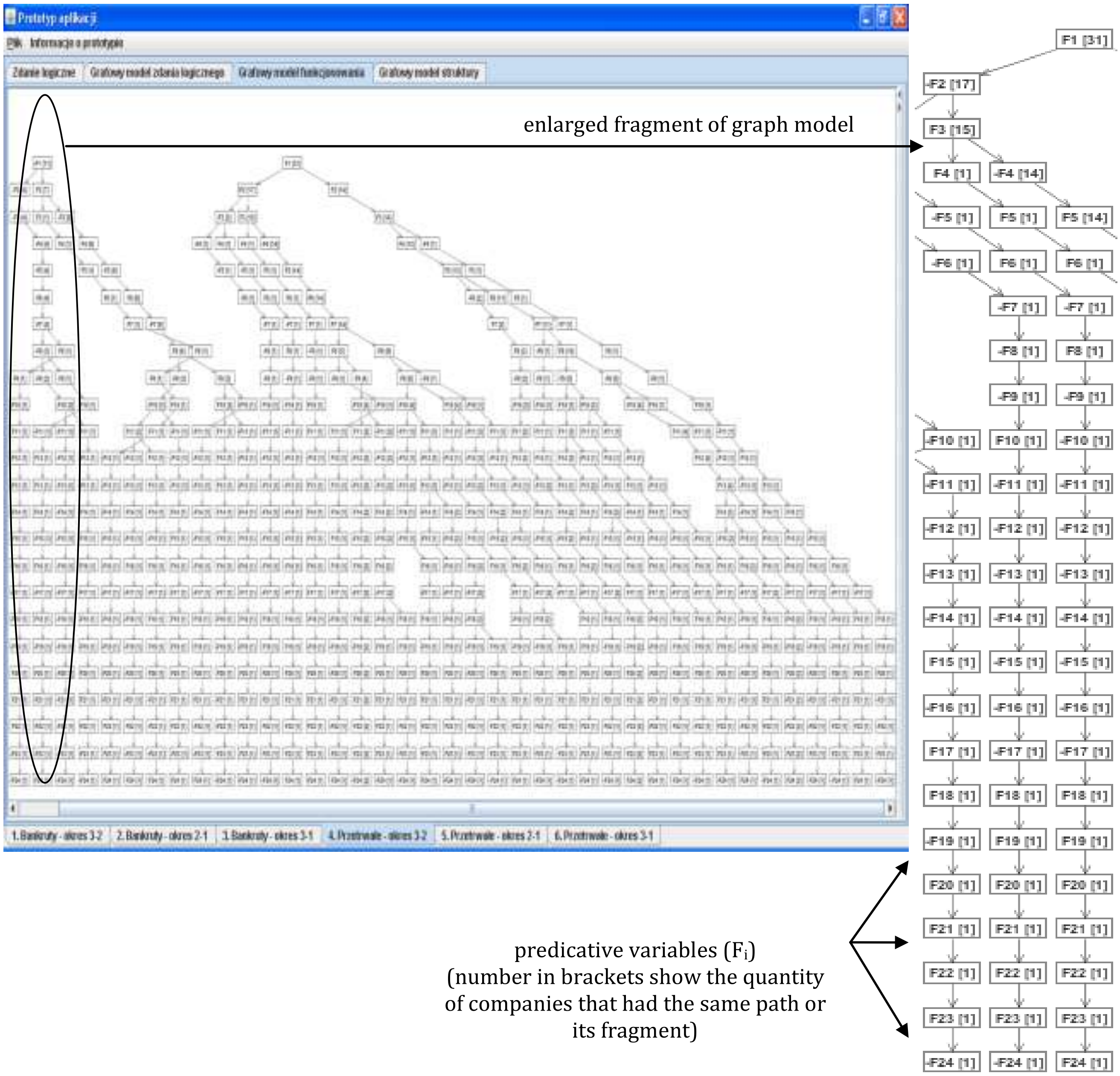

Figure 5. Example of survivor enterprises functioning graph model that realizes the logic predicate $\mathbf{ZP}_{\mathbf{t_2-t_3}}$
(*source: self study generated by prototype of IT system*)

Analysis of the most frequent paths of bankrupt enterprises allowed formulating the following conclusions:

- “most frequent” path in functioning graph model was identical in every analyzed period; this means that logic values of particular predicate variables are equal,
- enterprises deepened their state of bankruptcy in the successive time periods – increasing number of enterprises is on the most frequent path, what is indicated by the increasing sums values of particular paths,
- enterprise that “found itself” on the frequent path usually characterized with the following changes in economical and financial condition (bankruptcy indicators):
  - in the 3rd , 2nd and 1st year before bankruptcy the company had negative value of the following indicators: return on assets (predicate variable: -F_1), return on net assets (predicate variable: -F_3), net profit margin (predicate variable: -F_5), return on equity (predicate variable: -F_7); this indicates that the enterprise had operating and net losses;

this loss increased what is highlighted by the decreases of the indicators: return on assets (predicate variable: -F_2), return on net assets (predicate variable: -F_4), net profit margin (predicate variable: -F_6), return on equity (predicate variable: –F_8) „I”,

- fixed assets value decreased (predicate variable: –F_9) in the following periods, this can mean that the enterprises liquidated its machine park or had increase in the depreciation charge (e.g. through investments in new manufacturing machines), however, losses were so great that they could not assure positive cash flow, calculated as the sum of net profit and depreciation, even if the depreciation charge would increase in time (value of the predicate: F_{23} equaled 0 – indicator described with F_{23} and F_{24} predicates informs about the ability to cover debt form cash flow) „I”,
- value of the following indicators decreased in successive time periods: reversed fixed assets turnover ratio (predicate variable: –F_{10}) and asset turnover ratio (predicate variable: –F_{11}); total analysis of the information allowed to conclude that the pace of revenue decrease and the pace value of fixed assets were similar; what is more, assets were less frequently “renewed” (their turnover dropped) „I”,
- value of the following indicators decreased in successive time periods: current liquidity ratio (predicate variable: –F_{12}) and quick liquidity ratio (predicate variable: –F_{13}); enterprise was loosing solvency „I”,
- in the 3rd , 2nd and 1st year before bankruptcy the company had deficiency of working capital (predicate variables: –F_{14} and –F_{16}), that increased in the following periods (predicate variables: –F_{15} and –F_{17}) „I”,

Table 3. Most frequent paths in the functioning graph models of bankrupt enterprises (*source: self study*)

predicate model ZB_{t2-t3}		predicate model ZB_{t1-t2}		predicate model ZB_{t1-t3}	
Path	No of enterprises	Path	No of enterprises	Path	No of enterprises
-F_1	27	-F_1	26	-F_1	33
-F_2	16	-F_2	16	-F_2	25
-F_3	15	-F_3	14	-F_3	24
-F_4	13	-F_4	14	-F_4	23
-F_5	13	-F_5	14	-F_5	23
-F_6	13	-F_6	14	-F_6	23
-F_7	13	-F_7	14	-F_7	23
-F_8	12	-F_8	14	-F_8	22
-F_9	11	-F_9	11	-F_9	16
-F_{10}	9	-F_{10}	10	-F_{10}	13
-F_{11}	6	-F_{11}	7	-F_{11}	7
-F_{12}	6	-F_{12}	7	-F_{12}	7
-F_{13}	6	-F_{13}	7	-F_{13}	6
-F_{14}	5	-F_{14}	5	-F_{14}	5
-F_{15}	5	-F_{15}	5	-F_{15}	5
-F_{16}	5	-F_{16}	5	-F_{16}	5
-F_{17}	5	-F_{17}	5	-F_{17}	5
F_{18}	5	F_{18}	5	F_{18}	5
F_{19}	5	F_{19}	5	F_{19}	5
-F_{20}	5	-F_{20}	5	-F_{20}	5
-F_{21}	5	-F_{21}	5	-F_{21}	5
-F_{22}	5	-F_{22}	5	-F_{22}	5
-F_{23}	5	-F_{23}	5	-F_{23}	5
-F_{24}	5	-F_{24}	5	-F_{24}	5

- value of the following indicators increased in successive time periods: stock turnover (predicate variable: F_{18}) and receivables turnover (predicate variable: F_{19}), what means that the enterprise was "manufacturing to stock" and had problems with executing of receivables (connected with drop in revenue – see point c) „I",
- value of the following indicators decreased in successive time periods: debt ratio (predicate variable: $-F_{20}$), debt to equity ratio (predicate variable: $-F_{21}$), reversed current liquidity ratio (predicate variable: $-F_{22}$), what corresponds with the necessity to pay up all short and long-term loans and (or) increasing value of moving assets (what is indicated by the increasing value of stock turnover and receivables turnover ratios – stock and receivables are part of the moving assets) „I",
- in the 3rd , 2nd and 1st year before bankruptcy the company had negative value of the following indicator: ability to cover debt form cash flow (predicate variable: $-F_{23}$), what meant that losses of the enterprise were considerable and they were not able to balance the depreciation charges „I",
- value of the following indicator decreased in successive time periods: ability to cover debt form cash flow (predicate variable: $-F_{24}$), what corresponds to the disability to pay the liabilities.

Performed interpretation concerns only the "most frequent" paths in the successive functioning graph models of bankrupt enterprises. This interpretation has its limitations, due to the fact that every case of enterprise is different and not always the selected path led to bankruptcy. Similar analysis was performed on the group of survivor enterprises.

Whereas the comparative analysis of the functioning model sets of bankrupt and survivor companies (especially the most frequent paths) allowed formulation of the following conclusions:

- there are significant differences in the manner of operation of bankrupt and survivor enterprises (differences are visible in the values of successive logic predicates),
- there are slight differences in the most frequent paths among survivor enterprises; this means that various changes in economical and financial conditions that did not have significant influence on their manner of operation, can occur in this group (the enterprise survived),
- similarities in problems, faced both by survivor and bankrupt enterprises, are visible; this means that the totality of functioning conditions for these companies was identical, but only the ones that underwent certain changes in economical and financial condition were able to survive (e.g. increase of stock turnover ratio value is visible in survivor companies but it is connected with the decrease in receivables turnover ratio – despite stock sales problems the survivor companies had better playability of receivables; increase of debt but also possibilities to pay it off can be observed in cases where the stock and receivables turnover ratio increased – logic values of predicate variables F_{23} equal 1 and correspond to the positive value of the ability to pay debt from cash flow ratio).

4.5 Construction, analysis and interpretation of structure graph model sets

Corresponding structure graph model was elaborated for every elaborated functioning model. Structure graph models are interpreted together with functioning models, which indicates full realization of logic predicate. The following were created as a result of performed experiments:

- set of structure 3-graph models that connect common characteristics of enterprises from the group of 42 bankrupt enterprises,
- set of structure 3-graph models that connect common characteristics of enterprises from the group of 42 survivor enterprises.

Structure graph models are interpreted together with functioning models, which indicates full realization of logic predicate. Mutuality of the interpretation was reached through the use of atomic (transforming) predicate, which is identical for ever functioning model. This indicates that particular paths in every graph correspond to the paths of successive enterprises from the functioning model.

Figure 6 presents an example of a structure graph model of bankrupt enterprises, elaborated on the basis of corresponding functioning model.

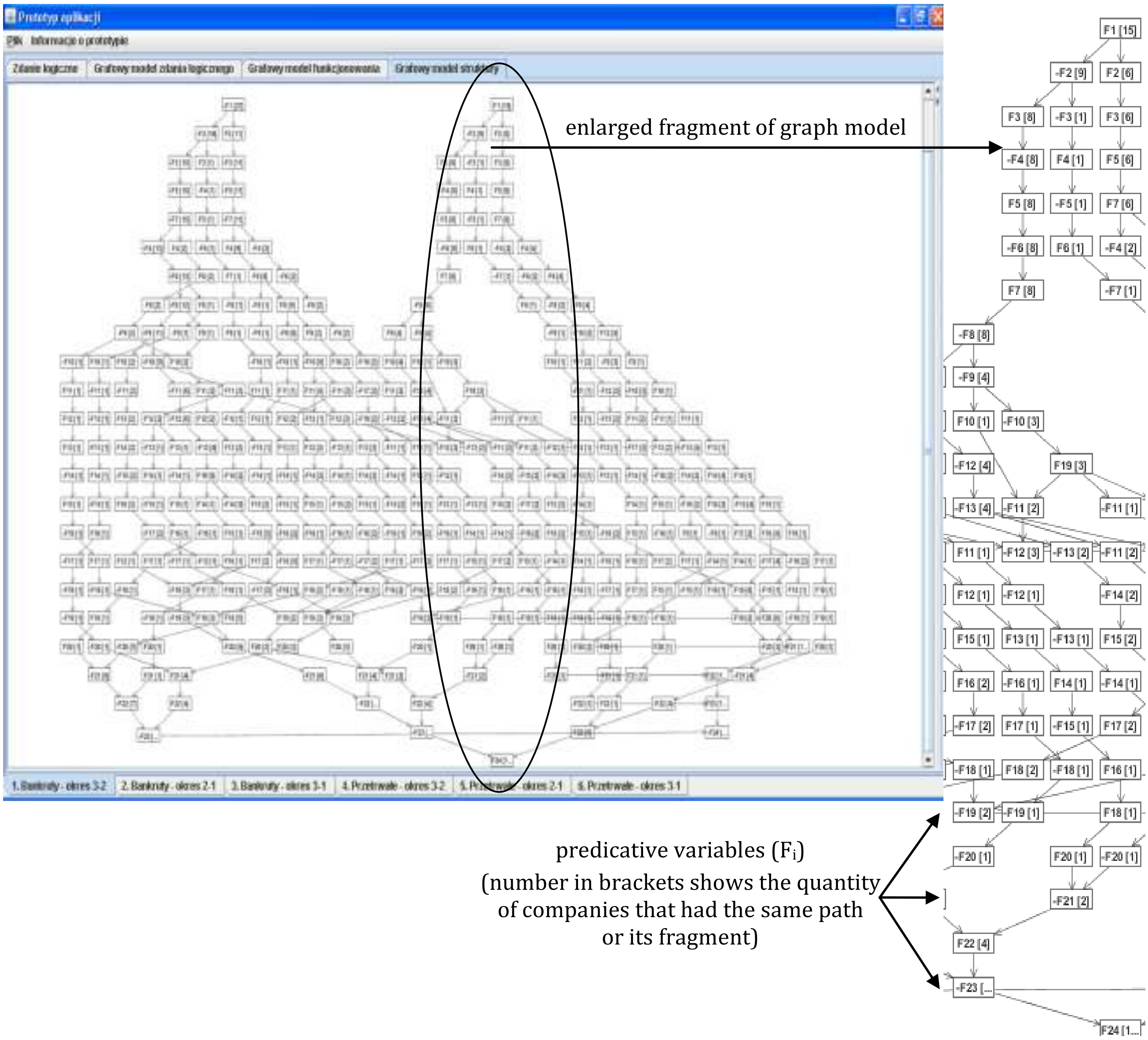

Figure 6. Example of a structure graph model elaborated on the basis of corresponding functioning model for the logic predicate $ZB_{t_2-t_3}$ describing the bankrupt enterprises in t_2 in comparison with t_3 time periods (*source: self study generated by prototype of IT system*)

Interpretation of particular paths in successive structure graph models should be performed similarly to the functioning graph models – path in the graph describing the changes in the economical and financial condition of the enterprises indicates that it reached:

- positive (negative) value for no. 1 indicator (predicate variable F_1) „I",
- value for no. 2 indicator (predicate variable F_2) decreased (increased) „I" ,
- value for no 3. indicator (predicate variable F_3) was positive (negative) „I" ,
- value for no 4. indicator (predicate variable F_4) decreased (increased) ... „I" ... ,
- value for no. 24 indicator (predicate variable F_{24}) decreased (increased).

Similarly to the functioning graph models the following can be observed in the structure graph models:

- each graph has as many levels as the number of predicate variables, that is 24 levels corresponding to successive predicate variables (F_1, ... F_{24}), which had various logical values in particular paths of the graph,
- every path in a graph has the same length, which means that it connects all 24 vertexes; this corresponds to a single part of ea logic predicate and is compliant with the set economical and financial

condition, which is analyzed on the basis of constructed set of indicators,

- every path in a graph corresponds to a single enterprise case; this allows observation and evaluation of differences (characteristics expressed with economical and financial indicators) that occurred between particular enterprises; such differences can indicate "individual" reasons that led to survival or bankruptcy of a company.
- the most significant (common) characteristics of the enterprises are located in the upper and lower levels of the structure graph model; this indicates that these characteristics can be the greatest determinants of a survival or a bankruptcy of an enterprise; in other words, the order of appearance of predicates and their logical values is different from the one in functioning graph model (mainly because the main characteristics "merged" – grouped in a form of a path).

Graph match index was elaborated for the need of structure graph models analysis. Index informs about the degree of match (in percentage) of particular path (case of enterprise) to the most frequently used path. In other words, match degree of single enterprise characteristics (changes in economical and financial condition) in relation to the characteristics of the enterprise group.

Average value of the index reached by the selected enterprise, for the set of all structure graph models (within the selected enterprise group), should be interpreted as:

- insolvency threat in three upcoming years (structure models of bankrupt enterprises),
- survival chance in three upcoming years (structure models of survivor enterprises).

Increasing or decreasing index value, between successive graph models, informs about the changes in insolvency threat or survival chance of the enterprise in the upcoming years.

4.6 Bankrupt and survivor structure graph models tests in the classification of enterprises

Tests of structure graph models of particular enterprises were performed as part of research experiments. Tests were performed to answer the following questions:

- in what degree the elaborated structure models properly classify (differentiate) the enterprises that originate form different enterprise groups (evaluation on the basis of research sample of 42 cases of bankrupt and survivor enterprises)?
- in what degree the elaborated structure models properly classify the enterprises that do originate from the research sample (evaluation on the basis of 10 enterprises not included in the research sample)?

Tests based on the graph match index were performed to reach an answer for these questions:

- for every case from 42 bankrupt enterprises the graph match index to the structure graph models of survivor companies was calculated (for a selected period of 2nd year in comparison with 3rd year, 1st year in comparison with 2nd year, 1st year in comparison with 3rd year),
- for every case from 42 survivor enterprises the graph match index to the structure graph models of bankrupt companies was calculated (for a selected period of 2nd year in comparison with 3th year, 1st year in comparison with 2nd year, 1st year in comparison with 3rd year),
- for every case from 10 bankrupt enterprises from the test sample the graph match index to the structure graph models of survivor companies was calculated (for a selected period of 2nd year in comparison with 3rd year, 1st year in comparison with 2nd year, 1st year in comparison with 3rd year),
- for every case from 10 survivor enterprises from the test sample the graph match index to the structure graph models of bankrupt companies was calculated (for a selected period of 2nd year in comparison with 3rd year, 1st year in comparison with 2nd year, 1st year in comparison with 3rd year).

In case when the enterprise went bankrupt (or survived) had an average index value in the structure model of survivor (or bankrupt) companies it was classified as "survivor" (or "bankrupt"). The number of wrongly classified companies in relation to 42 enterprises sets the general efficiency of functioning graph model sets as part of particular enterprise group. Table 4 collects the results of performed tests.

Table 4. Efficiency of structure graph models in classification of enterprises (research sample, test sample) *(source: self study)*

	Structure models of bankrupt enterprises		Structure models of survivor enterprises	
	Proper classification	Classification error	Proper classification	Classification error
Research sample (42 cases of bankrupt enterprises, 42 cases of survivor enterprises)	69% (29 enterpr.)	31% (13 enterpr.)	78% (33 enterpr.)	22% (9 enterpr.)
Test sample (10 cases of bankrupt enterprises, 10 cases of survivor enterprises)	70% (7 enterpr.)	30% (3 enterpr.)	90% (9 enterpr.)	10% (1 enterpr.)

The following can be assumed on the basis of tests performed on the research sample:

- overall efficiency of bankrupt enterprises' structure graph models set (classified as bankrupt, survivor on the basis of economical and financial status condition changes) equals 69%; in other words, when the enterprise reaches higher average of graph match index, for bankrupt enterprises structure graph model sets, it can correspond with the manner of functioning of this enterprise group with 69% certainty,
- overall efficiency of survivor enterprises' structure graph models set (classified as bankrupt, survivor on the basis of economical and financial status condition changes) equals 78%; in other words, when the enterprise reaches higher average of graph match index, for survivor enterprises structure graph model sets, it can correspond with the manner of functioning of this enterprise group with 78% certainty.

Test analysis, performed on 10 bankrupt and 10 survivor enterprises that did not originate from the research sample, allowed drawing the following conclusions:

- Efficiency of enterprise classification, based on structure graph model sets, is similar both for the "research sample" and "test sample" and equals approximately 70% (with 69% for „research sample"). Result of this test should be evaluated positively. Whereas, in case of structure models for survivor enterprises the classification efficiency equaled approximately 90%. This can indicate that the sample of 10 survivor companies was strongly correlated with the "research sample".
- Reached result can contain certain error due to relatively small number of enterprises (thus a small diversity of the enterprises) – probably different results would be reached if the "test sample" would be as numerous as the "research sample" – 42 cases of enterprises.
- Average match level, to the structure graph models' set for bankrupt (survivor) enterprises, exceeded 50% in all properly classified enterprises originating from "test sample". Reached result should be evaluated positively. It indicates that changes in economical and financial condition of these companies in a great degree corresponded with bankrupt (survivor) enterprises.
- Graph match index, as an indicator of insolvency threat and survival chance, can be evaluated as sufficient to perform an analysis of any enterprise on the basis of structure graph models' set. This indicates that classification to a particular enterprise group (structure graph model) is, to a great degree, independent of the research sample, on the basis of which the graph models were constructed ("test sample" results greatly emphasize this fact).

4.7 IT system prototype

IT system prototype was constructed for this particular research. System allows the detailed analysis of:

- every enterprise that is the part of the „research sample" in the context of:
  - set path in the functioning and structure graph model,
  - match degree to the functioning and structure graph model,
  - comparison of particular enterprises among the group they belong to (e.g. bankrupt enterprises) an between groups (bankrupt, survivor) on the basis of set path and (or) graph match index,
- any enterprise, which can be introduced to the prototype in the following manner:
  - creation of logic predicate based on constructed set of indicators,

- comparison of match degree to the structure graph model of bankrupt and survivor enterprises,
- comparison of the path set for the analyzed enterprise with the “most frequently” used path in the structure graph models’ set of bankrupt and survivor enterprises.

Elaborated prototype version can be a tool that supports enterprise management in case of insolvency threat. However, its current functional limitations can be a major issue in practical application. It might be necessary to construct the final version of the IT system.

Figure 7a and Figure 7b present main screenshots form the prototype application.

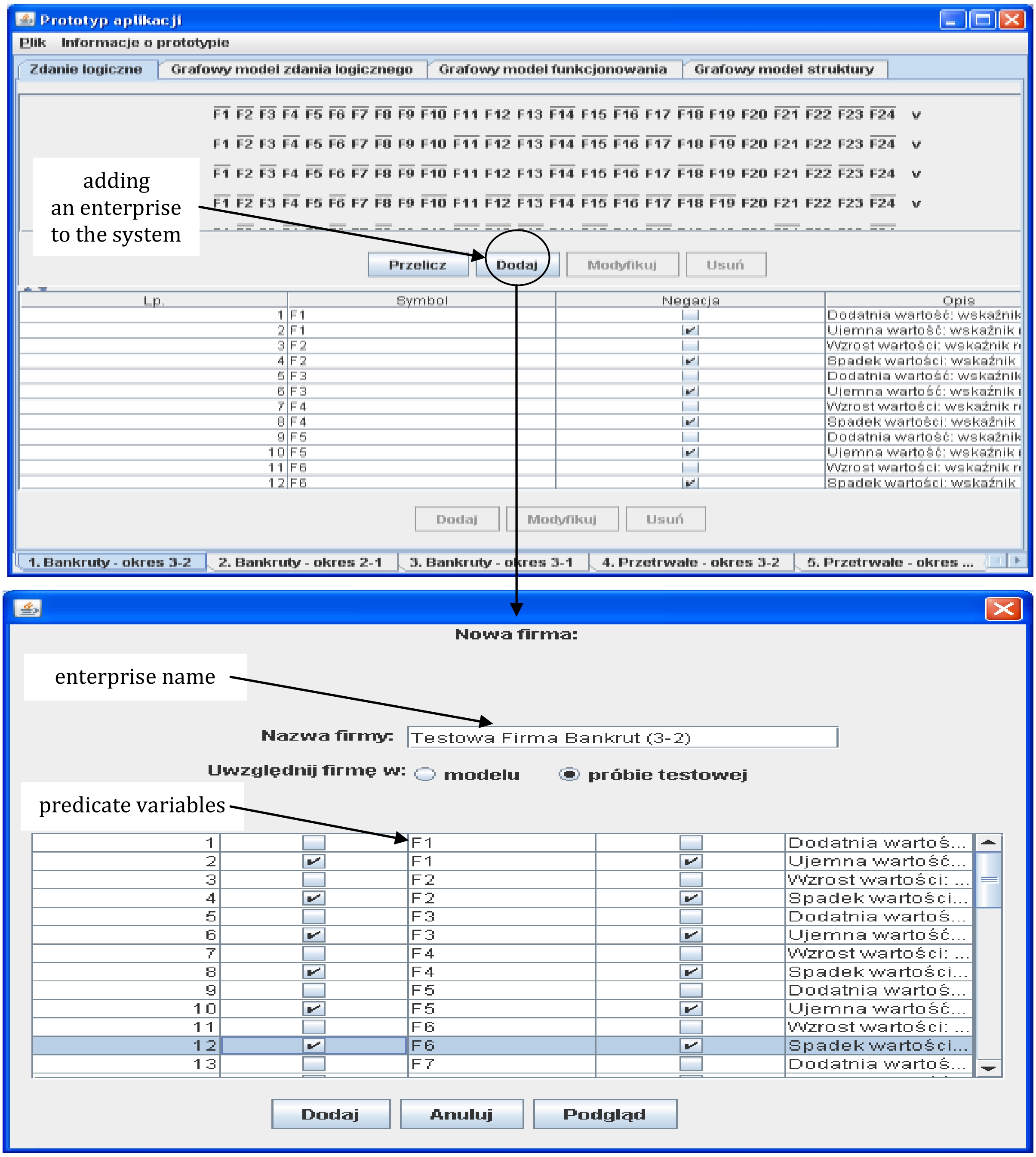

Figure 7a. Screen of the application prototype with functions adding an enterprise and adding predicate variables to the system (*source: self study - generated by the prototype IT system*)

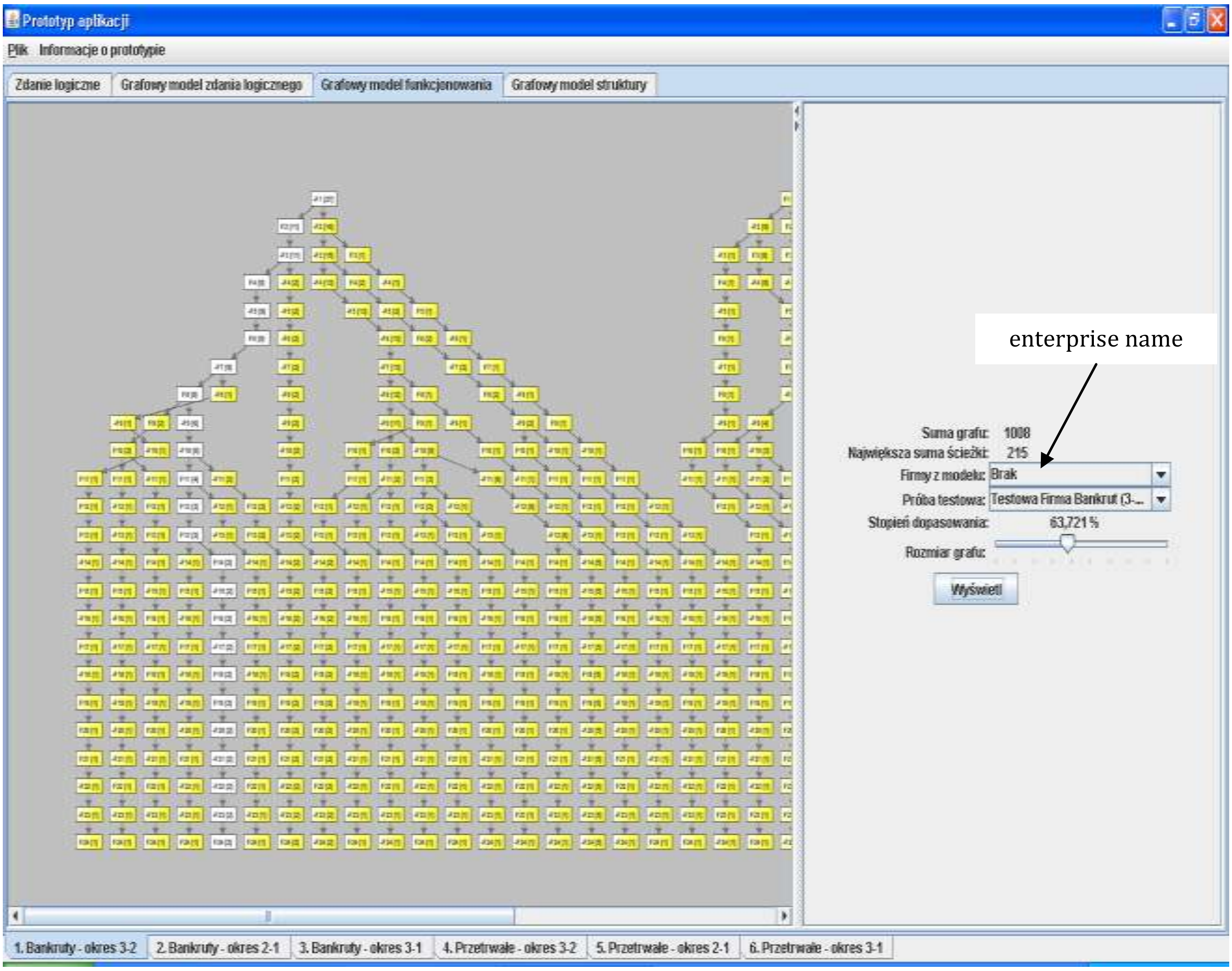

Figure 7b. Screen of the application prototype with generated functioning graph model
(*source: self study - generated by the prototype IT system*)

5 Summary

Presented experiment results allow to conclude that structure and functioning graph models' sets, elaborated on the basis of Gorbatov principle, can be used in enterprise management to:

- evaluate the insolvency threat level (or survival chance) in the context of changes in economical and financial condition,
- determine activities, which need to be executed to minimize the insolvency threat (or increase the chance to survive).

Manner of functioning of the model in the management process is presented in the Figure 8:

- identification <1> stage records changes in economical and financial condition of the enterprise (characterization principle), which is described with financial indicators,
- diagnosis <2> stage aims at the evaluation if the economical and financial condition of the enterprise and comparison (confrontation) with the set of functional and structural models elaborated according to the characterization theory; set of structure and functioning models is a knowledge registration form of mechanisms that:
  - enable the enterprises to survive in the market,
  - led the enterprise to bankruptcy,
- conclusions from this stage can be treated as remarks for the future <3> for the management of the enterprise, which needs to implement corrective activities that will prevent insolvency.

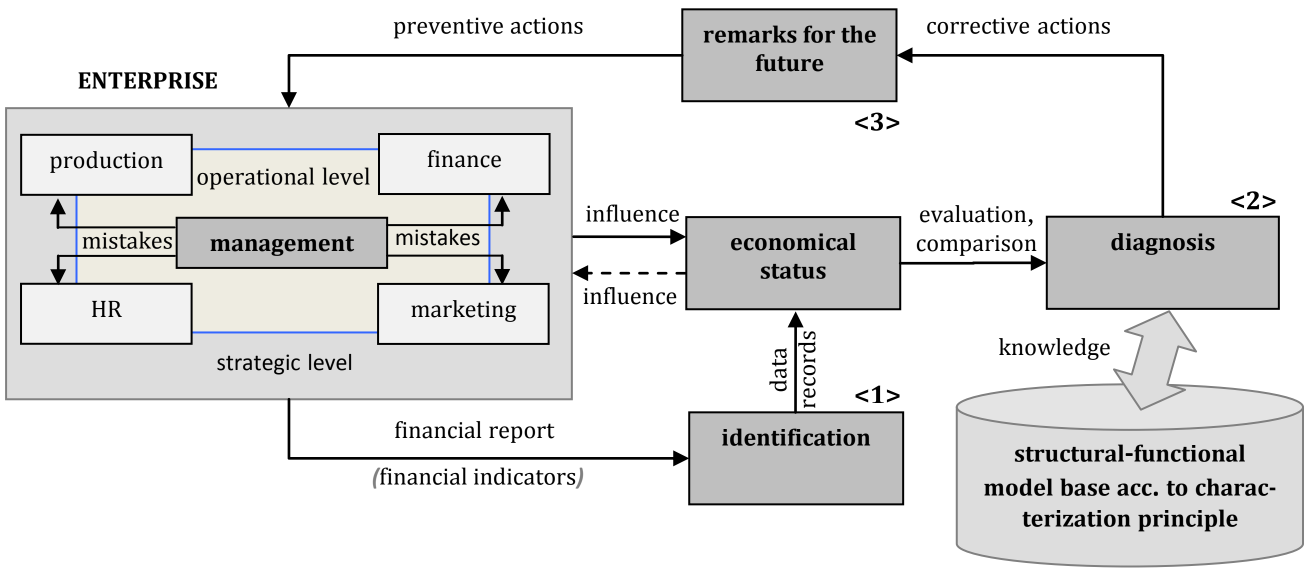

Figure 8. Insolvency threat level evaluation model functioning in the management process (*source: self study*)

Contrary to the currently used insolvency threat evaluation models (multidimensional discriminant analysis, logic analysis, artificial neural networks, genetic algorithms), elaborated models allow to:

- evaluate the condition of an enterprise threatened with insolvency on the basis of a more numerous,
- set of economical and financial indicators, including their mutual relations,
- analysis of increasing or decreasing insolvency threat in time,
- evaluation of activities that need to be undertaken in the basis of comparison with structure graph models' set of survivor enterprises.

What is more, elaborated set of functioning and structure graph models' includes changes in the economical and financial condition of bankrupt (or survivor) enterprises. In other words, sets of graph models reveal the reasons that caused bankruptcy or survival of the enterprise.

Authors of this paper have not encountered ay research that would present models able to compare groups of bankrupt and survivor enterprises (what was achieved with the help of Gorbatov characterization principle). Results of performed experiments indicate that the comparative analysis of models elaborated for particular groups can provide information about characteristics of insolvency threat and conditions favoring survival in the market.

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Attachment A

Attachment presents the formal recording of a research problem solution that was presented in point 3.3. This recording was formulated on the basis of Gorbatov characterization principle and was the basis for the experiments described in point 4.

A1 Formulas describing enterprises and their financial and economical status

Let us consider the formula below:

$$W = B \cup P \quad \text{(a1)}$$

where:

W – collection of all n analyzed enterprises W_i, also:

$$\forall_{W_{i=1}^{n}} W_i \in W$$

P – collection of m analyzed enterprises P_i that survived, also:

$$\forall_{P_{i=1}^{m}} P_i \in P$$

B - collection of o analyzed enterprises B_i that bankrupted, also:

$$\forall_{B_{i=1}^{o}} B_i \in B$$

where n = m + o.

Formula (a1) states that considered set of enterprises is a sum of sets of bankrupt and survivor (still functioning) enterprises.

Every enterprise (P_i - survivor and B_i - bankrupt) has financial records, which determine its financial and economical status. This status can be expressed with indicators calculated on the basis of certain positions in the financial statement of the enterprise.

Let us consider the following formulas describing the financial statement of the enterprise and its financial indicators:

$$\forall_{Ps_{t,i=1}^{l}} Ps_{t,i} \in PS_t \quad \text{(a2)}$$

$$SP_t(PS_t) = SP_t(Ps_{t,1}, \ldots, Ps_{t,l}) = \wedge_{i=1}^{l} Ps_t \quad \text{(a3)}$$

where:

SP_t – financial statement for the t period,

$Ps_{t,i}$ – i position in the financial statement for the t period,

PS_t – collection of positions in financial statement for the t period,

t – considered financial period,

l – number of positions in financial statement.

Formulas (a2) and (a3) represent the following sentence: financial statement for the t period consists of l positions form t period that are included in this period.

Let us consider the (WSK) set of economical and financial indicators (Wsk_i):

$$\forall_{Wsk_{t,i=1}^{p}} Wsk_{t,i} \in WSK_t \quad \text{(a4)}$$

where:

p – number of considered indicators Wsk_i,
t – considered financial period.

Formula (a4) states that every considered economical and financial indicator for particular time period t originates only form the indicator set that was appointed for this period.

Formula that describes the financial indicators has the following form:

$$\forall_{Wsk_{t,i=1}^{p}} R(Wsk_{i,j}) \quad \text{(a5)}$$

where:
R – projection of considered indicator $Wsk_{t,i}$ for the position PS_t of the financial statement SP_t; the R projection has the following form:

$$R(WSK_t) = \\ = \{(Wsk_t, PS_t) \in R \text{ for a certain } Wsk_t \in WSK_t\} \quad \text{(a6)}$$

Formula (a5) represents the sentence: every considered indicator Wsk_t for the t period is a projection of specific positions from the financial statement from this period. Projection R can have different forms according to the considered indicator. It means that direct position from the statement or quotient of positions e.g.Ps_1/Ps_2, product e.g. $Ps_2 \cdot Ps_3$, combination e.g. $Ps_2 \cdot Ps_3/Ps_4$, also with the use of addition e.g. $[(Ps_1 + Ps_2)/ Ps_4]$ or subtraction e.g. $[(Ps_1 - Ps_2)/ Ps_4]$.

Let us consider the following formula, which describes economical and financial status (S) of the enterprise in selected period t:

$$S_t(WSK) = S_t(Wsk_{t,1}, \dots Wsk_{t,p}) = \wedge_{i=1}^{p} Wsk_{t,j} \quad \text{(a7)}$$

Formula (a7) represents the sentence: economical and financial status of an enterprise in considered period t is described with p indicators $Wsk_{t,i}$ calculated for this period.

Basing on the formulas (a6) and (a7) one can state that the following formula is true:

$$S_t(WSK_t) = \wedge_{i=1}^{p} R(Wsk_{t,i}) \quad \text{(a8)}$$

Formula (a8) represents the sentence: economical and financial status (S) in period t is described with a product of all financial indicators ($Wsk_{t,i}$) belonging to the WSKt, set based on the ($Ps_{t,i}$)positions of the financial statement (SP_t) from this period.

Every considered case of enterprise belonging to the W set can be analyzed with indicators ($Wsk_{t,i}$) that describe its economical and financial status in selected period t (formula 7). Therefore the following formula is true:

$$\forall_{W_i} Q(W_i) \quad \text{(a9)}$$

where:

Q – projection of and enterprise W_i belonging to the W set for its economical and financial status S_t, described with indicators.

$$Q(W_i) = \{S_t \in S : (W_i, S_t \in Q \text{ for certain } W_i \in W)\}$$

S_t – set of economical and financial statuses of enterprises from considered period t.

On the basis of the formula (a9), determining the projection of selected enterprise on its economical and financial status, later in this paper, concept of economical and financial status and enterprise (company) will be used interchangeable.

A2 Definition and formal recording of logic predicate

It is assumed that in logic predicate (Z_t), for the t period, the predicate variable ($F_{t,i}$) for this period will be the recording of the ($Wsk_{t,i}$) indicator changes direction in the period t. Predicate variable can assume two logical values: truth (1) or false (0). For the formulated research problem:

- predicate variable $F_{t,i}$ in the period t assumes the value 0, when the $Wsk_{t,i}$ indicator value in the period t+1 decreased in comparison with period t,
- predicate variable $F_{t,i}$ in the period t assumes the value 1, when the $Wsk_{t,i}$ indicator value in the period t+1 increased or did not change in comparison with period t

or:

- predicate variable $F_{t,i}$ in the period t assumes the value 0, when the $Wsk_{t,i}$ indicator value in the period t was negative,
- predicate variable $F_{t,i}$ in the period t assumes the value 1, when the $Wsk_{t,i}$ indicator value in the period t was positive or equaled 0

what can be recorded in the following way:

$$\forall_{F_{t,i}} O(F_{t,i}) \quad \text{(a10)}$$

$$F_{t,i} = \{0,1\}$$

where:

$F_{t,i}$ – predicate variable in the period t assuming one of the values (1) or (0),

O – projection of $Wsk_{t,i}$ indicator change on the predicate variable $F_{t,i}$.

$$O(F_{t,i}) = \{Wsk_{t,i} \in WSK_t: (F_{t,i}, Wsk_{t,i}) \in O \text{ for a certain } F_{t,i} \in F_t\}$$

F_t – set of considered predicate variables $F_{t,i}$.

Assuming that formulas (a7), (a8) and (a9) describe the economical and financial status (S_t) of any enterprise (W_i) in the period t, one can see that the number of predicate variables is equal to the amount of p considered indicators ($Wsk_{t,i}$).

Including formula (a10), formula (a7) assumes the following form:

$$S_t(F_t) = S_t(F_{t,1}, \ldots F_{t,p}) = \wedge_{i=1}^{p} F_{t,i} \quad \text{(a11)}$$

Formula (a11) is the representation of a sentence: economical and financial status of an enterprise in considered period t is described with p predicate variable $F_{t,i}$ for this period.

On the basis of formula (a11) one can see that theoretically there is $k = 2^p$ (p – number of considered financial indicators $Wsk_{t,i}$) zero-one possibilities of occurrence of all predicate variables in a logical sentence. For example, if we consider economical and financial status (S_t) of an enterprise described with p-element set (WSK) of financial indicators (Wsk_i) than e.g. for the set of 21 financial indicators (predicate variables) we have 2 097 152 theoretical possible states that can describe the enterprise[1].

Identifying the enterprise (W_i), with its status (S_t) in the period t that describes it, one can see that in the (W) enterprise set there are as many disjunctive economical and financial sates as the number of considered enterprises. That is why the following formula is true:

$$Z_t(S_t) = \vee_{i=1}^{n} W_{t,i} \quad \text{(a12)}$$

On the basis of formula (a12) the following recording of logic predicate was assumed for the bankrupt (B_i) enterprises was assumed:

$$ZB_t(S_t) = \vee_{i=1}^{o} B_{t,i} \quad \text{(a13)}$$

where:

o – number of considered bankrupt enterprises' cases B_i,

ZB_t – logic predicate describing bankrupt enterprises in the period t.

Identifying bankrupt enterprise (B_i) with the economical and financial status that describes it we have:

$$ZB_t(S_t) = \vee_{j=1}^{o}(\wedge_{i=1}^{p} F_{t,i}) \quad \text{(a14)}$$

where:

o – number of bankrupt enterprises (B_i),

p – number of predicate variables ($F_{t,i}$).

Predicate (ZB_t) represents the set of considered z economical and financial states of bankrupt enterprises (B_1, B_2, ... B_o). Because of differences in functioning of enterprises, every economical and financial state (single enterprise case) is presented in the form of disjunction.

The following logic predicate recording was assumed on the basis of formula (12) for the survivor enterprises (P_i):

$$ZP_t(S_t) = \vee_{i=1}^{m} P_{t,i} \quad \text{(a15)}$$

where:

m – number of considered survivor enterprise cases P_i,

ZP_t – logic predicate describing survivor enterprises in the period t.

Identifying survivor enterprise (P_i) with economical and financial status, which describes it, we have:

$$ZP_t(S_t) = \vee_{j=1}^{m}(\wedge_{i=1}^{p} F_{t,i}) \quad \text{(a16)}$$

where:

m – number of survivor enterprises (P_i),

p – number of predicate variables ($F_{t,i}$).

Predicate (ZP_t) represents set of „economical and financial states" of survivor enterprises (P_1, P_2, ... P_m). Every single economical and financial state (single enterprise case) has the form of disjunction, due to differences in the functioning of enterprises.

On the basis of Figure 14 and Figure 16 one can assume that every part of a logic predicate has the length of (p) – includes the same number of predicate variables ($F_{t,i}$). Length of the alternative part results directly form the assumed knowledge representation model - economical and financial state of enterprises is analyzed on the basis of considered set of indicators (set of 17 indicators for which 24 predicate variables were elaborated). Number of predicates for selected group of enterprises is equal to the number of analyzed time periods.

[1] The use of Gorbatov characterization principle allows the search of a solution based on the analysis of its characteristics without the need to consider as many possible cases.

For every group of enterprises a set of three logic predicates will be constructed, considering the data form the period of three years.

A3 Forbidden figures – definition and interpretation

Functioning graph model is created, due to fission of forbidden figures in predicate graph model. Elimination of forbidden figures form the predicate graph model allows such connection of vertexes that:

- do not fit any of analyzed enterprises – there is no relevant part in the logic predicate, which can realize the graph connections,
- do not suit the economical and financial status definition (formula (a7)) – every enterprise is considered according to a strictly determined set of financial indicators. Therefore, analysis based on a sample of fewer indicators than considered set, is not allowed (it does not provide the full information about the economical and financial status of the enterprise).

Concept of path, which determines the connections between graph vertexes, was defined for the functioning graph model. Path (v) was defined with the following formula:

$$v(M) = \wedge_{j=1}^{s} M_j \quad (a17)$$

$$\forall_{M_{j=1}^{r}} M_j \in M \quad (a18)$$

where:

s = {1, ... r} – determines length of the path,

M – set of predicate variables M_j present in a logic predicate.

Formulas (a17) and (a18) indicate that the path is created due to connection of graph vertexes, which belong to the M set. However, two vertexes to belonging to the same path need to be different, what is described with the formula below:

$$\forall_{M_i, M_j} \in v(M) \quad M_i \neq M_j \quad (a19)$$

Also in case of bankrupt companies (B):

$$\forall_{(M_i, M_j \in v(M))} T(M_i, M_j) \wedge U(M_i, M_j, B) \quad (a20)$$

where:

T – relation sequence, determining the M_j element (graph vertex) as the consequent of the M_i (graph vertex) element in the path v(M),

U – M_i, M_j appurtenance relation to any alternative part of the B collection (bankrupt enterprises).

However, in case of survivor companies (P):

$$\forall_{(M_i, M_j \in v(M))} T(M_i, M_j) \wedge U(M_i, M_j, P) \quad (a21)$$

where:

T - relation sequence, determining the M_j element (graph vertex) as the consequent of the M_i (graph vertex) element in the path v(M),

U - M_i, M_j appurtenance relation to any alternative part of the P collection (survivor enterprises).

Formulas (a19) – (a21) represent the sentence: for each pair of path successive vertexes there must be an alternative part, which includes these vertexes. Path in a functioning graph model is a directed path and the graph cannot be cyclical.

With the use of the (a17) – (a21) formulas forbidden figures are determined as any paths v(M), which do not fulfill the following formulas:

$$\forall_{M_{i=1}^{s} \in v(M)} \exists_{B_j \in B} M_i \in B_j \quad (a22)$$

$$\forall_{M_{i=1}^{s} \in v(M)} \exists_{P_j \in P} M_i \in P_j \quad (a23)$$

$$s = p \quad (a24)$$

$$\exists_{M_i \in v(M)} \{\wedge_{j=1}^{t} [M_i \in v_j(M)]\} \wedge O[M_i, M, v(M)] \quad (a25)$$

where:

B – set of bankrupt enterprises,

P – set of survivor enterprises,

v(M) – path in a graph,

M_i – i path vertex in a graph,

s – number of vertexes (M),

p – number of predicates (considered financial indicators),

t – number of considered paths,

O - „relation of common predecessors" determining whether the set of preceding vertexes (starting form the considered vertex M_i) in considered paths is identical.

Formulas (a22) – (a25) indicate that:

- every path vertex must belong to at least one alternative part (from the collection of all alternative parts) in logic predicate for any group of enterprises - formula (a22) and (a23),
- length of the path has to correspond with the length of the alternative part (formula (a24),
- condition of common vertexes has to be met – particular vertex is common for considered paths if it belongs to every of them and all preceding in these paths are identical (formula (a25)).

A4 Functioning graph model

Functioning model is a graph representation of considered enterprises' "manner of operation", bankrupt and survivor, from the viewpoint of changes in their economical and financial condition. This model is created when forbidden figures are eliminated from the graph model of logic predicate. Elimination of these figures results in the functioning model assuring the proper realization of the logic predicate. Proper functioning model is created for every group of enterprises and every, constructed for it, logic predicate. Construction of functioning model is started form its definition, which in case of bankrupt enterprises is given as the combination:

$$\Psi_a(B) = \langle M, B \rangle \quad (a26)$$

In case of survivor enterprises as:

$$\Psi_a(B) = \langle M, P \rangle \quad (a27)$$

where:

M – set of predicate variables, with inclusion of their values in the logic predicate:

$$M = (F_1, \overline{F_1}, F_2, \overline{F_2}, F_3, \overline{F_3}, F_4, \overline{F_4}, F_5, \overline{F_5}, F_6, \overline{F_6}, F_7, \overline{F_7}, F_8, \overline{F_8}, F_9, \overline{F_9}, F_{10}, \overline{F_{10}}, F_{11}, \overline{F_{11}}, F_{12}, \overline{F_{12}}, F_{13}, \overline{F_{13}}, F_{14}, \overline{F_{14}}, F_{15}, \overline{F_{15}}, F_{16}, \overline{F_{16}}, F_{17}, \overline{F_{17}}, F_{18}, \overline{F_{18}}, F_{19}, \overline{F_{19}}, F_{20}, \overline{F_{20}}, F_{21}, \overline{F_{21}}, F_{22}, \overline{F_{22}}, F_{23}, \overline{F_{23}}, F_{24}, \overline{F_{24}})$$

B – set of relations determined with p – element alternative parts for the group of bankrupt enterprises,

P – set of relations determined with p - element alternative parts for the group of survivor enterprises.

One can see that the number (card (M) = r) of possible logic predicates is included in the range:

$$p \leq r \leq 2^p \quad (a28)$$

A5 Construction procedure of structure graph model – definition of atomic predicate

Possibility to transform the functioning model to structure model is described with atomic predicate:

$$P_0(\psi_a, \psi_b) \quad (a29)$$

where:

Ψ_a – functioning model of any group of enterprises,

Ψ_b - structure model of any group of enterprises.

Use of atomic predicate allows determining (on the basis of the functioning model Ψ_a) the structure model Ψ_b. Structure and functioning models are mutually interpretable [2]. Observation and analysis of structure models allows determining common characteristics of enterprise groups form the economical and financial viewpoint. Structure models allow:

- determination of characteristics that indicate bankruptcy (structure models of bankrupt enterprises) or contributed to the survival in the market (structure models of survivor enterprises),
- determination of insolvency threat level for any enterprise (on the basis of match degree of economical and financial condition of an enterprise to the structure model of bankrupt and survivor enterprises),
- determination of necessary activities preventing bankruptcy (on the basis of comparison of structure models of bankrupt enterprises with structure models of survivor enterprises).

Atomic predicate P_0 takes a form of a procedure, which transforms functioning model Ψ_a into the structure model Ψ_b. Successive steps of the procedure are:

- Step 1

Set of vertexes is created for any predicate variable F_i (regardless of its logical value) belonging to different paths v(M) in graph functioning model. All possible two-element subsets, as a combination of vertex pairs (F_i, F_j), are created on the basis of this set. Every pair is subjected to analysis in step 2.

- Step 2

For every pair of vertexes (F_i, F_j) the compatibility condition, of their logical values and the logical values of their successors in relation to their logical values, is checked. If they are compatible than:

  - predecessor of F_i vertex is connected via a path with vertex F_j,
  - vertex F_i, with successors is disconnected from its predecessor.

- Step 3

Existing connections between vertexes and their predecessors are transformed into a path directed form predecessor to the vertex, after the consideration of all vertex pairs.[3]

[2] Functioning model and corresponding structure model are created for every logic predicate - 3 functioning and 3 structure models are constructed in case of three considered time periods.

[3] Presented procedure leads to the creation of structure graph models without forbidden figures, through connection of common characteristics.

DATA ANALYTICAL PROCESSING IN DATA WAREHOUSES

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Abstract: The article presents issues connected with processing information from data warehouses (the analytical enterprise databases) and two basic types of analytical data processing in data warehouse. The genesis, main definitions, scope of application and real examples from business implementations will be described for each type of analysis. There will be presented copyrighted method of knowledge discovering in databases, together with practical guidelines for its proper and effective use in the enterprise.

Keywords: data, data warehouse, data management, data analytical processing, OLAP, data mining.

1 Introduction

Current record of economical events is a basic data tool for the needs of operational management. This data is necessary for proper functioning of an organization on the level of everyday business processes. Transactional systems are implemented in order to increase the effectiveness of operational data gathering and storing. However such solutions do not allow making the processed information available what can be extremely helpful in management decision making. One of the reasons for such state of things is the aim of creation of transactional systems as well as the character of data stored in them:

- operational data is usually detailed, whereas managers expect aggregated information,
- data model of transactional base is optimized in order to speed up the realization of basic transactional processing operations and not the analytical processing of this data,
- data needs to be periodically deleted from the transactional system in order to maintain the satisfying level of its efficiency, whereas the analysis usually requires the historical data to be complete,
- enterprises usually have many different transactional systems, while the full picture of the analysis can only be reached on the basis of integrated data originating from all its systems,
- analytical processing of data in a transactional system will result in the drop of its efficiency and current transactional operations will not be processed.

Sharing the solutions built on the basis of transactional systems' resources, directed at analytical, not transactional, needs, becomes a necessity. Such requirements are fulfilled by the decision making supporting systems that are based on data warehouses [16]. The main task of data warehouses is to gather, integrate and process operational data in order to gain data that is new, previously unknown and useful from the business point of view, which can support the decision making process. The aim of this article is to present issues connected with processing information from data warehouses – the analytical enterprise databases.

The article presents two basic types of analytical data processing. The genesis, main definitions, scope of application and real examples from business implementations will be presented for each type. Copyrighted method of discovering knowledge from data, together with practical guidelines for its proper and effective use, will be presented.

2 Meaning of analytical data processing for the decision making process in an enterprise

Currently every enterprise can gather a data collection of a practically unlimited size. For example the data resources of eBay equaled to 2 PB in November of 2006 [24]. RapidShare hosting company shared a disk space of few petabytes with its customers [23] in the October of 2007. Yahoo! website announced that it is the owner of the biggest structured database that was ever implemented in a manufacturing environment, equal to 1 PB [2], in May of 2008. The company also stated that the database will grow to reach 10 PB in 2009.

However, rapid growth of databases in enterprises, organizations and institutes led to limitation in the analysis and interpretation of gathered data. For example Google in the December of 2008 announced that it is able to sort 1 PB of data in 6 hours and 2 minutes but it needs 4000 computers to realize this task [11].

It is a perfect example of the complexity of the free access issue to the data stored in an enterprise. In order to not only possess but also share the data with potential users, it needs to be organized in sorted and usually central databases, where data warehouses are currently the biggest known databases. Currently the biggest data warehouse is set in the Sun SPARC Enterprise M9000 server and administered with Sybase IQ relation database [3]. It is able to perform a single download of 1 PB of independent and unstructured data. Therefore one can assume that there are tools that allow the enterprises not only to gather data but also put it to effective use. However, the tools and techniques for automatic and intelligent analysis of databases, in order to gather processed information, supporting the management decision making processes became a necessity.

The necessity to make decisions is accompanying the activities of managers since the beginning of organization management history. Development and practical implementation of IT techniques in management allowed decision making process supporting with IT systems, known as decision making aiding systems. One of the first decisions aiding systems' definitions states that they are systems supporting business and organizational decision activities [11]. These systems include applications, which are used to analyze, conclude, simulate, model and evaluate models, schedule or forecast [11]. DSS systems (Decision Support System) prove useful in such decision activities, which do not have procedures leading to optimal solutions and their task is to provide exact, processed information for managers, purchasers and analysts. Their task is to increase the effectiveness of decision making process realization due to limitation of the three following latencies [4]:

- data latency – time necessary to gather and prepare the data for analysis,
- analysis latency – time necessary for analysis and transformation of data into a useful managing information,
- decision latency – time necessary for transferring the data for analysis, interpretation and decision making on needed actions.

Meanwhile, the reaction time, from the moment of the event's start until the moment of making a decision, has a key meaning for the business value of decisions made. The bigger the latency is, the greater is the value decrease (see Figure 1) - even the most valuable information that is not up-to-date will have no significant meaning in the enterprise management.

In order to limit the effects of the latencies, DSS solutions need to assure: access to data coming from many different and dispersed sources, data analysis according to the classification, forecast and simulation methods and finally an easy distribution of this data to the high management responsible for decision making.

Therefore, they are based on data warehouses and analytical processing of gathered data, providing the best functionality and support for decision making, which is based on multilevel historical data analysis. Modern DSS solutions allow reaching for external (not originating form the enterprise) and real-time data (operational), in order to increase the value of the analysis.

The heart of such solutions is the data warehouse. W. H. Inmon [7], the creator of the concept, defines the data warehouse as directed, consistent, chronological and unchangeable data collection. On the other hand, S. Kelly [8], emphasizing the business issues, defines data warehouse as a structure independent of the operational, designed for users who need deep economical knowledge – not only IT knowledge. Moreover he claims that the warehouse structure should relate to the structure of the organization, be unchangeable and reflect the status of the organization in time. Summing up, data warehouse is an independent, but operating within an existing system, directed read-only database, which is used as a basis for decision making support. The main idea of data warehouse is to connect the data from different transactional bases in one base.

Thus data warehouses assure access to gathered resources in a form, character and scope optimized towards the realization of complex multilevel analysis. However, the realization of these analyses is a task for analytical systems, which can be divided into two main groups of tools: current analytical processing and data exploration. Detailed characteristics of both types of data will be presented in the following chapters.

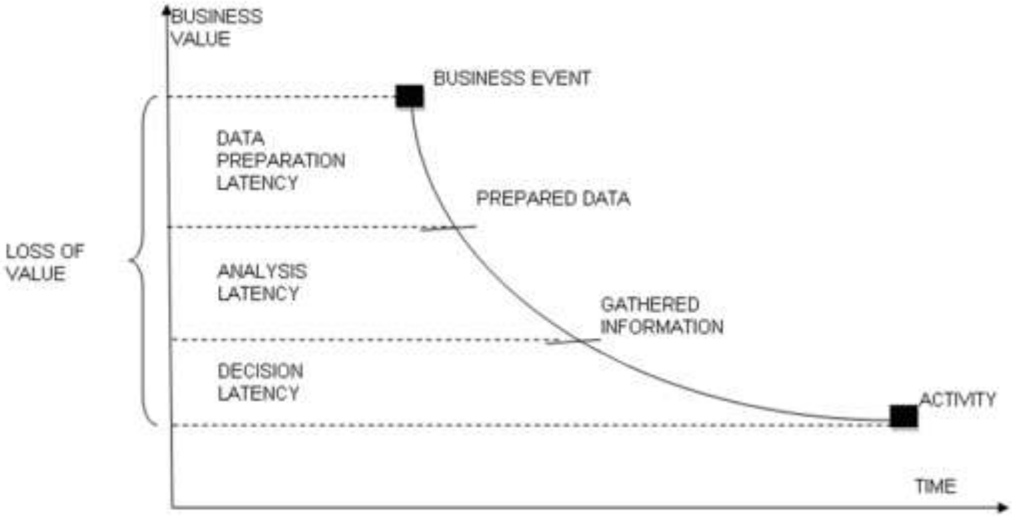

Figure 1. Loss of business value of managing decision
(source: [5])

3 OLAP – OnLine Analytical Processing

The basic type of analysis performed in data warehouses is the current analytical processing OLAP (On-Line Analytical Processing). This concept was introduced in 1993 by E.F. Codd. He claimed that data originating from transactional systems are not sufficient to provide complete answers for the managers. He based his theory of online analytical processing on these observations. The basic idea of OLAP is to allow the users to manipulate data models in many dimensions in order for them to understand the changes taking place in the data. E.F. Codd elaborated a set of 12 rules that distinguish analytical processing OLAP ([1], pp. 12-17):

- multidimensionality – the system needs to assure a multidimensional data view with the possibility to create complex dimension hierarchies system and building data sections simultaneously in relation to many dimensions,
- understandability and usability for the user – users do not need to possess advanced IT knowledge to use OLAP tools; they use commonly known tools to gather data necessary for proper business related decisions,
- availability – OLAP is a middle-ground between operational data sources and the analytical area; used tools should allow finding a proper data source adjusted to a particular analytical case and next performing necessary data conversion,
- collective availability - OLAP tools should support teamwork as well as analysis and idea exchange between the users,
- client-server architecture – OLAP tools should be able to work in the client-server environment; server should be intelligent enough to allow connecting and integration of many different clients with minimal memory usage and amount of programming,
- automatic adjustment of the physical level – OLAP system should adjust its physical scheme automatically in order to adapt itself to the type of model, data volume and the level of data dilution,
- generality of dimensioning – all dimensions must be equal both in the structural and operational possibilities manner; basic data structures, report and form formatting should be equally easy to perform in all dimensions,
- intuitive data manipulation – possibility of direct activities on the data through direct dragging of the objects, realized with a computer mouse, without the need to use complex menu systems or performance of other complex operations,
- unlimited number of dimensions and aggregations – technically it is an unreachable (impossible) feature due to limitations of the hardware that is realizing the processing; in most cases no more than ten dimensions and few hierarchical levels are used; acceding to Codd the maximal number of dimensions should not exceed twenty,
- homogenous efficiency of reporting - reporting efficiency cannot be considerably weakened with

the increasing number of dimensions or the changing of the database size,

- flexible reporting – user should gain every required data view and present it in a way that suits him or her.

Listed specification indicates that fulfilling all of the Codd rules is rather impossible, even though many producers of analytical data processing tools claim the compliance of their products with the OLAP standard. In most cases these systems fulfill only some of the requirements. Some of the manufacturers even modify the general OLAP requirements what is weakening their original meaning. It is relatively easier to gain compliance with other OLAP definition – FASMI from 1995. FASMI stands for Fast Analysis of Shared Multidimensional Information. All of the definition concepts can be explained in the following way ([15], p. 12):

- fast – most questions are performed in few seconds and the basic analysis take less than a second,
- analysis – users can define their own calculations,
- shared – system implements all kinds of data protection, even the ones for single cells,
- multidimensional – the system needs to provide multidimensional, conceptual data view with the possibility to define dimension hierarchy and creation of different data sections,
- information – system provides all necessary information, gathered from data resources of any size.

Summing up, OLAP is a software category, which enables the managers and analysts a free access to information through fast, interactive and broad selection of views that includes properly transformed data and analysis results.

These views reflect the multilevel nature of an enterprise in a way that it is perceived by the user. Users have the possibility to define their own analysis based on available data, creation or modification of analysis dimensions as well as the creation of the aggregates with the use of statistical functions analysis. Presented results can be additionally formatted with the use of: upward and downward drilling, rotation, slicing and dicing, dimension modification, adding own calculating formulas, graphical data presentation, exporting of data to external bases in order to perform detailed analysis (e.g. data exploration). The idea of OLAP analysis is presented below in a simple example.

Example 1

OLAP cubicle, which was created on the basis of a star schema, consists of one fact table and three connected dimension tables (see Figure 2). In this case OLAP's main task is to analyze the data concerning project analysis in a designer-servicing company.

Fact table consists of data: CzasProj (ProjTime), UdzialProc (PercShare), on the basis of which the analytical measures are calculated LiczbaProjektow (ProjectNo), CzasProjektow (ProjTime), and UdzialPracownikow (EmployeeShare). Dimension tables include data, e.g. MiejsceZat (PlaceOfEmpl), Stanowisko (JobPos, RokZak (FiscYear), MiesiacZak (FiscMonth), which will be the analytical sections. The structure defined this way allows to determine, which factors influence the number of realized projects, time scale and the level of employee engagement.

Created OLAP cubicle allows elaborating analytical perspectives (see Figure 3), where the cubicle dimensions stand for analytical sections, e.g. RokZak (FiscYear), MiesiacZak (FiscMonth), DzienZak (FiscDay), MiejsceZat (PlaceOfEmpl), Stanowisko (JobPos), Staz (Seniority) and the analyzed parameters are its measures, e.g. LiczbaProjektow (ProjectNo). Perspective presented in the Figure 3 allows determining the relations between the number of realized projects and the project finish data (with the division for year, month and day of the finish) as well as the project team (with the division for parent department, job position and job tenure).

Obtained pivot table can be also analyzed with the following methods:

- pivoting – determining measure and defining dimensions in which the selected measure will be presented,
- drilling down – is based on diving in the hierarchy of a particular dimension in order to perform a more detailed data analysis,
- drilling up – is based on navigating upwards particular dimension's hierarchy in order to perform an analysis on a higher level of dimensions hierarchy,
- rotating – allows to present the data in different layouts,
- slicing and dicing – allows narrowing analyzed data to selected dimensions and in terms of selected dimension – narrowing the analysis to specific values,
- ranking – allows data ordering in particular dimension according to the values of selected measures.

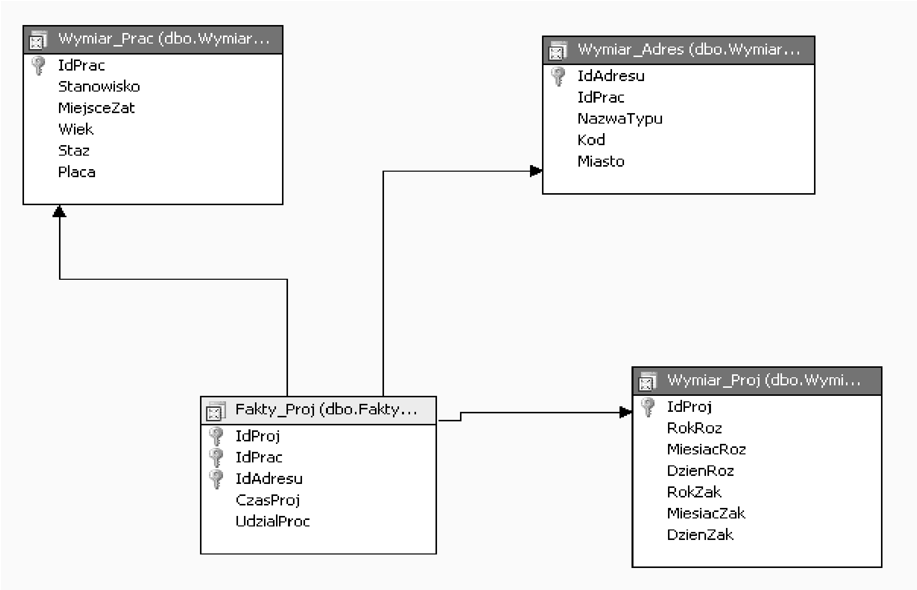

Figure 2. OLAP cubicle
(source: self study)

	Rok Zak / Miesiac Zak / Dzien Zak			
	⊞ 1996	⊞ 1997	⊞ 1998	Suma końcowa
Miejsce Zat / Stanowisko / Staz	Liczba Projektow	Liczba Projektow	Liczba Projektow	Liczba Projektow
⊞ 100	170	7	457	634
⊞ 110	30		328	358
⊞ 120	191	4	467	662
Suma końcowa	391	11	1252	1654

Figure 3. OLAP cubicle analytic perspective
(source: self study)

			Rok Zak / Miesiac Zak / Dzien Zak			
			⊞ 1996	⊞ 1997	⊞ 1998	Suma końcowa
Miejsce Zat	Stanowisko	Staz	Liczba Projektow	Liczba Projektow	Liczba Projektow	Liczba Projektow
⊟ 100	⊞ analityk		60		181	241
	⊞ kierownik		18	1	31	50
	⊞ projektant		68	6	144	218
	⊞ sekretarka		24		101	125
	Suma		170	7	457	634
⊟ 110	⊞ analityk				69	69
	⊞ kierownik				64	64
	⊞ programista				101	101
	⊞ projektant				84	84
	⊞ sekretarka		30		10	40
	Suma		30		328	358
⊟ 120	⊟ analityk	5			141	141
		11	18	1	9	28
		16	19		37	56
		Suma	37	1	187	225
	⊞ grafik				52	52
	⊞ kierownik		8		4	12
	⊞ programista		130	3	137	270
	⊞ projektant		16		8	24
	⊞ sekretarka				79	79
	Suma		191	4	467	662
Suma końcowa			391	11	1252	1654

Figure 4. Data drilling view
(source: self study)

Figure 4 presents an example of data drilling reached with dimension particularization for: MiejsceZat and Stanowisko.

OLAP analysis results can be directly used in the enterprise management process. Real life implementation of decision making supporting system, based on data warehouse and the OLAP tool, is presented below.

Example 2

Carbon S.A., company that belongs to SGL Carbon Group, is a leading manufacturer of carbon and graphite products. In the end of the nineties a problem of lacking data emerged, which included the whole production process [13]. This production process is extremely long (lasts from 1 to 3 months) and the production includes few hundreds of different products for many different customers. Tracking such amount of production cycles in a transactional base is very difficult. Therefore aggregated quantitative information about particular products was essential for effective management of production processes. Proposed IT solution, which was to improve the production process data access, was the MEDIA Management Information System, which was supposed to function on the basis of the data warehouse resources oriented towards production process and its technological parameters (see Figure 5).

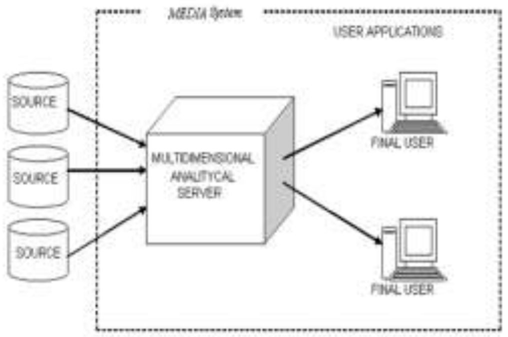

Figure 5. OLAP system in SGL Carbon
(source: self study on the basis of [13])

PMS Labs together with SGL Carbon employees tried to integrate quantitative information with selected technological parameters originating from production objects, product groups and particular products. This allowed to process management improvement through easier access to production data, dispersed in transactional bases and automatic production planning systems. Data warehouse was designed in MOLAP technology (Multidimentional OLAP), which uses multidimensional tables to store data. Such tables include different data from many sources.

Creation of proper relation structure makes it easier for the users to select interesting information e.g. product from certain batch, product from given operation in the production process.

Currently the system is gathering data from many transactional systems, aggregating it and enabling the tracking of a production process. Inbuilt tools, which enable the creation of hierarchical structures, allow performing the data drilling operations and the dynamic changes result data presentation form as well as creation of individual inquiries. Due to these functions the user is able to quickly analyze the production process flow for a single product or the groups of products. In the last level of detail, in order to further drill information, there is a possibility to engage transactional programs with source data originating from production process directly from the MEDIA system. SGL Carbon enterprise gained the following benefits due to the OLAM system implementation [13]:

- easier access to the production data,
- graphic environment of analysis and reporting,
- possibility to perform analysis for groups of products,
- online access to indicators that were previously inaccessible or needed to be calculated every time,
- working in a uniformed software environment.

Summing up, OLAP system is implemented in a mode designed for multiple users. It offers quick answers for inquiries and questions, independent of their size and the complexity of the database. It helps the analytical system user to synthesize the information about the enterprise via a comparative insight into its resources as well as through the analysis of historical, current and forecasted data in “what if?” analysis. One of OLAP’s characteristic features, being the system’s drawback at the same time, is that its activity is based on the verification of hypothesis constructed by the analyst. Therefore the effectiveness and usability of this method is, to high extent, dependent on the imagination and creativity of the people performing the analysis. OLAP technology assumes that the user has an absolute knowledge about the object of the analysis and can control this process. That is why the analyst is forming the questions and performs the analysis of the data stored in the warehouse. The second group of analytical data processing – data mining – is independent of this constraint.

4 Data mining

Data mining enables the data analysis for such problems, which were difficult to solve for humans (due to its volume) or the ones difficult to solve because of lacking knowledge (that is to be mined from the data). Data mining methods are based on effective revealing of new relations and connections between pieces of data. Automatic data mining brings new possibilities in the scope of user-warehouse data system interactions, enabling formulation of questions and inquiries on a more abstract level than the OLAP technology would allow. Data mining is treated as searching process leading to revealing the interesting regularities, patterns or anomalies in the data from the point of view of the user. These objects include information that is particularly interesting for the user and should aid the creation of e.g. OLAP cubicles. Such knowledge is new and unknown to the user. Business value of this knowledge is one of the evaluation criteria for the KDD - Knowledge Discovery in Databases process.

Knowledge discovering is one of the interdisciplinary sciences, which combines the elements of statistics, econometrics, computing, artificial intelligence methods and the database theory. Knowledge discovering concept first emerged in the literature in the late eighties and since that time it has many different definitions. One of the most popular definitions is the one published in 1991 by Frawley and Piatetsky-Shapiro [16], which describes the knowledge discovering process as: significant process of identification of important, new potentially useful and understandable data patterns. Knowledge discovering is a process of searching for new relations, tendencies and regularities, which can be observed due to detailed data analysis, gathered over a period of time. The greater the data collection and the longer the research time period is, the analysis possibilities are more significant as well as the results are of better quality. At the same time, the knowledge discovering process is an intensive process of cooperation between a human user and an IT system. It is the user who defines interesting and useful phenomena discovered during the research. On the other hand, the IT system is performing a preliminary information selection in order to allow the user to get to the most interesting pieces of information, presenting them in the form of a list e.g. according to the greatest degree of credibility.

It is important to highlight that data mining is only a stage of the analysis in the knowledge discovering process. Few definitions of this concept will be presented. David J. Hand [6] defines it as: science dealing with data gathering from large data collections or databases. M. J. Berry and G. S. Linoff [1] claim that this concept can be defined as: mining and analysis of large amounts of data in order to find significant relations, schematics, patterns and rules. According to A. Sokołowski [19] data mining is a process of finding interesting patterns, relationships, anomalies, hidden structures in large data collections gathered in data warehouses (without a determined research aim) what is typical for data mining is the entity of unsorted data and he necessity to use computers.

One of the crucial features of data mining is the possibility to realize it in two ways:

- main aim of the mining research is known from the beginning e.g. searching for factors collection that are responsible for loosing an employee to the competition,
- main aim of the mining research is not known from the beginning e.g. search for new, interesting and useful relations and patterns hidden in a data collection designated for the research.

Data mining, other than regular statistical analysis (usually one-dimensional), includes the simultaneous influence of many factors on researched phenomenon. This enables to distinguish feature sequences, usually connected with mutual hierarchies, which presence in the population increases or decreases the possibility of certain phenomenon's occurrence.

Data mining is a natural extension and supplement of data warehouses creation, which means organization of large, multidimensional data collections that aid analytical data gathering process.

Data mining techniques can operate on any kind of unprocessed data as well as they can be used to browse and compile data generated through OLAP inquiries and in this case can provide much more detailed and deeper multi-aspect knowledge. Data mining is an analytical approach that is the expansion of the OLAP techniques.

Mining analysis methods can be divided into eight basic classes [14]:

- association revealing – the most broad of all classes that is bases on revealing of new, unknown and interesting relations or correlations between data, defined as associations; association rules collections and sequence patterns are the result of the association methods,

- classification – includes model revealing techniques (classifiers) or the functions describing relations between set object classification and their characteristics,
- prediction – using well-known and recognized classifiers to describe new objects with unknown classification,
- grouping (data clustering) - includes data analysis methods and finding of finite sets of object classes with similar features,
- revealing of singular points – includes the techniques of singular point finding, which differ from the general data model (known from the classification and prediction methods) or class models (cluster analysis); usually the methods of revealing of singular points are the integral part of other data mining methods e.g. grouping methods,
- time tracking analysis – includes time tracking analysis methods used to find: trends, similarities, anomalies and cycles; revealed descriptions can have the form of characterizing or discriminating rules,
- trends and deviations analysis – includes the variable data analysis changes over a time interval in order to find differences between current and expected data values,
- exploration of selected data types – includes the following methods: spatial data mining, multimedia, text and websites.

Data mining is using all kinds of methods that allow creating knowledge from data (relationships, patterns, trends) and therefore it does not have determined standard techniques. However, there is a considerable collection of algorithms that are often used in mining and exploration research. This collection includes: association algorithms, regression, decision trees, neural networks, time series or Bayes networks. Proper selection of a data drilling techniques depends on the type of the problem. Some algorithms dedicated to specific tasks, can be highlighted in Table 1.

Mining research scenarios can also be determined, which would allow to gain certain knowledge concerning objects or events (see Table 2).

The idea of mining analysis is presented below on the basis of a simple example.

Table 1. Selection of data mining techniques for given analytical tasks
(source: self study on the basis of [22])

Analytical task	Mining algorithm
Discrete variables forecasting, e.g. does a certain customer use promotions tailored in marketing campaigns	- decision trees - clustering - naive Bayes classifier - neural networks
Constant variables forecasting, e.g. certain product sales forecast in the upcoming year	- decision trees - time series
Sequences revealing, e.g. click-stream in one session, specific for a certain website	- sequential clustering
Association revealing, e.g. stock transaction or purchasing portfolio analysis	- decision trees - association rules
Grouping, e.g. finding homogenous customer groups	- clustering - sequential clustering
Discrimination analysis, e.g. establishing characteristic product features of leading products in relation to poor performing products	- decision trees - regression

Table 2. Data mining scenarios
(source: self study on the basis of [21])

Detailed task	Mining algorithm
Main task: maximization of profits generated by customers	
Basic customer classification	- clustering
Establishing characteristic product features of high-profit customers	- decision trees
Customer preference recognition	- association rules
Customer behavior analysis	- sequential clustering
Potential customers profitability forecast	- neural networks
Main task: Construction of successful marketing campaigns	
Customer segmentation	- clustering - decision trees
Research on customer reactions on marketing campaigns	- decision tree - Bayes naive classifier - clustering - neural networks
Selection of sub-optimal campaign variant	- cluster analysis
Campaign receivers prediction	- neural networks
Strategy evaluation in relation to marketing campaign reactions	- listed models updating
Main task: Fraud detection and prevention	
Transaction sequence research	- sequential clustering
Unusual event detection	- neural networks - decision trees - clustering
Model update according to real-time data	- listed model access from the level of metamodels

Example 3

OLAP analysis data, in relation to example 1, turned out to be interesting enough to perform a detailed analysis with a mining model. Only 60 of 450 employees of a company take active part in the realization of projects. Board of the enterprise tries to activate its employees (or trigger changes in the employment structure) as well as wants to find out what kind of features of current and future employees should be welcome and expected. Therefore an additional variable, Effectiveness, was assigned to every employee in the data warehouse.

Employees, who participated in more than 10 projects and were engaged by more than 30% in at least one of them, will have the variable value equal to 1. Remaining employees will have a 0 mark for the Effectiveness variable. Such defined variable allows to perform classification analysis, which aims at description of an employee that is effective and committed in the project activities of the enterprise.

Three data mining techniques were used to perform this analysis: decision trees, logistic regression models and neural networks. Variables, which will be used in the model, need to be determined before the start of the analysis (see Figure 6). Effectiveness, the explained variable, in the models is marked as PredictOnly. Explanatory variables are marked as Input in the model. Exploration analysis reveals such values of explanatory variables that have the biggest influence on the value (1 or 0) of the explained variable.

Establishing and starting of the model will trigger the presentation of the results, which can have the graphical form (see Figure 7) or the descriptive form (see Figure 8).

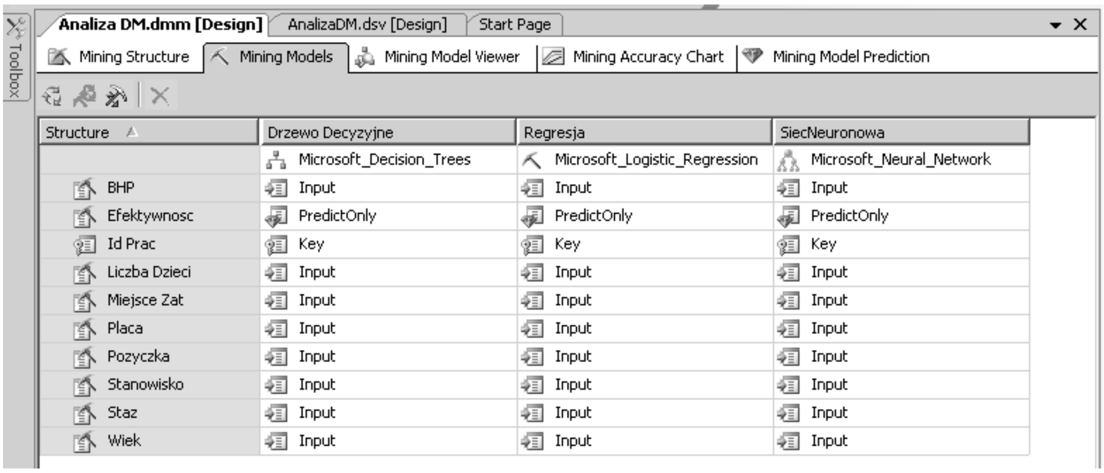

Figure 6. Mining models definition
(source: self study)

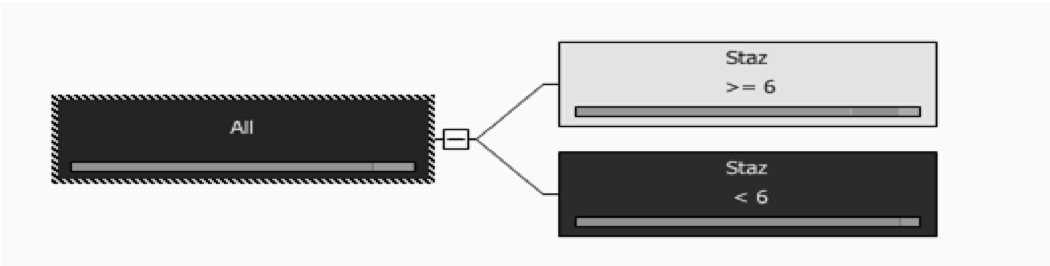

Figure 7. Decision trees model results
(source: self study)

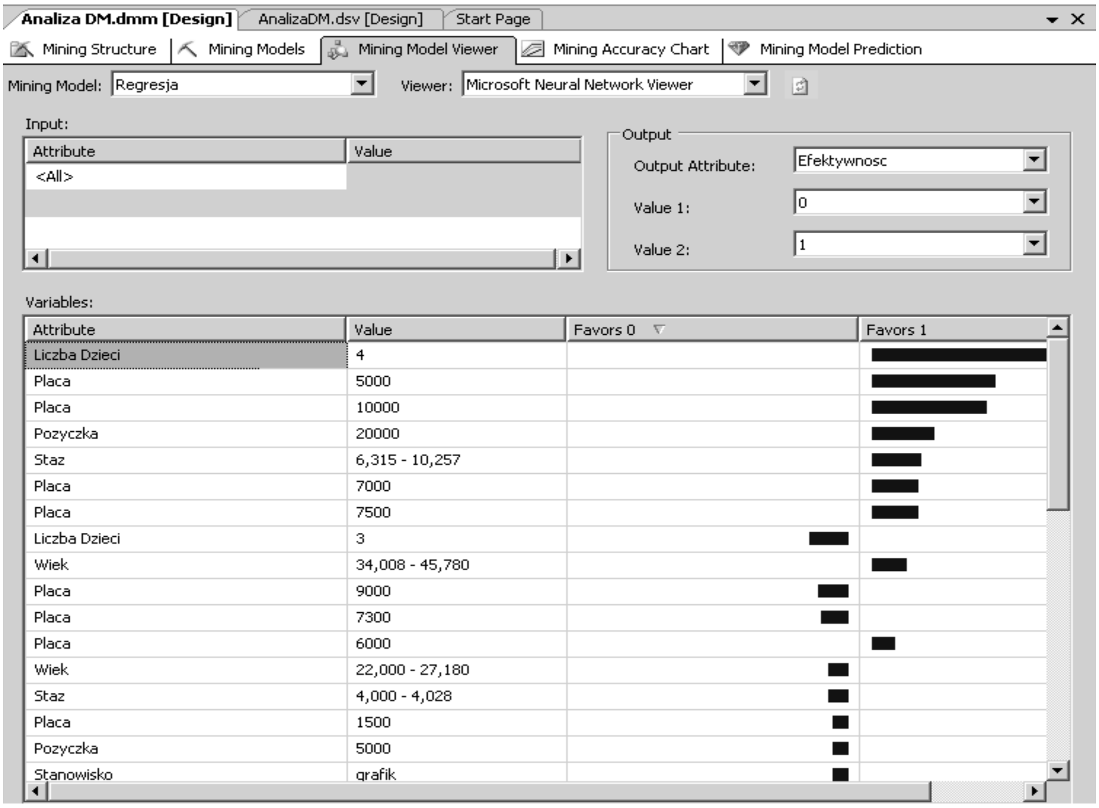

Figure 8. Logistic regression model results
(source: self study)

When analyzing the model results one can prepare a profile of an effective employee: it is a middle-aged person with numerous family and working experience, considerable salary and commitment to the company due to a relatively high loan, and the ineffective employee: young employee, low salary, low working experience – one of such examples is a graphics designer. This interpretation can lead to another analysis, which will try to find an answer to the question: why graphics designers do not willingly participate in enterprise projects. Maybe the work style does not allow the designers to be active as well as relatively low salary forces them to simultaneously work outside in another company to gain satisfactory salary level what results in spare-time limits and low commitment of this group. In this way data mining explores new, previously unknown, information that broaden the knowledge about the enterprise, its activities, customers, employees, threats, competition etc.

Example of a data mining system implemented in an insurance company is presented below.

Example 4

This example is a result of research performed by J. Kowalska and B. Trawiński [10] in a real time sales data of a manufacturing enterprise. The data included:

- product sales invoices issued in the first nine months of 2005 – products were characterized with the following attributes: brand, type, category, model, function, usage, size, color, offer etc.,
- product receivers – warehouses, shopping centers,
- sales managers.

Data from the relative structure were transformed into a flat structure, built upon invoice positions, including the quantity, values and dates of sales of particular products. The structure also included the product and receivers attribute values. In this stage of preparation the incoherent and zero sales data was rejected. About 65 thousand records were used to research customers and sales. The analysis was performed with the SAS Enterprise Miner tools.

Data mining included the factors influencing the sales value, sales prediction, sales volume increase, sales managers' evaluation and customer grouping. The following analysis techniques were used in this research: decision trees, regression, association rules, graphical visualization and cluster analysis.

Sales value increase factors analysis was performed with decision trees. Products were divided into product groups with similar average value and sales volume. High-runners (leading products) and low-runners (poor performing products), which need to be included in joined sales or sales promotions, were distinguished. Desired production volume was also determined for every of researched products.

Regression was used as supplementary to decision trees analysis. It allowed predicting the sales transaction values scope and not only the average value (determined with decision trees). This led to distinguishing of product groups with low sales volume and preparation of corrective actions.

Association rule analysis allowed determining which products can be included in joined sales and sales promotions. The aim of this analysis was to increase the sales of the products with low demand.

Graphs and figures were used to present the changes of volume and value of sales in particular provinces and for particular sales managers. This allowed the high management to evaluate the effectiveness of their employees. Managers were selected to service and support key customers as well as managers for less important customers and sales parts of lower importance.

In order to differentiate customers cluster analysis was used. Four customer groups were distinguished as a result of the algorithm activity:

- group 1 – customers who buy many products with medium or low margin; this group includes big number of transactions ant the customers generate large profits – this group does not require any corrective actions,
- group 2 - customers who buy few products with high price and medium margin; this group is especially valuable for the company but the volume of sales in this group should be increased e.g. through adding low-cost products as a bonus to the regular products, without any changes in product's price,
- group 3 – customers who buy very little products with low price and low margin; this group generate low profits – this group requires actions to increase the sales volume e.g. through researching the most popular products and offering sales promotion in this segment,
- group 4 - customers who buy little products with medium price and low margin; corrective actions for this group include actions similar to the ones' for the third group of customers.

Performed mining research led to the formulation of conclusions helpful for sales and marketing departments. It also led to the formulation of new research questions and issues that were the subject of following mining research. Therefore the effectiveness of production, marketing and sales departments increases with the maintenance or decrease of the functioning costs.

How is it possible to effectively organize and realize this type of research will be presented in the following chapters of this article.

5 Knowledge discovering methodology

Many IT tools that support the knowledge gathering processes were created. However even the best programs cannot solve all problems connected with the realization of the process and cannot assure the success of the endeavor. Effective and efficient methodology is necessary (see Figure 9).

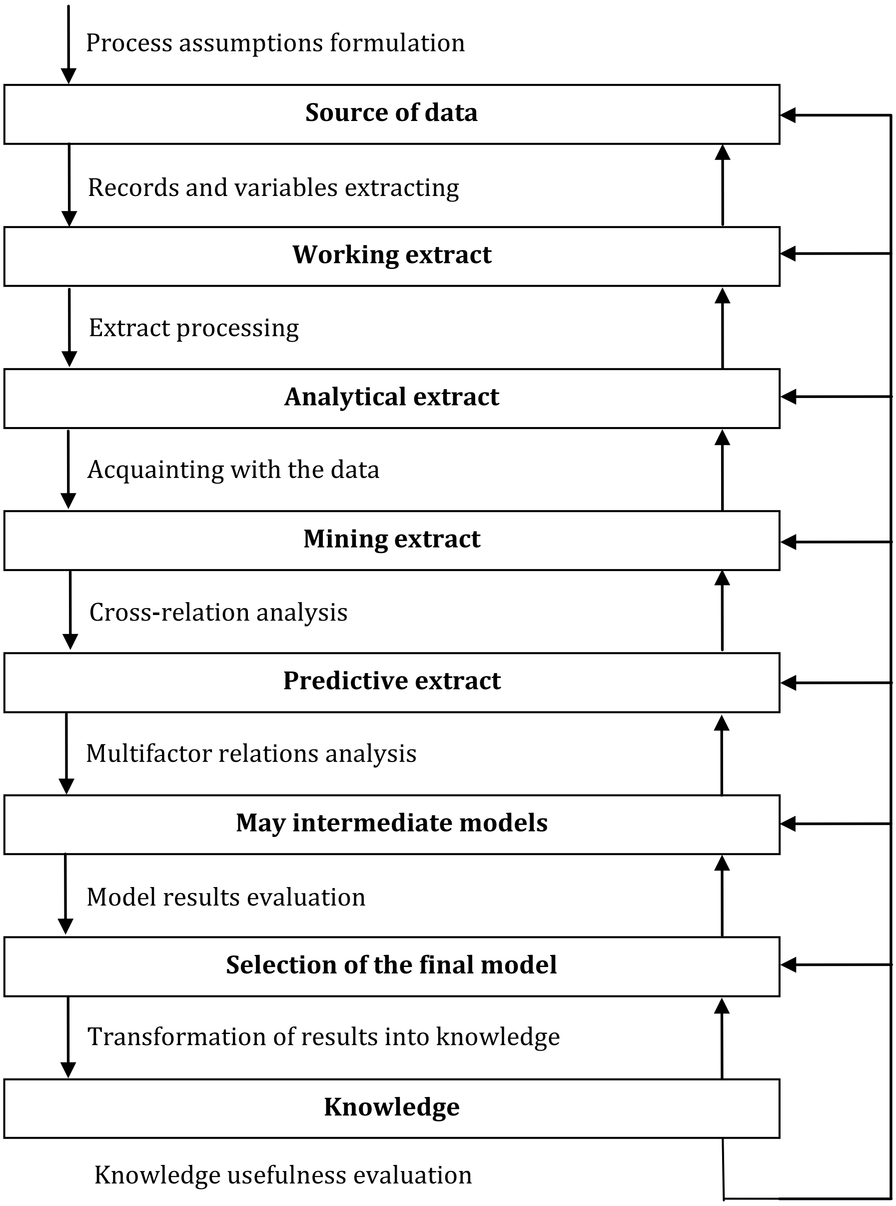

Figure 9. Knowledge discovering process methodology
(source: self study)

5.1 Project assumptions formulation

Knowledge discovering process assumptions need to ambiguously define user expectations in relation to the results of the whole process. Elements that should be included in the assumptions formulation are as following:

- aim of the research – defines the direction of the research and describes the modeled event,
- scope of the research – timescale and research scope determination,
- logistic parameters of the process – define the methodology of the process realization, process realization methods, place of realization, project coordination, research team, process consultants team,
- technical parameters of the process – define the software, network resources, programming and other tools necessary for the realization of the process,
- process realization schedule – presents successive process stages with the detailed information on: stage start date, stage realization characteristics and final stage result presentation, stage finishing date,
- process realization cost calculation – needs to include the following elements: cost of machine tools, cost of research team training, cost of process data preparation, and cost of consultancy and data warehouse usage, server and personal computer capacity.

Detail and accuracy of the process assumptions formulation influence the usefulness of process results and discover knowledge as well as if the process realization will have to be repeated.

5.2 Records and variables extracting

Creation of draft extract is based on the selection of proper records and variables, necessary for the knowledge discovering process realization and placing them in a single table. Time period of this scale directly depends on the quantity and structure of source data, which are the basis for extract data. If we speak of a single centralized data source, where identification of full history of observed extracts does not involve many connecting and searching operations, this stage will be relatively easy to realize. However, this matter complicates when instead of one data source we have a dispersed data source, which has the characteristics and history of observations collected in many tables or data sets. Before the start of data extracting it is crucial to ambiguously identify proper objects in data collections in order to reach full consistency of the data extract. With a complex data source it is necessary to elaborate programming tools, which in the following stage will automatically extract the records to the extract. It is a guideline for the enterprises, which plan to implement the data warehouses. Easy and quick extract generation possibility should be included in the design phase of the data warehouse structure.

5.3 Extract processing

Extract input data can have: diversified format (e.g. date of birth in short or long format), inconsistent values (e.g. sex of particular person can be determined as male and female at the same time) and can be "rough" (e.g. include city name in the field destined for car type). During the realization of this stage it is necessary to unify data formats, define allowable values (dictionary) for the variables and eliminate inconsistency in variable fields values. Many of such activities will be repeated in following extracts, therefore it is necessary to prepare IT tools to optimize the extract processing. Another of problems present at this stage is the lack of data. Variables with 20% of missing data are not relevant for the analysis. If the missing data exceeds 50% it should not be included in the analytical extract, because it would determine the process results. The simplest solution in case of missing data is the elimination of the variable from the extract. However, in many cases one cannot allow to loose a variable, which can have a significant influence on the researched event. In such case it is usually necessary to complete the missing data. There are many methods and algorithms in such cases and every tool designated to discovering knowledge from data has its own solutions. Moreover one can use own implemented data completion methods. Nevertheless it is important to remain cautious. Improper data completion can result in the analysis of the lost data, instead of real data, in next stages of the process.

Preparation and processing of a draft extract, in order to create an analytical extract, can become the most time-consuming part of the process and take up to 80% of the time designated for the realization. Therefore it is crucial to bear in mind that the stages will be process efficiently if the data source is prepared properly.

As a result it is necessary to predict realization of such processes during the construction of data warehouses.

5.4 Acquainting with the data

Main task of this stage is a detailed analysis of the variables that are a part of the data extract: values, distribution and description of the variables with the use of descriptive statistics values. Variables determined at this stage are usually: allowable values collection, mean average, minimum and maximum value in the set of observations, standard deviation, and median.

After acquaintance with the distribution of each variable, usually extreme observations that do not fit the entity are eliminated, if they can influence and disturb the analysis results (e.g. changing the value of mean average and median). Sometimes such extraordinary observations can be side effects of the process and become the input data for further analysis. All observations with monovalent and quasi-monovalent distributions are eliminated from the extract (they do not influence the analysis).

If regression models are to be used in following stages of the process, it is justified to transform qualitative variables into zero-one values in order to simplify the analysis and improve the quality of the predictive model.

This stage must end with an absolute knowledge of all variables, their values, distribution and influence on the researched event, because without this knowledge it is not possible to realize further stages of the process.

5.5 Cross-relation analysis

This analysis is based on the use of all possible techniques and statistical methods, which allow researching distributions of all explanatory variables in the particular values of the explained variable and determine the influence of individual variables on the research event.

Explained variable is the one which determine the aim of the modeling. For example in the research of the population of customers who break up insurance policies, Policy Value will be the explained variable and take two states “Broke the policy” or “Did not break the policy”. Every mining analysis must have defined at least one (and usually one) explained variable. Remaining variables in the set will be explanatory. Some of the used methods are:

- cross-relation tables,
- distributions of variables broken into the values of explained variable,
- values of descriptive statistics according to the value of the explained variable,
- correlation matrix,
- statistical cross analysis e.g., Kaplan-Meier analysis.

One of the simplest methods to research elations between explained and explanatory variables is the creation of cross-relation table (Table 3). It allows to research both the numeric and percentage data value distribution.

Table 3. Cross-relation table of explained and explanatory variable *(source: self study)*

Cross-relation table of explained/explanatory variable			
Explanatory variable	Explained variable		Sum
	0	1	
0	117907 61%	40842 21%	158749 82%
1	32 0,5%	18 0,5%	50 1%
5	884 0,5%	270 0,5%	1154 1%
10	23544 12%	9100 4%	32644 16%
Sum	142367 74%	50230 26%	192597 100%

Another form of analysis at this stage is the research of the distribution in graphical form. Numeric and percentage distributions presented both in tables and graphically should always be completed with descriptive statistics values.

If on the basis of cross-relation tables and distribution graphs of constant variables one will discover their non-linear influence on the explained variable, classification of these variables in to a finite number of groups – classes needs to be performed (it is best to analyze variables grouped in 2 to 6 classes).

Preparation of mutual variable correlation matrix is the following task of this stage (Table 4). Only one variable is left in the mining extract from the group of correlated variables (correlation index of these variables is higher than the determined value e.g. 0,5) on the basis of the matrix results. Selection of one variable from every group of the correlated variables is a task for the analyst. One of the common causes of the drop of effectiveness and quality of the predictive model is the presence of few correlated variables in the model.

Table 4. Table of mutual correlation of variables
(source: self study)

	va1	va2	va3	va4	va5
va1	1,0000	-0,2953	-0,0195	-0,0098	0,0975
va2	-0,2953	1,0000	-0,0451	-0,0288	0,0338
va3	-0,0195	-0,0451	1,0000	0,8048	-0,0824
va4	-0,0098	-0,0288	0,8048	1,0000	-0,0465
va5	0,0975	0,0338	-0,0824	-0,0465	1,0000

It is possible to observe strong single-dimensional influences of the explanatory variables on the explained variable at this stage. Interesting issues and production anomalies in the population can be identified and distinguished from the mining extract. Such case can influence the direction of further studies as well as the method and techniques selection of the predictive models. However, one should not expect that the cross-relation analysis will bring unexpected results (even if the results seem extraordinary it is necessary to verify them with a predictive model). At the end of this stage variables that create predictive extract are selected. These variables always include the explained variable and a set of explanatory variables, which can differ between different predictive models.

5.6 Multifactor relations analysis

Multifactor relations analysis, in other words data mining, focuses on building of a sub-optimal mining model. Mining models should be constructed on the basis of a certain part of the extract (usually about 40%), namely the training set. Remaining part of the extract is divided between the validating and testing sets (usually about 30% each). These sets are used to teach the models and evaluate the effectiveness of its successive variants. Another important issue of this stage is the selection of proper analytical methods and techniques, used to build mining models.

Each analytical model brings result information. However, it is necessary to evaluate the usefulness of such information and the possibility to use it in particular business activities. For example, discovered relation that the customer will not break the 20 year insurance policy during upcoming 10 years with the probability of 99,9% is not very useful for an insurance company representative. It does not mean that the information is useless. It can be applied elsewhere e.g. to elaborate the tariff for the insurance fee payment for such policies. This example indicates that the selection of the final model and research results evaluation is connected not only with statistical evaluation of the correctness and effectiveness of the model, but also with the subjective evaluation of the customer – user of the knowledge.

5.7 Model result evaluation

Every mining tool must enable an unambiguous evaluation of correctness of model's results. Such evaluation consists of two elements:

- statistical evaluation of reached results,
- model use effectiveness evaluation.

Statistical evaluation is based on the determination of the statistical error, which is accompanying model's results (Table 5). Collects the results indicate the strength and direction of the influence of population's particular features on the researched event. Value of the estimator is determining the influence. However, every value of the estimator has a certain statistical error, which determines in how many real cases determined value was estimated wrongly. Allowable error of the estimator is between 5-7%.

Table 5. Statistical evaluation of model's results
(source: self study)

Feature	Estimator value	Estimator error
Education = Higher	0,3077	0,0456
Education = Secondary	0,2567	0,0022
Education = Vocational	-0,6780 ↓	0,0034
Sex = Female	0,4567 ↑	0,0076
Sex = Male	0,1234	0,0123
District = Mazowieckie	-0,2222	0,0099
District = Małopolskie	0,8677 ↑	0,0233
District = Pomorskie	0,0900	0,0001

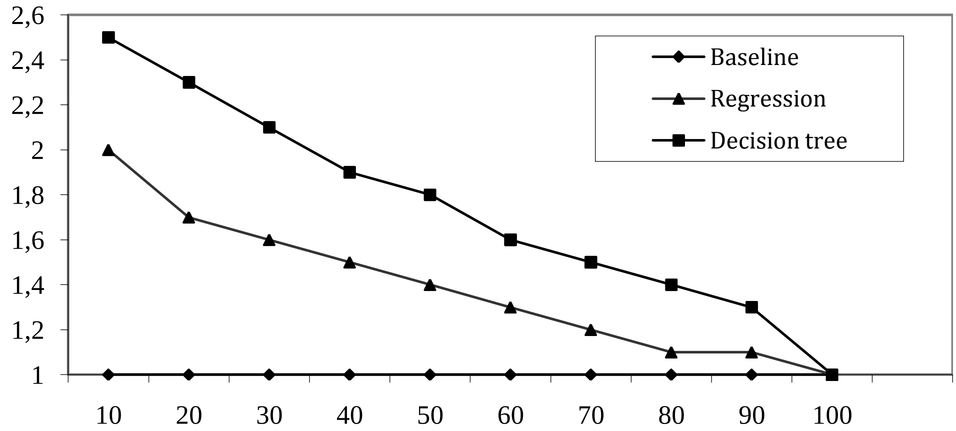

Figure 10. Raising graph
(source: self study)

Table collects the results that indicate the strength and direction of the influence of population's particular features on the researched event. Value of the estimator is determining the influence. However, every value of the estimator has a certain statistical error, which determines in how many real cases determined value was estimated wrongly. Allowable error of the estimator is between 5-7%.

Second element of the model evaluation is the determination of its effectiveness. Such evaluation consists of two main elements:

- number of times the analytical model is better than a random sample,
- evaluation of number of times that the model result was confirmed and he number it was wrong in real life.

In order to evaluate the effectiveness of a model in relation to the random sample one needs to use the raising graph (see Figure 10).

This graph should be interpreted as follows:

- if the 10% trail of the whole researched population is casted or the 10% trial of the whole population is selected with a use of a model, model trial will have 100% higher prediction than the random trial for the regression model (regression forecasting will be 2 times more accurate that the random trial) and with 150% higher prediction that the random trial for the decision trees (decision trees predictions will be 2,5 times more accurate than the predictions of a random trial),
- if one would cat or select a 50% trial of the population, regression model will be better by 50% than the random trial and the decision trees model will be better by 90%.

Usually models selected for implementation are characterized with 2-times higher efficiency than the random trial for the 10% of casted or selected population.

Whereas for the evaluation of event classification accuracy with the use of a model an event classification graph is used (see Figure 11).

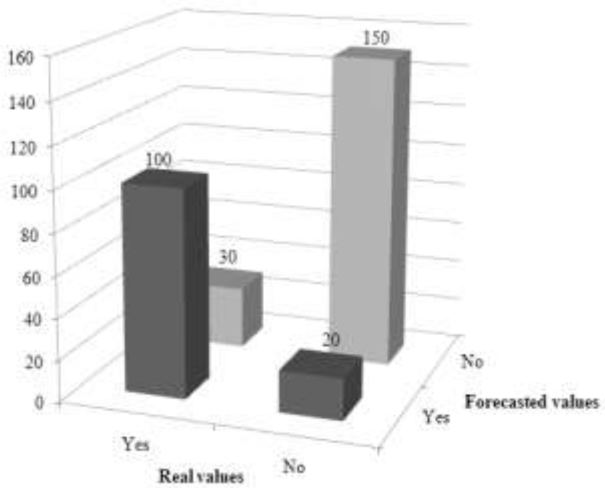

Figure 11. Even classification graph
(source: self study)

Figure 11 shows, for 130 real cases with the YES value, that the model has properly classified 100 cases (real value = value prognosis) and wrongly classified 30 cases (real value ≠ value prognosis). In 170 real cases with the NO value, the model has properly classified 150 cases and wrongly classified 20 cases. It is necessary for the model to classify properly the majority of the cases before its implementation.

5.8 Transformation of results into knowledge

Accepted results of the final model need to be transformed into particular knowledge that concerns researched event. Estimator values (e.g. the example from Table 5) should be changed into the profile description of the clients who break and maintain the insurance policy:

- customer with the highest probability of maintaining the policy is a female from małopolskie district,
- customer with the highest probability of breaking the policy is a person with vocational education.

However the interpretation of model results and transferring them into practical knowledge is not always that simple. For example, if the model result will be determined by one feature e.g. number of paid insurance fees since the start of the insurance agreement. In this case it is not enough to claim that if the customer will pay 3 fees, the probability of maintaining the policy till its end is 99%. There needs to be an explanation provided for the fact that most of the insurance policies are broken in first months. Usually in such cases the experience and knowledge of people who know, better than the research team, the factors influencing the researched event.

5.9 Knowledge usefulness evaluation

This is the final stage of knowledge discovering, although it does not have to be the end of the process. At this stage user evaluates the usefulness of the gathered data for the realization of determined business aims. If the goals were not reached, it usually means returning to one of the previous stages or even restarting of the whole process. It is crucial to emphasize that such problem emerges relatively often (20% - 30% of all performed analysis) and it does not have to mean a negative impact on the process. Complexity and diversity of both the analyzed data and the analytical tasks usually leads to a deviation between user expectations and results reached in knowledge discovering process. It does not indicate that the process failed. Such event gives a signal that thee are corrections which need to be implemented and that the process has to be restarted. It is important to point out that the most time consuming and difficult are the stages which lead to the elaboration of the mining extract. If this stage was discussed with the users and turned out to be success, repeating of following stages, even multiple, will never be as costly and complicated.

Accepted, implemented and effectively used data mining model should be periodically updated in order to assure that the data is correct and up-to-date, which is dependent on parameters that change in time (e.g. seasonality, economical situation of a market sector, new trends in activities of the competition).

6 Summary

Data warehouse and analytical data processing tools are the basic elements of the system aiding the management decision making processes. Traditional warehouses are directed at processing of text and numerical data with statistical and visualization methods, based on current analytical processing technology. At the same time, many modern solutions, dealing with spatial and timely data analytical processing, data with complex structure (semi-structural, objective and multimedia) and the analysis of constant data, are developing.

There is a number of issues, mostly scientific and technical, to be solved for this type of data.

One of the most significant types of analytical tools, based on data warehouse resources, are the applications that allow data mining. There are many software packages in the market, which offer mining of text files or analytical databases. Due to the fact that the process is extremely complex, time consuming and simultaneously the quality of taken decisions is dependent on its efficiency, the proper methodology of the process is a crucial success factor.

The article presented issues connected with analytical data processing that was divided into two groups: current analytical processing and data mining. Methodology of knowledge discovering process, which included the use of data warehouses and both types of analystical data processing tools, was proposed.

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THE ROLE OF INFORMATION TECHNOLOGY SYSTEMS IN KNOWLEDGE MANAGEMENT

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Abstract: Presented article describes the research on organizational IT knowledge management system model. Research was started with the analysis of current scientific knowledge status on knowledge management as well as supporting the process with Information Technology. Methods of knowledge management systems were analyzed and a system suitable for a case study was selected. Case study results allowed to build a knowledge management system and the model was verified on the basis of knowledge management system prototype research.

Key words: information, IT systems, knowledge management systems, knowledge, knowledge management.

1 Introduction

According to the World Bank one of the four tasks accompanying the implementation of a knowledge based economy is the “creation of database system, information infrastructure providing different services in gathering, processing and storing of information and knowledge [6]. Gartner Group [10] estimations reveal that even 75% of expanses on knowledge management are used to finance computer and telecommunication hardware as well as suitable software. This fact shows the important role of IT technology in knowledge management. At the same time in the research on knowledge management corporate portals, performed by the Polish division of KPMG consulting company, a following statement is present: “using many dispersed applications is difficult, time consuming and costly” [20].

This research justifies the need to implement technical solutions integrating dispersed applications and information and knowledge resources in order to perform more accurate decision making and improve organization’s activities and as a result aid knowledge management processes.

The article describes the construction and verification process of a knowledge management system in an organization, which includes the following stages: KMS (Knowledge Management System – this abbreviation will be used in the following part of the article) classification method elaboration, KMS analysis method elaboration (case study on existing solutions)analysis of existing knowledge management systems, construction of a knowledge management system in an organization, knowledge management system prototype construction and research on constructed prototype in order to verify the correctness of assumptions of the model.

Elaborated research results can be used by few recipient groups. KMS designers can construct a system compliant with current knowledge level and best practices in the market. Scientists can use the knowledge management system analysis method in order to perform further research and the management system model can be used to create knowledge management system prototypes. High management and IT department managers can use the knowledge management system in order to verify or confirm the selection of a knowledge management system in their organization.

2 Knowledge management in relation to IT technologies

Concepts of knowledge and science were subjects of many analyses, starting from Plato and his student Aristotle who started rationalism and empiricism. In modern ages both these trends have found followers among the greatest thinkers and philosophers and evolved thus creating new trends being their modification or synthesis.

Alfred Marshall, one of the first economists who recognized the value of knowledge, claimed that capital is mostly made of knowledge and organization [12]. F. A. Hayek [7] and J.A. Schumpeter [15] were the next researchers of issues connected with the economic aspect of knowledge. They claimed that organization not only has access to common determined knowledge, but also can use its own, subjective knowledge. Hayek divided knowledge into open and tacit – different for different circumstances, which can be specific for given organization as well as he emphasized the importance of tacit knowledge.

Along with the development of IT sciences and organizational theory sciences the nature of the decision making and problem solving process became a subject of the research. H.A. Simon [18] in his research built up a theory describing these processes. He recognized that human beings can create new knowledge and use it in decision making during the information processing process. Therefore the organization should minimize the necessity to distribute knowledge and at the same time decrease the weight of knowledge placed on a single employee. This formalized way of activities should be based on explicit knowledge.

Simon omitted tacit knowledge, treating it as a disturbance, even though Michael Polanyi in his works from that period emphasized its significance and stated that "true invention cannot be based only on a set of rules and algorithms. Knowledge is accessible and for general use but at the same time personal, because it is created by people driven by passion and emotions. Knowledge that lies at the basis of accessible knowledge is of fundamental meaning – the entity of knowledge is either tacit knowledge or a knowledge concluded from it" [14].

2.1 Knowledge management in organization

Figure 1 presents a modified knowledge pyramid that includes current proportions between: data, information, knowledge, understanding and wisdom as well as determines the possibility of using modern IT systems and organizational structures in order to process them. Knowledge pyramids proposed by D. Skyrme [19] and R. Ackoff [1] were used in creation of this pyramid.

Knowledge definition, which was used in the elaboration of knowledge management system in the organization, is as follows: "knowledge is a combination of experience, information and expert opinion, which assures basis for development and implementation of new experience and information. It is originated and is used in the minds of people who posses this knowledge. In organizations it usually is stored not only in documents or data banks but also in methods of activity and best practices, processes and norms" [4]. Knowledge management system is also basing in the corporate knowledge creation theory and three knowledge management models, which will be described in the following part of the article.

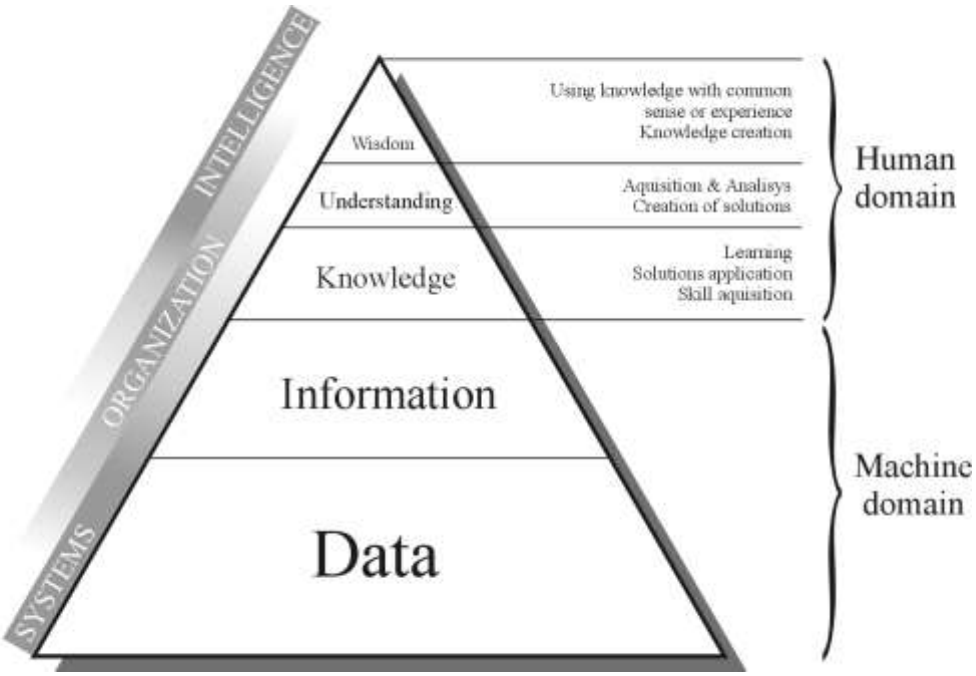

Figure 1. Knowledge pyramid
(source: [1] p. 2, [19] p. 2)

2.2 Organizational knowledge creation theory

Theory of organizational knowledge creation of Nonaka and Takeuchi' brings a description of knowledge creation process in an organization. The authors claim that allowing constant changes of one knowledge type into another is a basis for the creation of new knowledge in the organization. This process is defined as knowledge conversion. It distinguishes four modes of knowledge conversion:

- conversion of tacit knowledge into tacit knowledge (socialization),
- conversion of tacit knowledge into explicit knowledge (externalization),
- conversion of explicit knowledge into explicit knowledge (combination),
- conversion of explicit knowledge into tacit knowledge (internalization).

Even though, according to I. Nonaka and H. Takeuchi, organization does not create, it can provide suitable conditions for the creation of it. Authors distinguish five of these organizational conditions:

- organizational intentions – awareness of the strategic value of knowledge,
- empowerment in order to increase motivation level,
- creative chaos, state in which the organization, under the influence of different signals coming from its environment, is able to adjust its knowledge system,
- redundancy – existence of information redundancy for the knowledge creation processes is desirable,
- requisite variety, which allows adjusting the organization to the variety of the environment.

2.3 Knowledge management models

The theory of organizational knowledge creation was chosen for the construction of KMS model, due to its holistic description of knowledge creation process. Apart from this theory, three knowledge management models were selected:

- SECI Nonaka model – due to the holistic description of knowledge creation process in the organization as well as distinguishing the “Ba” cyberspace – virtual space in the organization, which on the basis of existing knowledge creates and regularizes new knowledge [13],
- Probst, Raub and Romhardt model – due to its orientation towards practical aspects of knowledge management and a description of particular knowledge management processes [16],
- Carayannis model – due to its possibility so support the knowledge management evaluation process through the determination of knowledge possession in particular areas of the enterprise’s activity [2].

These models will be used to build a relation model for the knowledge management system in the organization.

3 Method for knowledge management systems classification

One of the basic assumptions in the creation of a KMS model is to use the results of case studies of existing knowledge management systems. Selection of systems suitable for research required the use of a method, which would allow classifying given system as a KMS. The following were used in the elaboration:

- KM Connection company method [21],
- method elaborated by R. Cobos, J.A. Esquivel and X. Alaman [3],
- copyrighted method named Extended Classification Method – ECM.

KM Connection and R. Cobos, J.A. Esquivel and X. Alaman methods were selected on the basis of literature study. ECM method is an expansion and regularization of these two methods. The ECM method has the following criterion, which allows recognizing KMS, determined:

- knowledge management system, similarly to the KM Connection method, must be dedicated to aid knowledge management processes and cannot be a part of systems excluded by KM Connection,
- system stores knowledge in a structured manner, which is not dependent on the knowledge object format (text, graphics, sound, multimedia), as well as is equipped with categorization and relation identification mechanisms (possibly automatic),
- system uses systems that allow automatic gathering of knowledge from external sources (inside and outside of the organization),
- system allows intuitive search of necessary knowledge as well as its browsing in networked and hierarchical manner,
- system supports its users in knowledge base use, simplifying and automating the process, as well as assuring the influence of users on the quality of the information,

- system aids individual knowledge sharing of particular organization participants as well as provides mechanisms for efficient communication and teamwork.

Apart from fulfilling the listed requirements, KMS should assure a determined level of security for gathered knowledge (key resource of the enterprise) as well as provide mechanisms for reporting and controlling of functioning of the system and its users. Figure 2 presents the relations between particular methods.

4 Case study

In order to construct a relation model for KMS an analysis of existing KMS was necessary (case study). Case study included the following steps:

- selection of systems to perform research,
- preliminary research,
- detailed research,
- synthetic KMS research results.

Block scheme of the course of the case study is presented in the Figure 3.

Due to considerable amount of solutions, determining systems as KMS, present in the market, selection of the system for research was done in three steps. First step used three groups of systems, used for knowledge management, elaborated by the Business.com, Inc., KM World Magazine and the KM Connection, as well as systems provided by Polish manufacturers (196 systems altogether).

Al systems categorized as knowledge management systems were selected for further study (both Polish and foreign). Next step included verification of 37 (33 foreign and 4 Polish) solutions according to: its functionality (determination whether the system that is claimed to be KMS by its manufacturer truly fulfills all knowledge management system's requirements) and is it up-to-date (whether the system is continuously developed and is the company still present in the market). As a result of this analysis 16 systems were selected, which were analyzed with preliminary questionnaires - based on KMS classification method, especially the Extended Classification Method.

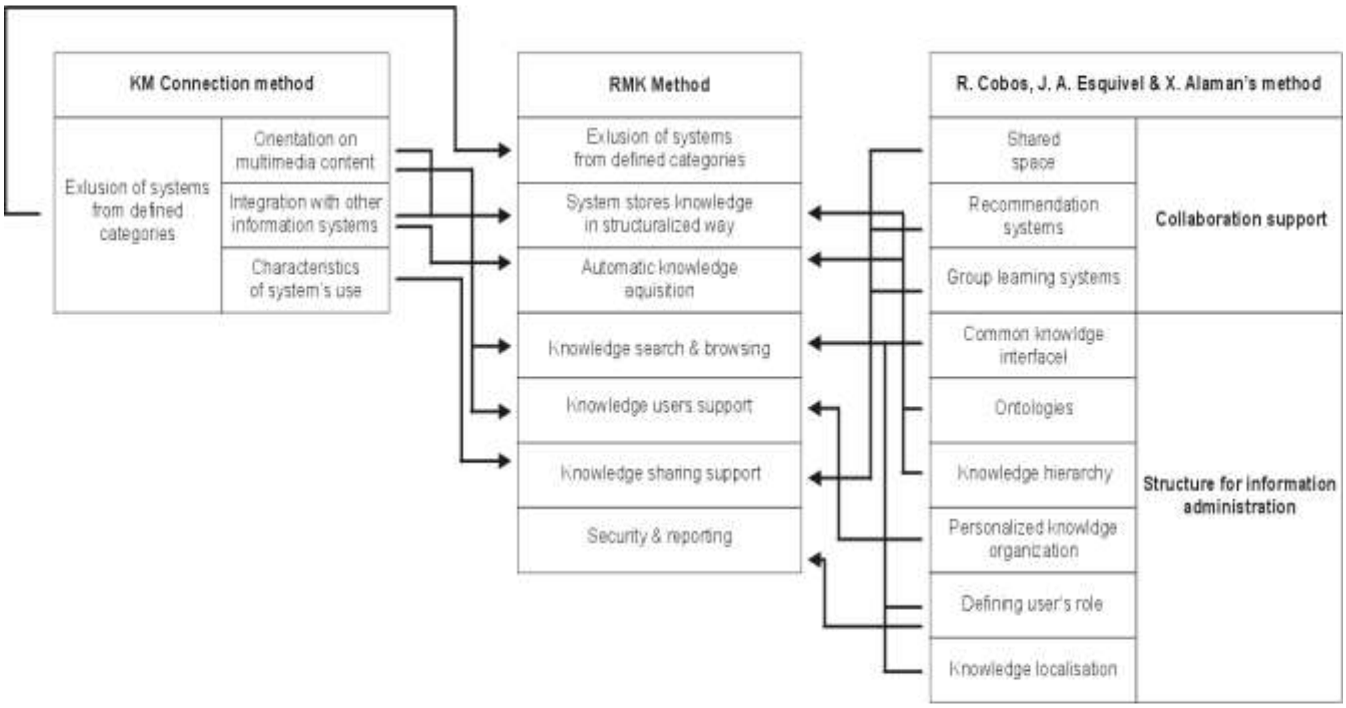

Figure 2. Relations between knowledge management systems classification methods
(source: self study)

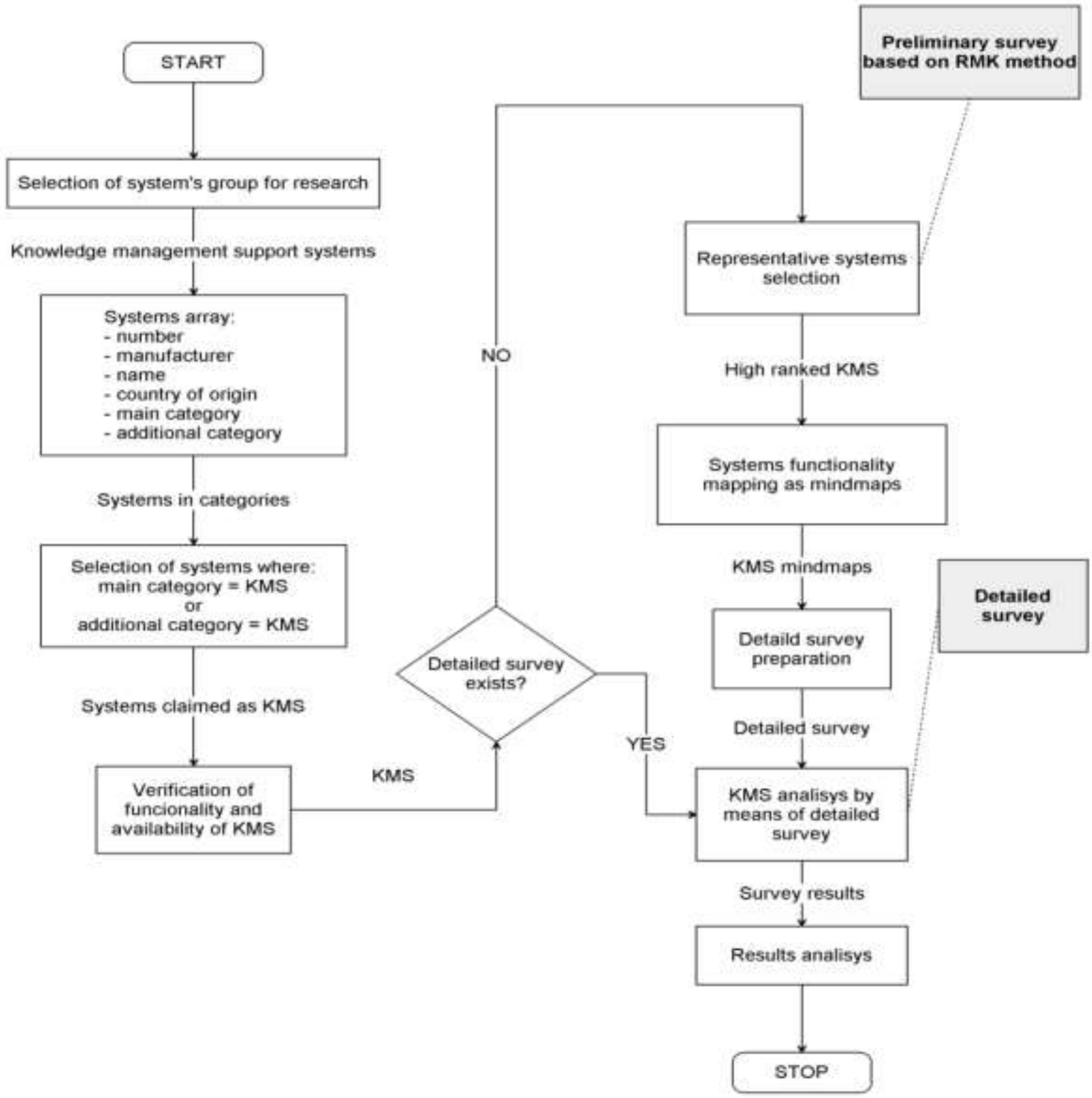

Figure 3. Case study block scheme
(source: self study)

The aim of preliminary research was to create a ranging of systems, which would allow the selection of solutions best fitting the next step – detailed research. Solutions place in the first half of the rank were selected for the elaboration of a detailed questionnaire. Functionality of the systems was mapped in the form of knowledge maps (example of the map in the Figure 4).

4.1 Detailed research

Detailed questionnaire was used to re-check all 16 knowledge management systems with a higher level of detail. As a result of the research, connected with knowledge gathering and organization, it was determined that the system should be equipped with knowledge repository (94% of positive answers) as well as should refer to knowledge sources trough abstract layer (88%). Text data is the one most commonly stored in the system (75%), rather than multimedia (50%) and also the content indexing is the most popular way to allow quicker access to gathered data (63%).

The use of metadata is a solution of repository functioning efficiency improvement (50%) ant the XML language is the dominating one among technical solution.

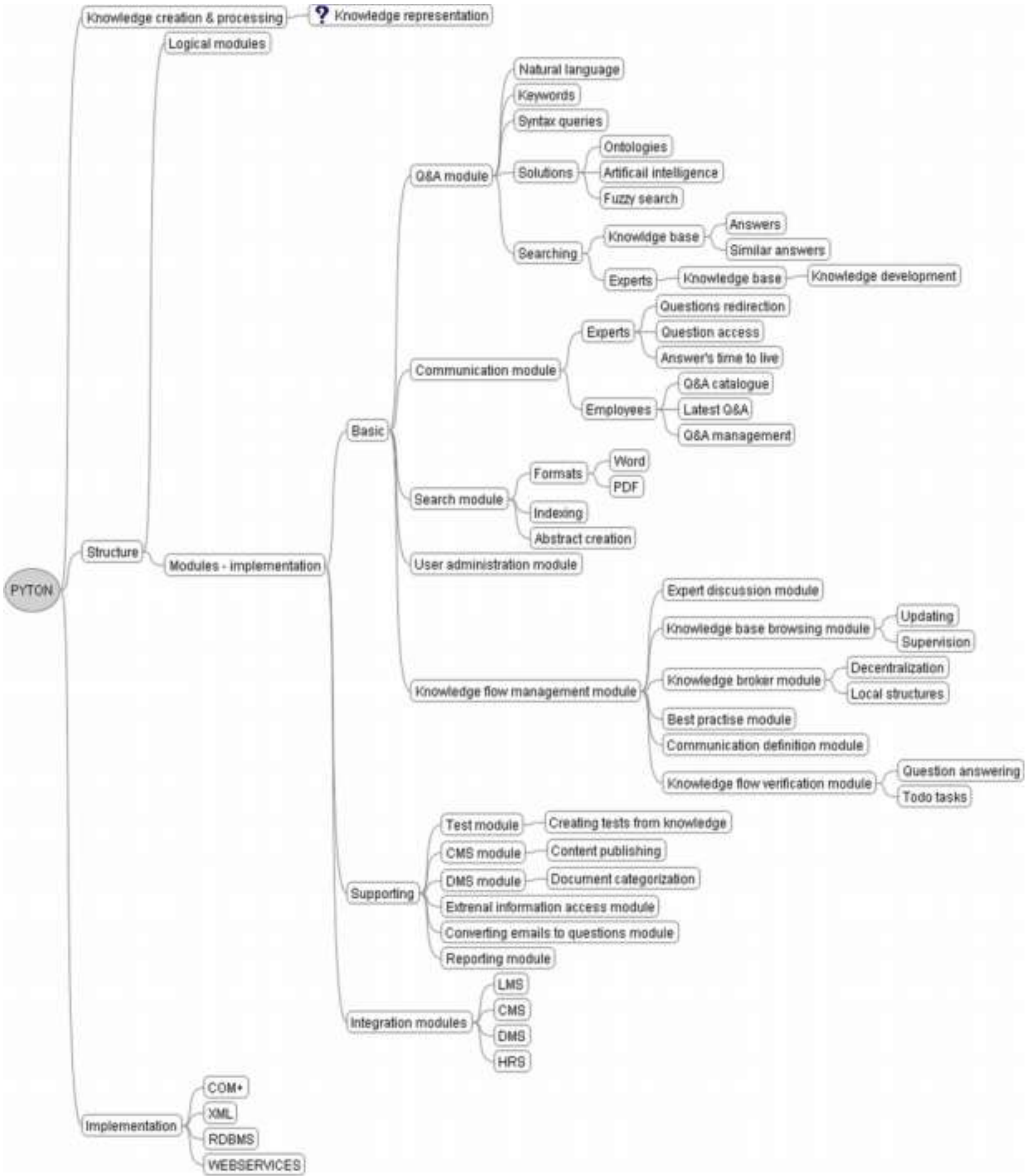

Figure 4. Knowledge map for the Pyton system
(source: self study)

Knowledge use function analysis leads to a conclusion that practically no KMS can function without knowledge gathering mechanisms (94%). Another way of accessing knowledge is the navigation through the resources (69%) through browsing according to a determined hierarchy, reviewing dictionaries (38%) or browsing through visualized knowledge resources (25%), which is extremely helpful to spot the relationships between resources. Knowledge usage stimulating mechanisms, realized through the use of recommendations, are also playing an important role in knowledge management systems (50%). To allow such possibility there has to be a knowledge evaluation system as well as system interface personalization, which allow it to be adjusted to requirements of particular users.

Tacit knowledge cannot be codified and transferred directly. It can only be transferred through models, examples or metaphors, usually through the contact with a person who is gaining the knowledge. Finding an expert form the key area is essential to gather the necessary knowledge, which he or she possesses. Most of the researched systems are equipped with expert knowledge management mechanisms (69%) and the most common basic solution is the expert browser (69%), which allows to find proper human resources in the organization through searching criteria. The possibility to evaluate experts, directly or indirectly – through the evaluation of their input into the knowledge management, is essential according to knowledge seekers. On the other hand experts value the possibility to create the "expert communities", organizational forms allowing creating and sharing knowledge, in the knowledge management system.

The possibility to create local structures is present in 50% of the systems. One of the essential issues is to allow the organization participants a real-time contact. Another possibility is to record knowledge transferred through telephone or audio and video conferences.

Knowledge requires protection from internal and external threats through administrative and security assurance solutions. One of the basic requirements is the authentication system (63%). Another of such solutions is the groups (38%) and roles (50%), which allow defining general user authorization for particular system resources and functions.

Possibility to evaluate knowledge usage as well as the supervision of participants' activity can give important information to high management whether the knowledge management system with the use of IT tools is bringing the expected effects. The system should have the possibility both to present detailed reports for the system administrator and also analytical reports for the management.

4.2 Knowledge management system research results

Detailed research on knowledge management system function results allowed pointing out the development directions of particular functions:

- increase of the support for the use of ontology to build knowledge hierarchy as well as determine the meaning in knowledge resources,
- development of browsing with the use of natural language and the use of ontology,
- popularization of recommendation mechanisms and knowledge evaluation as well as the use of agents in order to make the knowledge resources easier to browse,
- popularization of the access to recorded information exchange between experts and knowledge seekers,
- implementation of expert communities creation mechanisms,
- increase of the influence of organization participants on the modeling of expert environment,
- increase of knowledge sharing processes that takes place during teamwork,
- implementation of real-time communication mechanisms (possibility to record the conversation in the repository for future use),
- introduction of roles and groups mechanisms in order to use default accessibility to resources for different users,
- increase in the usability and ergonomics of the access interfaces in order to avoid using general rights by the system administrators,
- implementation of protocols ciphered in the communication process,
- adjustment of the reports and statistics collection to the scope of knowledge management system in order to monitor its processes (lack of evaluation limits the possibility to verify the system usage).

One of the basic conclusions, after the detailed analysis of knowledge management systems, is the lack of complex solutions that aid knowledge management processes.

5 Knowledge management system model

KMS model, which is basing on knowledge management models and including current technological possibilities as well as situation in IT knowledge management systems, was created as a result of performed research. Basic model assumptions concerning its functions and modules are as following (see Figure 5):

- knowledge structured storing repository must exist in the system, apart from the format it was gathered in,

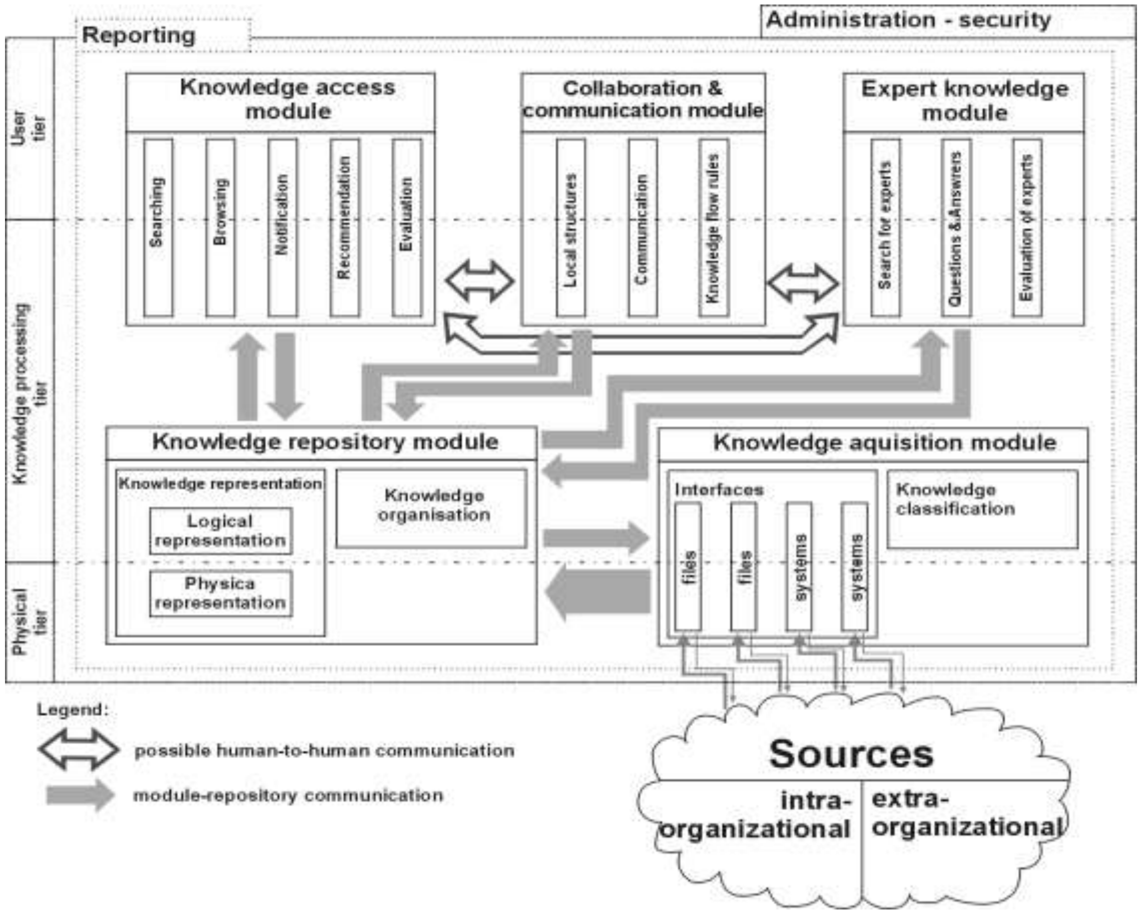

Figure 5. Functions and modules of knowledge management system
(source: self study)

- knowledge gathering can be performed in two ways: automatic, on the basis of set criteria, and extorted, triggered by a conscious need of the system user or the knowledge repository,
- gathering knowledge from organizational internal and external sources is performed through interfaces adjusted to work with one source (or few sources that provide data in the same format),
- accessing knowledge from the repository can take place through navigation and browsing systems,
- access to the knowledge of other organization participants is realized through communication and co-operation as well as through expert knowledge management,
- cooperation and communication mechanisms should aid the gathering of the tacit knowledge and information and data exchange should be recorded in the repository,
- expert knowledge management system is necessary due to the critical significance of expert knowledge,
- administration and safety assurance concerns all areas of the system,
- all operations, realized through the system, are recorded for the need of detailed and analytical reporting.

Description of functionality of particular modules is presented in the following chapters.

5.1 Knowledge management

The necessity to search and browse through knowledge sources in different formats (text and multimedia) is a challenge for the KMS designers. One of the solutions to this problem is separating logical and physical representation of knowledge. The solution for knowledge representation depends on the number and type of knowledge sources, size of the organization as well as its financial and organizational possibilities. Knowledge representation module, which allows ordering the existing knowledge resources into a structure that allows easier, searching, browsing and resource relations creating. The basic functions of this module are:

- storing knowledge in the KMS repository in the form of objects based on the frame theory. OWL is the knowledge representation language (knowledge objects that cannot be processed directly by the system are stored in the form of metadata, recorded in the OWL language),
- knowledge objects versionization, knowledge objects access control in order to assure the integrality of the repository and assurance of the multi-laguage nature of the objects,
- storing text in the repository,
- sorting of multimedia and data difficult to browse in the form of metadata (allows the possibility to add reviews),
- physical representation of the knowledge on the basis of database management system, file system and XML and its derivative files.

Knowledge stored in the repository cannot function without the determining of its organization. Basic function of the system is the possibility to create its own knowledge organization.
Other functions of the system are:

- assurance of the structure and hierarchy (organization) for the knowledge stored in the repository,
- organization of knowledge through ontology (use of OWL system for recording and storing of the ontology as well as the possibility to create much ontology).

5.2 Knowledge gathering

Another component necessary for the proper system functioning is the part responsible for gathering the knowledge stored in the repository. Knowledge possessing module functions are:

- automatic repository knowledge possessing either single or periodical (communication with external systems is realized through interfaces),
- manual repository knowledge gathering (communication of the KMS user realized through forms),
- assurance of form creation possibility,
- assuring the possibility of interface creation, which allows the change of knowledge provided from sources with different into the standard used in repositories (files and systems interfaces),
- manual, semi-automatic and automatic mechanisms of knowledge classification,
- knowledge resources classification in the form of text based on keywords analysis (system classifies knowledge resources on the basis of metadata analysis or the use of examples stored in the system),
- knowledge objects relation analysis,
- use of artificial intelligence,
- automatic change of the knowledge organization.

5.3 Knowledge access

The role of repository and knowledge gathering mechanisms is crucial from the point of view of correct functioning of the system. However, these components, responsible for knowledge access, are used directly by the organization participants. Knowledge access module needs to share solutions that allow knowledge fining in minimal time and with the use of minimal number of operations. Knowledge access module functions are:

- searching for knowledge in the repository (full-text search, use of syntax, parametric search),
- placement of the most popular content (or “best practices”) search results in the top,
- knowledge browsing according to existing knowledge organization,
- creation of dictionaries and classifications (alphabetical and hierarchical),
- notification about the appearance of new knowledge objects and the modification of objects existing in the repository,
- defining of knowledge resources for the notification,
- defining programming agents,
- knowledge recommendation through the presentation of significant content/objects, corresponding content and highly evaluated content,
- possibility of knowledge quality evaluation, best practices nomination and the possibility to add comments to knowledge objects.

Knowledge access chapter is the description of the interface, which is used to access the knowledge management system. The basic user interface functions are:

- KMS user interface has the form of a slim customer,
- interface personalization possibility,
- posiibility to manage the user profile,
- communication with KMS via email,
- assurance of access to many platforms.

5.4 Expert knowledge management

There can be many sources of knowledge in the organization, which can be stored in a repository. The possibility to manage this knowledge results from the functions described below:

- browsing through experts,
- searching according to the profile of an expert, activity history and the search with the use of natural language,
- searching for questions and answers,
- viewing questions and answers,
- possibility to ask question to experts through user interface (possibility of anonymous question asking),
- determining the priorities for asked questions,
- notifying experts about the questions that are waiting to be answered,
- possibility to evaluate the work organization and the quality of the experts' knowledge,
- proposing experts.

Described functions determine the functioning of an interface. Additional interface functions are:

- possibility to manage questions and answers,
- possibility to manage one's profile.

5.5 Cooperation and communication

Assurance of teamwork and communication mechanisms is one of the solutions supporting tacit knowledge management (results of these contacts should be placed in a repository). The main functions of the cooperation and communication model are:

- possibility to determine the scope of and the participants of the local structure as well as the assurance of the safety of a local structure,
- possibility to discuss,
- possibility to share resources,
- possibility to notify the group members,
- creating virtual rooms,
- communicator sharing,
- possibility of voice communication,
- conferences (real-time resource sharing).

5.6 Administration and safety

Administration and safety functions are not describing the additional module and are a collection of solutions implemented in KMS in order to assure proper system functioning. KMS is designated for the organization's participants that are active in different geographical areas and are using computer networks in order to gain access to the system resources. Basic functions provided by the system are:

- user management,
- group management,
- role management,
- access to resource groups, resources and resource elements,
- resource access according to roles and groups.

It is crucial to assure compliance of the KMS with the safety policy requirements in the organization as well as to train the users in organizational knowledge safety [8].

5.7 Reporting

Periodical knowledge evaluation and target verification in the knowledge management process is an essential issue according to Probst model. KMS should be equipped with in reporting mechanisms that realize the following functions:

- user activity monitoring in the scope of frequency and time of using the system,
- identification of important subjects, experts and resource decision making aiding,
- identification of lacks in organizational knowledge.

5.8 Integration with other systems

Many systems can function in an organization and every one of them can be a potential knowledge source for the KMS. However there are systems, whose integration is extremely important either because of the data they transfer or the role it is playing in the everyday work of organization's participants. There are also particular communication standards, which are realized through the following functions:

- possibility to integrate with other IT systems,
- possibility to integrate with systems coming from other producers,
- possibility to integrate with system classes (CMS, CRM, DMS, ERP, HRMS, LMS),
- the use of COM+ and CORBA standards,
- the use of Web Services standard.

KMS model does not impose particular solutions, however the designers should use platforms that assure most of described functionalities and use open standards. Selection of an operational system or the database management system depends on the language or platform the implementation will be realized on.

Knowledge management system should be built with the use of such technology, which assures independence and transferability between different operational and database management systems. In case of implementation language selection it is necessary to take into consideration the possibility of application functioning in different systems.

6 Knowledge management system prototype

Knowledge management system prototype was built and implemented in order to verify the KMS model. It was based on function and module schematics of the knowledge management system (see Figure 4). The following modules were implemented in the prototype: knowledge repository, knowledge gathering, knowledge access and administration, safety and reporting functions. Cooperation and communication modules as well as expert knowledge management models were not used in the prototype due to limited resources.

6.1 Preliminary assumptions for the KMSP

It was determined that KMSP implementation should be possible in small and medium enterprises. The following additional requirements were set for the prototype:

- cost – system should use technologies with relatively low cost,
- standards – system should use standard technologies,
- internet – system should be based on protocols used in the internet,
- usability – use of the system should require only an internet browser.

KMSP was tested in two environments and freeware licenses technologies were used in the implementation. The following software was used: internet browser (Internet Explorer 6.0 and Mozilla Firefox 1.5.0.9), Apache HTTP Server 2.2.2 and 2.2.3 with PHP module version 4.4.4 and 4.4.2, MySQL database server version 5.0.22 and 5.0.24a, Windows XP Professional and Linux Slackware 10.2. operational systems. System functioning was correct in both cases and did not require any additional adjustments to fit the selected environment.

KMSP is built on the basis of internet protocols. Some of them, like HTTP, HTML or CSS, are imposed by the environments described above. Selection of OWL language for recording and storing of knowledge is compliant with W3C requirements [11], which determine this language as the latest knowledge recording standard.

Interface design is based on the assumption that the user can only access the system with a computer equipped with any kind of operational system and internet browser. Unfortunately a knowledge engineer or knowledge expert needs to use additional (freeware) software to record knowledge in the OWL language (Protégé).

6.2 KMSP architecture

KMSP was built in a three-layer architecture [17], where user, knowledge usage, processing and physical level are based on applications presented in Figure 6.

KMSP plays an essential role in knowledge processing level. It was built on the basis of IPS system [5], which is a content management system with designed and manufactured modules as well as implemented libraries, which allowed managing the knowledge gathered in the OWL format.

Using file system in the physical level was limited to the storage of the OWL file, which includes ontology elaborated for the need of KMSP. It is also provided in this form from the knowledge engineer using Protégé software. External libraries were used to input OWL format data into the relation table of the database.

6.3 Model functions implementation in the KMSP

Knowledge management system implementation was limited to the functions with the highest priority. Function group connected with the logical representation of knowledge includes:

- knowledge objects representation function – using OWL language allowed knowledge objects representation in a form similar to the one resulting from the frame theory,

- metadata usage function – default in the OWL language,

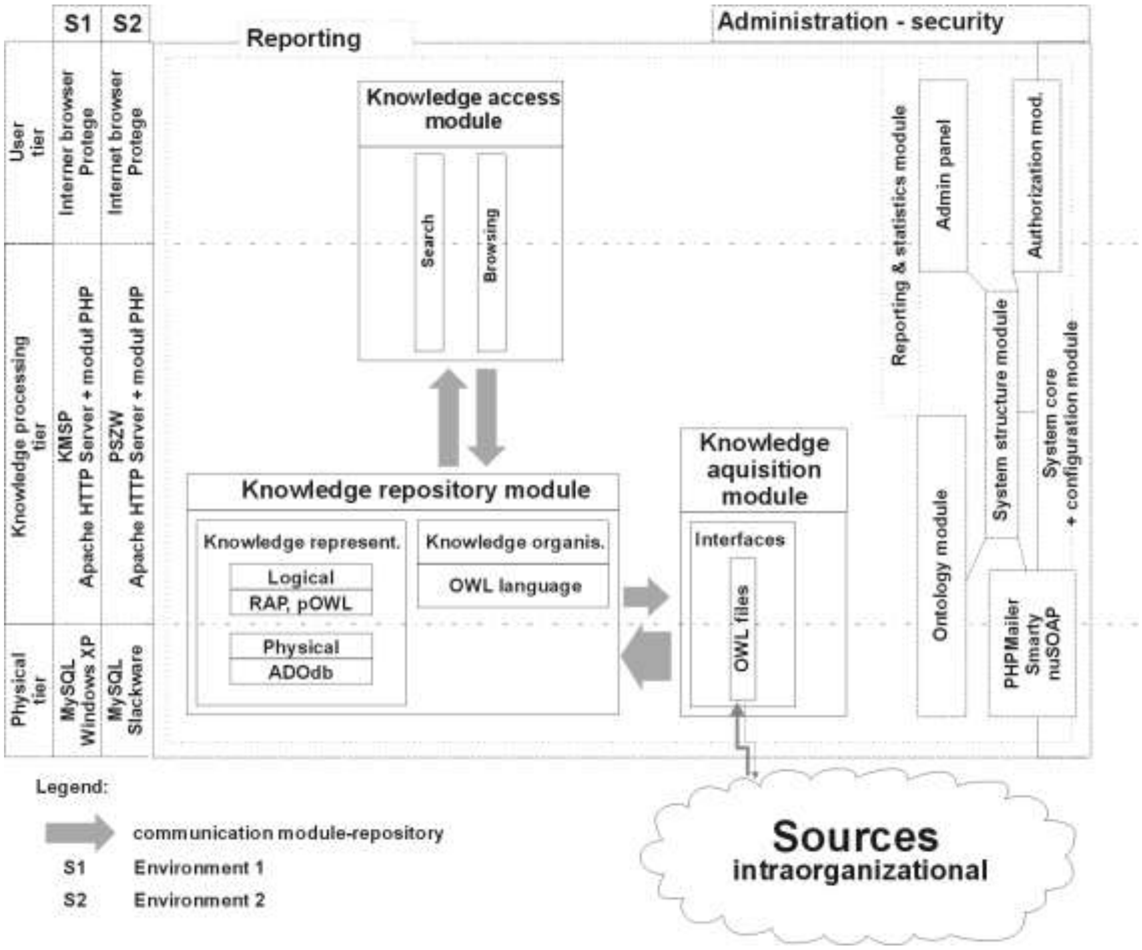

Figure 6. KMSP architecture in relation to KMS model functions and modules
(source: self study)

- versionizing, access control and multilanguage functions – system does not support versionizing and multilanguage, access control is performed on a general level of all stored knowledge,
- text content support function (1/1) – current system supports only text content.

Function group connected with the physical representation of knowledge includes functions of physical knowledge representation in database management and XML file systems (XML is OWL derivative).

Knowledge organization includes assurance of proper structure and categorization of knowledge with the use of OWL language.

Repository knowledge gathering in KMSP is only performed manually by the knowledge engineer's work. Group of basic functions connected with knowledge gathering is:

- manual knowledge gathering (Protégé application),
- form creation functions,
- interface creation functions (OWL format files).

Automatic knowledge classification function was omitted in the prototype due to priorities set during the research as well as the complexity of implementation activities.

Knowledge access functions are crucial from the point of view of the system user and they can decide about the success of the implementation. In the first version of the prototype knowledge browsing was not implemented, only knowledge viewing was possible. In following questionnaire research it was revealed that 60% of the respondents thought of the knowledge browsing function as essential. The following issues were implemented in the prototype:

- browsing according to existing knowledge organization,
- dictionary and classification functions,
- general knowledge searching functions
- syntax use functions.

Functions connected with knowledge resources notification, knowledge recommendation and knowledge evaluation were not implemented, even though they have a significant role in knowledge access. Low priorities decided about the implementation of knowledge recommendation and evaluation. In case of knowledge notification it was rejected due to accessibility dedicated only for the prototype research. Remaining knowledge management system functions were implemented to enable the functioning of the system.

6.4 Course of experiment and system access

The aim of the experiment was KMSP functioning verification that led to evaluation of KMS model assumptions. Object area of knowledge repository concerned the basic concepts from the area of enterprise management. KMSP was shared in internet at: www.pszw.wip.edu.pl/ (user: wiedza password: knowledge).

Knowledge resources can be viewed in a hierarchical manner. Index in alphabetical order (dictionary) can be accessed from all levels of knowledge browsing. Browsing function was added in the second version of the prototype due to questionnaire research results that indicated lack of functionality in this area. Request for experiment participation, using manual and questionnaires was distributed among potential respondents. Users were to use the system and check the issues described in the questionnaire. Afterwards the questionnaire was filled in and sent back to the author. In addition, the “Experiments” bookmark included instructions necessary to perform experiments in the scope of knowledge management with the use of KMSP (see Figure 7).

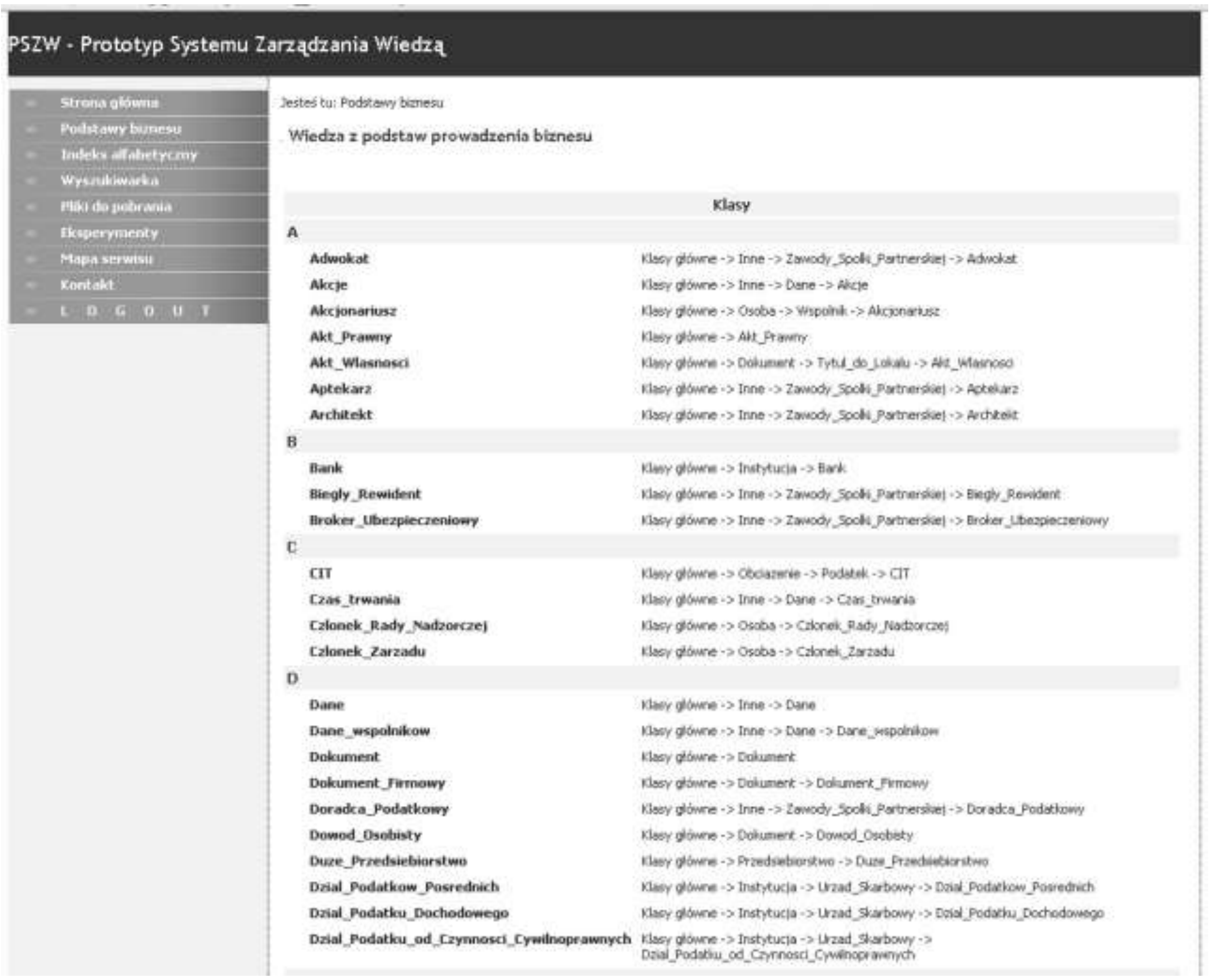

Figure 7. KMSP user interface
(source: self study)

6.5 Prototype research

Most of the research included issues that needed to be verified with the use of methods originating from social research. Five-point Likert [9] scale, compliant with the Rensis Likert method, was used to design the questionnaire and allowed to determine the degree of acceptance, view or feeling on researched issues.

The respondent group included two environments: scientific (students) and business. First part of the questionnaire included questions that gave a general view on knowledge management and the use of computer skills. Over 60% of respondents were familiar with the concept of knowledge management and most (59,2%) of them identified IT resources management with this concept and knowledge resources processing (34,7%). Respondents determined their computer skills as good or very good (70,2%).

Ability to search for information was determined as good by 73,8% of the respondents and the number of respondents familiar with tolls like internet forums, communicators and chat rooms was considerably different in each of the two groups. It is connected with the correlation of universality of such tools in different age groups, because the correlation index between the age and the knowledge of the tools equaled -0,56, what indicates that the distribution of this features is negative linearly. In addiction selected group of respondents participated in the research and questionnaire research results are credible.

Second group of questions concerned the KMS prototype. Over 82% of respondents accepted the descriptive forms of knowledge transferring (manuals, text books). Question about structured knowledge description form, recorded in class hierarchy and its mutual relations, was in favor of 64,8% of respondents and 24,4% of respondents thought of such form of knowledge transferring as not suitable.

Knowledge resources browsing was seen as not innovative by 61,9% of respondents. It can be treated as either the failure in reaching required knowledge resources browsing solution or an advantage – adjusting user interface to common standards.

In question on knowledge hierarchy (its content, not form) 80,7% of respondents treated it as understandable. Three following questions concerned the presentation of particular knowledge classes. In case of the descriptions of knowledge classes most of the respondents (61,4%) indicated that the descriptions were not sufficient. Features of particular classes were understandable for 64,3% respondents. It was indicated that also the descriptions of knowledge classes are insufficient by 56,1% of respondents and 43,9% found it sufficient. To sum up, answers confirmed the popularity of descriptive knowledge transferring and the form of particular classes' properties presentation.

The remaining questions dealt with functions not present in the system, but desired by the users. First one concerned knowledge browsing – 29,8% of respondents noted that this function was missing. However 58,3% of the respondents decided that knowledge browsing is necessary, therefore every knowledge management system should be equipped with it.

Following questions concerned knowledge evaluation:

- answer distribution does not give a direct answer to this question,
- 36,9% of the respondents are missing such possibility,
- 32,1% find it indifferent and 31% thinks of it as redundant,
- on the contrary 54,8% of respondents think that adding comments and corrections to the knowledge is necessary.

Additional questions dealt with advanced aspects of knowledge management systems and verified the correctness of some of the assumptions of the KMS modules. 47,6% of the respondents think that the possibility to create knowledge hierarchy by the users should be limited and 36,9% would like to have such possibility.

Next question researched the need of communication between KMS users (chat-rooms, internet forums etc.). 77,4% of the respondent think that such solutions should be implemented in the system.

Most of the respondents think that register of such FAQ's and conversations should be implemented in the system and accessible in the knowledge repository. 84,5% consider the presence of experts in the system as crucial (in both of the environments). Email was the most common answer for the communication channel with an expert. Final question dealt with data security.

20,2% of the respondents think that knowledge should be more secure than other enterprise resources and 27,4% required restricted use of knowledge.

Answers of the respondents lead to the following conclusions:

- research respondent group was confirmed,

- use of KMSP form organizational knowledge management was verified,
- there was no direct answer about the necessity of knowledge structuring in KMS model,
- browsing function implementation was found as crucial and added in the second version of the prototype,
- cooperation and communication modules significance was confirmed as well as the expert knowledge management; user preference of IT tools for KMS communication was determined.

Correctness of the KMS model was verified and some issues, designated for further study including KMS implementation variants dependent of the organization type and the influence of KMS on the knowledge management in an organization, were identified on the basis of KMSP implementation and research results.

7 Summary

Construction and verification process of the relation model for a knowledge management system in an organization brought many tools to its receivers. Extended Classification Method (ECM) of knowledge management systems can be used by scientists and designers to select a KMS for their study and the knowledge management system analysis method can be used to research the existing KMS.

KMS system should aid the system designers to create solutions compliant with current knowledge level and the KMS prototype can lead to an implementation of a complete KM system or development of existing system in an organization. Scientists can use the KMS prototype as a basis for knowledge management systems research and the high management and IT managers can analyze KMSP as an example of practical implementation of KMS in a business environment.

Further research directions were determined as a result of the study: elaboration of KMS variants according to the complexity of KMS relation model and further research with KMS prototype implementation, including the implementation of all modules and relation functions.

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